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ABSTRACT

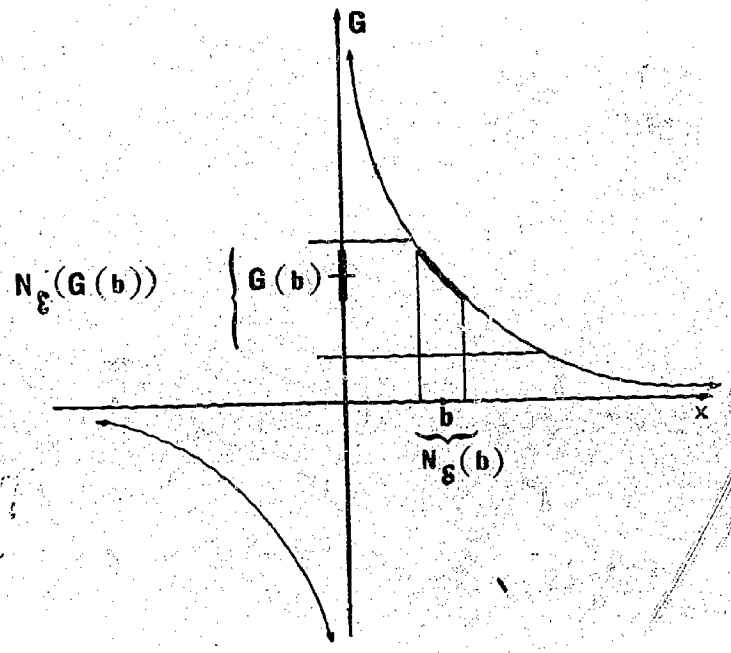
This bulletin contains: (1) a summary and conclusions of a study of mathematics curricula in Europe and Japan, and (2) a description of beginning efforts to evaluate the Secondary School Mathematics Curriculum Improvement Study (SSMCIS) project. Some of the conclusions of the European and Japanese study are: (1) the study of Euclidean synthetic geometry has been replaced by an axiomatic presentation of affine geometry, then transformations and vector geometry; (2) probability and statistics are becoming integrated into secondary school mathematics; (3) all countries have included calculus as a secondary school study; and (4) vector spaces and linear algebra are the newest comers to secondary instruction. Although in its sixth year, no results are yet available from evaluative efforts of the SSMCIS project. During 1970-71 achievement and attitude tests were constructed and administered. Data analysis, according to the author, are underway. (JG)

6

Information Bulletin

Fall 1971

SECONDARY SCHOOL MATHEMATICS CURRICULUM IMPROVEMENT STUDY



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CONTENTS

SECONDARY SCHOOL MATHEMATICS CURRICULUM IMPROVEMENT STUDY

BULLETIN 6

PREFACE

This Bulletin contains a summary and conclusions of an on-the-site study of mathematics curricula in Europe and Japan. The complete report of the study, including the school organizations, syllabi in mathematics, examinations, and trends in reform may be obtained from SSMCIS under the procedure described on the last page of this Bulletin. The study was financed by the National Science Foundation under funds available in the SSMCIS grant. The report has significance for the improvement of mathematics education in the schools of the United States of America.

This Bulletin also contains a first report on the endeavors to date, in evaluating the SSMCIS experimental program. This evaluation is under the direction of Professor Jeremy Kilpatrick. A table of contents of Courses I through VI completes the Bulletin.

Summary and Conclusions of Mathematical Study In European and Japanese Secondary Schools

A comparison of the programs in mathematical study at the secondary school level in the countries examined show significant differences in organization, in content, in objectives and in methodology of presentation. However, they likewise show significant common trends in adapting instruction to a wider group of students, and presenting the subject more in harmony with con-

temporary notions of the nature of mathematics. The following analysis may prove of value to those who are concerned with developing, and continuously revising the program of mathematical studies in their own districts so as to best meet the needs of their youth in the years that lie ahead.

1. The "wild West" days of opening up a new land for frontiersmen in the realm of mathematical education are over. Contemporary viewpoints of using sets, relations, mappings and operations as a foundation for all school mathematics have been established and accepted. They are no longer a case at issue in any country of the world. The use of structures--groups, rings, fields, vector space--are now included in all programs even though the names of these structures are not always explicitly stated and their use is sometimes delayed to the last years of study.

