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ABSTRACT

This is a summary of a final report which was a historical study of the status of mathematics education from 1955 through 1975 based on a review, analysis, and synthesis of the literature. The summary contains a brief introduction, a description of the procedures followed in the study, and a summary of the findings. The findings are presented as summary statements based upon each major section of the final report and are keyed to the original section from which they were drawn. (MS)

THE STATUS OF PRE-COLLEGE SCIENCE, MATHEMATICS, AND SOCIAL SCIENCE EDUCATION: 1955-1975

VOLUME II. MATHEMATICS EDUCATION

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY: MATHEMATICS EDUCATION

I. Introduction

This historical study provides evidence on the status of mathematics education in the 20-year period beginning in 1955, in order to ascertain causes and effects of educational policy formation. Since this time period witnessed dramatic attempts to reorient the mathematics curriculum, instructional practice, and teacher education, the process and outcomes are traced in the hope that events of the past can be used to provide guidance for making future decision-making more rational.

The following questions are addressed:

(1) What were existing practices in mathematics education for curriculum, instruction, teacher education, learner performance, and needs assessments?

(2) Was the information about practices used or ignored in decision-making concerning policy in education?

II. The Research Approach

Since this is a historical study, the procedures focused on obtaining, searching, and analyzing the literature of the period. New information was not generated; rather, existing documents were collected and examined carefully. In particular, published articles, committee reports, and influential books were studied; pertinent documents from the ERIC data base, state educational archives, and other institutional archives were collected; and research reported in journals, monographs, dissertations, and other sources was considered. Documents were selected in terms of (1) evidence of significance, (2) validity and generalizability of conclusions from data, and (3) perception of the quality of the work.

Three major themes are treated:

(1) The schools -- organizational, instructional, and curricular patterns; student characteristics, evaluation, materials, and costs.

(2) The teachers -- preservice and in-service education, background, competence, and behaviors.

(3) Needs assessments -- planning documents and assessment results at national and state levels.

A section of the report corresponds to each of these themes. Summaries highlight major conclusions derived from the historical record. A concluding section attempts to integrate major findings and to anticipate trends for the immediate future. The task of determining goals for future activity in mathematics education exceeds the scope of this historical record, although information is provided about the determination, implementation, and rationality of educational policy.

III. Findings

Selected highlights from each section provide a brief summary.

The Schools. Evidence describing practices in mathematics education is presented, with an attempt to trace patterns and the mode of decision-making for seven areas of concern. For most areas, no discernible patterns could be found; needs and the basis for decisions were only rarely documented. The factors which influence practices are varied and complex; change is not linear.

A. Overview, 1955-1975 page 27

- The 20-year period witnessed:
  - continuing curriculum reform
  - extensive federal funding, with federal policy increasingly affecting curriculum development
  - changing roles for federal agencies as they assumed varying degrees of responsibility for the cost of curriculum development and teacher retraining

- an explosion in research as well as development efforts
- concern for the mathematically able, especially at the secondary level, and for the disadvantaged, especially at the elementary level

- The need for curriculum reform was generated by:
  - 1955 - public dissatisfaction with existing curricular outcomes: concern from mathematicians and mathematics educators
  - 1965 - concern for the economically and educationally disadvantaged; reassessment of the need for mathematical rigor
  - 1975 - patterns of declining achievement scores; especially at the college-entrance level; pressures for accountability

B. Organizational Patterns page 31

- There appears to be no <u>one</u> organizational pattern which will increase student achievement in mathematics.
- The self-contained classroom at the elementary level and the fixed-period schedule of the secondary school remain the predominant organizational patterns.

C. Curriculum and Content page 48

- "New math" was not a single phenomenon, but a two-decade series of developments that evolved and changed continously.
- Initially, curriculum reform focused on the college-bound student at the secondary level, while most early elementary projects developed supplementary materials. Changes in intent accompanied changing needs.
- As reflected in print, the content of school mathematics curricula changed. The number and variety of courses offered at the secondary level increased, but inclusion of "new math" content in the elemeatary school may be illusory.
- Curriculum guides vary in format and emphases, but have little variance in content. Behaviorally stated objectives distinguish many 1965-1975 guides from earlier guides.
- Enrollment increased in secondary mathematics courses, especially in advanced courses. A large percentage of students have used materials from one or another of the curriculum development projects.

- Enrollment patterns seem relatively stable in the 1970s, with continued small increases in advanced courses and in basic or remedial mathematics.

D. What Goes On in Classrooms

- Knowledge of what goes on in schools is limited; few studies have described the actual classroom situation. However, it appears that:
  - Approximately 20% of the elementary-school day is allocated to mathematics, with the number of minutes increasing as grade level increases. At the secondary-school level, approximately 200-300 minutes per week are allocated to mathematics.
  - A large proportion of time is taken up by non-instructional activities; thus, how time is used may be of more importance than how much time is available.
- Classrooms have changed litte over the past 20 years, despite the innovations advocated. Predominant patterns continue to be:
  - Instruction with total-class groups
  - Tell-and-show followed by seatwork at the elementary-school level, and homework-lecture-new homework at the secondary-school level
  - It appears that no one mode of instruction can be considered best.
  - Few variables consistently make a difference in school performance
  - Teachers frequently do not differentiate instruction. They tend to gear instruction to skills already achieved by their students.
  - There is little evidence that self-paced programs for individualized instruction are any more effective than "traditional" instruction, but they cost much more than traditional instruction costs.
  - The disadvantaged student can profit from special attention, but such students differ individually more than as a group.
  - The needs of the talented are not being well-served in the 1970s. Enrichment programs are especially needed for those in small schools.

- Advanced Placement serves the needs of those using mathematics better than of those majoring in mathematics.

E. Evaluation of Achievement page 83

- The scope and role of evaluation has been greatly expanded during the 20-year period. Evaluation information is now expected to provide guidance for programmatic decision.

- Standardized tests have assumed increasing importance. Recognition that scores form tests are being misused has also increased.

- The greatest change in testing has been the increasing use of objective-or criterion-referenced tests.

- Instructional objectives and test items compare favorably on content involving computation, but not geometry, measurement, and other topics.

F. Student Characteristics page 96

- The range of mathematics achievement scores increases as grade level increases.

- Attitudes toward mathematics are generally positive in the elementary school and appear to peak at approximately age 12.

- While mathematics educators and teachers believe that attitudes toward mathematics are related to achievement in mathematics, there appears to be no meaningful or significant relationship between the two.

- Sex-related differences are not universal across the factors related to mathematical ability differences in aptitude and achievement vary more with individuals than by sex.

  - Girls and boys at the early elementary level do not differ significantly in mathematical achievement. In upper elementary and junior high school year, differences are not always apparent; when they do occur, they likely favor boys on high-level tasks and girls on computation.

  - No conclusions regarding sex differences can be reached concerning secondary students; fewer girls take mathematics, however.

- Socioeconomic factors appear to account for much of the variance in mathematical achievement.

G. Instructional Materials page 114

- The textbook is the primary determinant of mathematics curricula, and many teachers use no instructional materials except textbook and chalkboard.

- About half the states have mandated textbook adoption lists, with more listing multiple texts; however, a single text is used in most classrooms.

- Variance across textbooks at the elementary level is largely in terms of amount of space allocated to a topic, approach, and design. At the secondary level, wider variance is obvious as the type of course varies.

- Teachers tend to follow the textbook closely with regard to content selection and sequencing, though components which they do not consider essential may be ignored.

- Use of manipulative materials decreases as grade level increases; however, use of such materials appears to be effective at all age levels and with all types of students.

- Computers are used more widely in mathematics classes than in any other subject-matter field. The problem solving mode is most often used.

- The hand-held calculator has the potential to change the curricular focus on computation.

H. Costs of Instruction page 127

- For at least 15 years, education has been the largest item in the budgets of most state and local governments; the amount of federal funding for education has increased dramatically.

- The amount of money devoted to mathematics instruction is difficult to determine; 18% to 20% seems plausible but cannot be verified from available data.

- The amount of money spent per pupil has not been found in most studies to be significantly related to mathematical achievement.

- Since 1968, increased emphasis has been placed on evaluation of federally funded projects. Evaluation from outside reviewers rarely indicates the degree of success that those involved in a project declare.

I. The Teachers page 178

Dramatic changes in the nature and quality of preservice and in-service education transpired during the 20-year period.

- The mathematical background of students completing preservice programs increased significantly.

- Teachers are acquiring a second professional degree in greater percentages and at an earlier age than ever before.

- Teachers want in-service education and prefer that it be related to programmatic and instructional needs, and be neither purely mathematical nor purely methodological.

- Leadership for in-service education at the local school level can appreciably change its character and teachers' perception of its worth.

- Research provides little supportive evidence that participation in in-service education improves the effectiveness of teachers.

- Competence of teachers, when assessed in terms of promoting mathematical growth of students, is apparently related to a complex interaction of an assortment of factors. Teachers' mathematical background and attitudes do not account for a substantial amount of the variance in their students' performance.

- Competency-based teacher education (CBTE) does not appear to be a significant factor of sustained impact on teacher education programs.

- Computer literacy and the background to use the computer in teaching mathematics is not a component of certification requirements in most states or in the institutions that train teachers.

- The most significant trend in preservice teacher education is the move toward incorporating pre-student-teaching field experiences.

- There is a significant trend toward including laboratory or activity learning emphases in both the mathematical and methodological phases of preservice elementary teacher education.

- The teacher shortage characteristic of the 1950s and 1960s has given way to oversupply in the 1970s, but evidence suggests that an undersupply of secondary teachers in particular may occur in the near future.

J. Needs Assessments

Reflections of needs are evident in a variety of sources. Most involve goals; this type is the one to which the term "needs assessment"

is applied. The term "progress assessment" is used in referring to achievement and other status test data.

1. National Concerns page 193

Repeatedly discussed and cited are the need to:

- examine mathematical goals in relation to societal needs
- examine implications of technology
- establish minimal competencies
- increase attention to applications, statistics and probability, problem solving, the metric system; and basic mathematical skills
- provide for individual needs, particularly of less-able pupils and the talented
- improve articulation of mathematics with other subjects and across grades
- conduct research on the learning of mathematics, link research and curriculum development, and improve the implementation of research
- improve pre- and in-service teacher education, to strengthen teacher competency both in knowledge of content and methods of teaching
- develop better evaluation techniques
- improve cooperation between mathematics educators in universities and schools

- Discrepancy in the selection or ranking of goals -- between educators and public, college personnel and classroom teachers, students and teachers -- is common.
- Increasingly, federal and state legislation has been encroaching on local control of schools.

2. Needs Assessments in the States page 198

- Relatively little attention has been given in most states to documenting the history, status, or needs of mathematics education.
- Mathematics education per se is seldom cited in state goals; it is most frequently one aspect of a "competency in basic skills" goal.

- Where needs assessments specific to mathematics have been conducted, both "knowledge of basic skills" and "applications of skills to real-life problems" have been high on the list of needs.

- Discrepancy among concerned groups is apparent in the priorities assigned to mathematical goals.

3. Progress Assessment at the National Level page 208

- National Assessment of Educational Progress (NAEP) data indicate specific strengths and weaknesses, although the real function of NAEP is to provide longitudinal information on the status of mathematical achievement.

- A comparison of data on computational skills indicated that these skills are not acquired on the basis of initial instruction, but performance tends to stabilize during junior high school.

- College-entrance and some other standardized test scores indicate declines in achievement across years, with more extensive decreases for verbal than for mathematical portions of the tests.

4. Progress Assessments in the States page 217

- As of April 1977, eight states had minimal competency legislation, 10 had state board of education rulings, and legislation was pending in 10 states.

- As of June 1974, thirty states had some type of accountability legislation.

- State progress assessments vary greatly in s of objectives, type of test; and reporting procedures.

- Content areas in which weaknesses have been identified by assessments are ones which have long been known to be difficult; fractions, division, and subtraction with regrouping head the list.

V. Synthesis and Conclusions

The purpose of the study is to describe the evidence that bears on the rationality of making policy decisions in mathematics education. The evidence shows that progress and change have resulted form federal intervention. Some claim that the federal investment in mathematics education

has been the vital margin in determining whether a change would be realized or not. We see little evidence that the future will be otherwise. Thus, thoughtful policy formulation at the federal level is critical since it guides the investment of dollars for mathematics education.

It is not sufficient simply to recommend increasing the magnitude of the investment in mathematics education to make desired changes. More money must be invested wisely in order to accomplish change expeditiously and efficiently in the areas of greatest need in mathematics education. Recognition of deficiencies in policy formation processes is an important first step toward improving the payoff of the investment toward improving the learning and the teaching of mathematics in the schools.

Three sources of failure in the process of policy formation for mathematics education are apparent:

(1) Educational policy is frequently determined without collecting enough information to allow the process to be rational.

(2) Educational policy is frequently constructed without using information that is readily available.

(3) The point at which values enter into policy formation and the effects of the differences in the values held by various groups concerned with the schools are frequently not recognized in determining priorities.

Documented in the report are numerous examples of the first type of failure. Regarding practices in the schools:

- Too little is known about what happens in the typical classroom.
- Too little is known about the extent to which teachers differentiate instruction.
- Too little is known about the extent and nature of teachers' use of instructional materials and tools.

- The extent of teachers' dependence on drill-and-practice teaching strategies in not known.

Regarding teacher education practices:

- Data concerning supply and demand of secondary mathematics teachers are only conjectural.
- Too little is known about the characteristics of teachers not participating in in-service activities.
- Too little is known about how much, what kind, and when early field experience is best or how it actually contributed to helping the prospective teacher become competent.
- The characteristics of teachers that contribute to the effective learning of mathematics by students are neither well-described nor verified.

The sections on existing practices describe many other blank spots in the knowledge base for effective policy formation. A major difficulty is that these missing segments are not used to define priorities for information collection or for deciding what research to support and fund.

Failures of the second type -- formulation of policy without using available knowledge -- are also readily apparent. Often the collection of information confirms what has been known previously. Some aspects of schools and schooling have an inherent stability and resistance to change. The formulation of policy frequently has not recognized this reality, and both energy and resources have been wasted in addressing the wrong concerns.

Shifts in interest and in funding levels in a variety of areas in mathematics education indicated shifting priorities. However, it often appears that these shifts have been based on little evidence about existing practices. Needs assessments confirmed existing problems and issues rather than being fadlike in character, is at stake.

The third type of failure -- not recognizing the point at which the

values of various groups enter into policy formation -- is similarly evident. Policy making was described in terms of operation at two levels, one incorporating professional judgments based upon information and the other that is political and reactive to prevailing societal attitudes and values. Change results only when there is significant agreement across the two levels. Needs assessments must systematically garner information not only relative to the schools and their performance, but also on the prevailing societal ethos that is a necessary condition for acceptance and support of change. Accurate and meaningful information must also be disseminated to develop broad bases of support and to improve rational decision-making. The gaps between expectancies and priorities of various groups need to be narrowed.

Policy formulation at the federal level typically has ignored existing practices in the schools except as mirrored in the disquietude of society. Information was collected after-the-fact of policy decision to confirm the actions taken. The amazing, significant conclusion indicated by this study is that progress has been made without systematic information collection about existing practices. Apparently, the societal/political ethos is sensitive enough to the goals, aims, and objectives of education to provide substantial direction. Thus efficiency in promoting change is the real problem to be faced. The inplication is that not only must appropriate kinds of information concerning practice in the schools be collected: sound application of this information must be made.

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APPENDIX A

TERMS USED IN SEARCH OF ERIC DATA BASE

TERMS USED IN SEARCH OF ERIC DATA BASE

Searches were limited by the terms Science and Mathematics (partial descriptors) respectively.

1. Student Outcomes

Student Needs
Student Attitudes
Student Interests
Student Opinion
Student Problems
Student Reaction
Achievement
Achievement Need
Teacher Attitudes
Teacher Characteristics
Teacher Distribution
Teacher Influence
Teacher Responsibility
Teacher Role
Academic Achievement
Administrative Change
Administrative Problem
Administrator Attitudes
Community Attitudes
Community Change
Community Influence
Community Involvement
Mathematics Teachers
Science Teachers

2. Needs Assessment

Achievement Tests
Educational Needs
Norm Referenced Tests
State Programs
Statistical Data
Student Evaluation
Technical Reports
Test Results
Academic Achievement
Academic Performance
Educational Objectives
Student Testing
Testing Programs
Educational Assessment
Program Effectiveness
National Surveys
Educational Assessment

2. Needs Assessment (continued)

State Surveys
Statistical Surveys
Needs
Student Needs
Achievement Need
Educational Policy
Problems (txt)
Enrollment Trends
Educational Trends

3. Teacher Preparation

Teacher Certification
Credentials
Teacher Certificates
Teacher Education Curriculum
Teacher Employment
Teacher Qualifications
Teaching Skills
Performance Based Teacher Education
Preservice Education
Inservice Teacher Education
Science Institutes
Summer Institutes
Teacher Background
Teacher Evaluation

4. Facilities/Equipment

Facilities (txt)
Greenhouses
Laboratories
Planetariums
Equipment
School Planning

5. Effectiveness/Efficiency

Cost Effectiveness
Educational Assessment
Evaluation Criteria
Educational Accountability
Management by Objectives
Performance
Teacher Effectiveness
Performance Contracts
Productivity
Program Effectiveness
Responsibility
School Responsibility
Educational Improvement
Educational Innovation

5. Effectiveness/Efficiency (continued)

Educational Economics
Organizational Effectiveness
Resource Allocations
Educational Responsibility
Effective Teaching

6. Student Characteristics

Academic Ability
Student Ability
Average Students
Low Ability Students
Academic Aptitude
Student Characteristics
Student Evaluation
Student Interests
Student Motivation
Student Science Interests
Student Self Image
Attitudes (txt)

7. Curricula Patterns

Curriculum (txt)
Program Descriptions
Course Organization
Units of Study (Subject Field)
Course Description
Science Course Improvement Project
Instruction

8. Career/Success

Science
Mathematics
Career Choice
Career Education
Career Planning
Careers
Science Careers

9. Research

Evaluation
Research Reports

APPENDIX B

KEY WORDS FOR SEARCHING

DISSERTATION ABSTRACTS INTERNATIONAL

KEY WORDS FOR SEARCHING .

DISSERTATION ABSTRACTS INTERNATIONAL

The term EDUCATION should be used as a major term, used as an and term with the list. To avoid a large number of false hits, the combined term PHYSICAL EDUCATION should be used as an and not term.

Anatomy
Astronomy
Atom
Atomic

Biochemical
Biochemistry
Biological
Biology
Botany

Cell
Cells
Chemical
Chemistry
Conservation

Density
DNA

Earth
Ecological
Ecology
Electric
Electrical
Electricity
Electromagnet
Electromagnets
Electromagnetic
Electron
Electronic
Electronics
Electrons
Element
Elements
Engineering
Environment
Environmental
Evolution
Experiment
Experiments

Field
Force
Forces

Gas
Gases
Genetic
Genetics
Geological
Geology

Ion
Ionic
Ions

Kinetic
Kinetics

Laboratory
Light
Liquid
Liquids

Magnet
Magnetic
Magnets
Marine
Mechanical
Mechanics
Medical
Meteorology
Microbiology
Model
Models
Molecular
Molecule
Molecules
Motion

Natural
Nature
Nuclear
Nucleus

Oceanic
Oceanography
Oceanology
Oxidation

Particle
Physical
Physics
Physiological
Physiology
Planetarium

Radiation
Radio
Radioactive
RNA

Science
Scientific
Sciences
Sea
Sound
Space
Speed

Velocity
Volume

Weather

Zoology
Zoo
Zoos

APPENDIX C

ORGANIZING CHECKLIST FOR STATE DEPARTMENTS OF EDUCATION DOCUMENTS

ORGANIZING CHECKLIST

DOCUMENTS

Type of Document	Year			
	1955-59	1960-64	1965-69	1970-now
I. Survey or Summary of Information				
-Enrollments				
-by courses/levels				
-sex ratios				
-socioeconomic ratios				
-attrition/drop out rates				
-Curriculum/Course Offering				
-required				
-elective				
-special program/student groups				
Curriculum Materials Usage				
-texts				
-supplemental materials, etc.				
-Instructional Practices				
-Teacher Information				
-work load				
-certified--noncertified				
-in-area--out-of-area				
-number of teachers teaching each course/level				
-degrees, advanced work				
-specialists/department heads				
-Equipment/Facilities				
-Financing/Budgeting				
-state expenditures for science, math, social science				
-state supervisor budget				
-efficiency/cost effectiveness of program				
II. Policies, Regulations, Mandates				
-Curriculum and Instruction				
-required courses, scope and sequence				
-special programs (special groups, EMR, etc.)				
-graduation requirements: credits, courses, performance, competence, etc.--exemptions.				
Textbook or Curriculum Adoption				
-adoption lists				
-scope and sequence				
-process of change				

Type of Document	Year			
	1955-59	1960-64	1965-69	1970-now
II. Policies, Regulations, Mandates (Cont.)				
-Teacher Preparation				
-certification				
-re-certification				
-maintaining certification				
-Accreditation Requirements				
-schools				
-colleges and universities (teacher education)				
-Accountability				
-plans, summaries				
III. Guidelines, Units, Syllabi				
-Required Courses				
-Elective Courses				
-Special Topics (cross disciplinary, etc.)				
IV. Testing, Evaluation				
-Pilot Testing of Programs/Materials				
-Achievement				
-Attitudes				
-Instruments/Units of Analysis				
V. Planning Documents				
-Needs Assessment				
-Statement of Needs				
-Systematic Process/Components, Persons Involved				
-Use and Purposes of Planning Information				
-Plans/Policy Statements				
-three year plans, etc.				
-staffing patterns				
VI. Legislation				
-Any Pending Legislation Related to Education				

GLOSSARY OF ACRONYMS

AAS	American Association for the Advancement of Science
AACTE	American Association of Colleges of Teacher Education
ACE	American Council on Education
ACT	American College Testing Program
AETS	Association for the Education of Teachers in Science
AIR	American Institutes for Research
AYI	Academic Year Institute
BSCS	Biological Sciences Curriculum Study
CBA	Chemical Bond Approach
CBTE	Competency Based Teacher Education
CCSP	Cooperative College School Program
CEEB	College Entrance Examination Board
CHEMS	Chemical Education Material Study
COPES	Conceptually Oriented Program in Elementary Science
EPIE	Educational Products Information Exchange
ERIC	Educational Resources Information Center
ESEA	Elementary and Secondary Education Act
ESCP	Earth Science Curriculum Project
ESS	Elementary School Science
ETS	Educational Testing Service
HEW	Department of Health, Education and Welfare
IPS	Introductory Physical Science
ISCS	Intermediate Science Curriculum Study
ISIS	Individualized Science Instructional System

LEA	Local Education Agency
MINNEMAST	Minnesota Mathematics and Science Teaching Project
NAEP	National Assessment of Educational Progress
NARST	National Association for Research in Science Teaching
NASDTEC	National Association of State Directors of Teacher Education and Certification
NCATE	National Council for Accreditation in Teacher Education
NCES	National Center on Education Statistics
NDEA	National Defense Education Act
NEA	National Education Association
NIE	National Institute of Education
NSF	National Science Foundation
NSTA	National Science Teachers Association
PACE	Projects to Advance Creativity in Education
PBTE	Performance Based Teacher Education
PSSC	Physical Sciences Study Curriculum
SAPA	Science-A Process Approach
SCIS	Science Curriculum Improvement Study
SAT	Scholastic Apptitude Test
SEA	State Education Agency
SES	Socio-economic Status
SI	Summer Institute
SSMA	School Science and Mathematics Association
UPSTEP	Undergraduate Pre-service Teacher Education Program
USMES	Unified Sciences and Mathematics in the Elementary School