2. All programs initiate secondary school mathematics on an intuitive level. The degree to which this level is gradually replaced by more formal and more abstract approaches to learning varies greatly from country to country. Even in programs which do become formal at an early stage there is no attempt to be strictly axiomatically rigorous--easier theorems will be proved but more difficult theorems will be illustrated numerically or graphically, i.e. algebraically or geometrically, and then accepted for application. The stress on logic appears to be in the ratio of the stress that is placed on teaching practical applications to that of teaching abstract development of the subject itself. England is very application minded--in France

mathematics has always been treated abstractly.

3. Most countries provide different programs in mathematics in the senior high school years to provide for individual interests and needs of their youth. Different countries accomplish this in different ways but practically all countries give all youth the same mathematical study in the compulsory school years of grades 7, 8, and 9. Some countries stream individual students to proceed in their learning at a rate which they have exhibited in their past learning. This can be done by using different classes, by group instruction or using individualized self-learning techniques. A school certificate is available to those who have learned what is deemed every citizen must learn before he leaves school. For those who wish to continue, passing of examinations is a key to further study.

Those who are capable and will attend university study pursue different courses in the senior high school. Thus the mathematics and scientific students study more mathematics, with a more abstract presentation and with more weekly hours of study than the students in the economics-sociology line, or the students in the humanistic line. Only in the U.S.A. do we now find one standard college preparatory program for all students regardless of their future aspirations.

4. In all countries the study of Euclidean synthetic geometry has been eliminated from the senior high school. In its place, geometry is presented in several forms usually beginning with a simple axiomatic presentation of affine geometry and then

making use of coordinates, transformations and vectors. The study of geometry is developed to mesh with algebra and algebraic structures and thus to serve in the subsequent study of mathematics.

5. In all countries there is a trend to make a genuine unification of the study of mathematics--that is, to interrelate all the classical branches into a contemporary setting where the common elements of all subjects form a foundation of the study. While sets, relations, mappings, and operations occur in all programs, the way they are used to bring about a unified approach varies from country to country. The unity that does appear is far less in those countries where there is a desire to keep much of the good old know-how of the classical treatment than in co ies where there is the general agreement that new emphasis on concepts and structure are very important. How to teach the new without losing the values of the old is a serious problem to all nations.

The foregoing remarks relate to didactical considerations concerning the curriculum structure, learning theory, individual differences in interest and learning ability, and the unification of mathematical study. The general program that emerges in all countries is a more or less structured-unified one, in which intuition, meaning, understanding, exemplification and application are used to introduce the program. From this base a more or less structured study of algebra and geometry are united under a vector space of two and three dimensions. Here affine space and Euclidean space are studied by algebraic means to set a base for the subsequent study of analysis as well as

finite mathematical applications. In this respect the following other trends appear.

6. A recognition of probability and statistics as a very important application, as well as a mathematical discipline in itself, is emerging in all countries. The penetration of this subject into all modern affairs has made its knowledge a prerequisite of the modern educated man. That it can be learned in an elementary way, at a much earlier age than heretofore thought, has gradually entered the thinking of curriculum makers. In some nations the subject is introduced in the seventh year and elaborated upon each succeeding year of the school study. In other countries it is presented in the senior high school instead of being delayed to university study. It seems quite evident that probability is going to become integrated with all the rest of secondary school mathematics instruction.

7. In the United States the study of calculus was always conceived as collegiate study. During the past ten years it has been grudgingly permitted in the twelfth year of secondary school study for a privileged elite group known as the advanced placement students. In Europe, since the beginning of this century, an introduction to calculus was considered a necessary part of secondary school instruction. Today, all countries that have a twelve year school program include a comprehensive course in differential and integral calculus as secondary school study. In most countries the intuitive introduction is made in the tenth school year and extended over

the next two succeeding years. Even the college preparatory lines called social and humanistic learn about the calculus, especially those functions which most likely will occur in their own disciplines. It would appear that analysis (calculus) will be an integral part of, and unified with, secondary school mathematics instruction.

8. The newest comer to secondary instruction is vector spaces and linear algebra. This subject has come down from graduate to undergraduate collegiate mathematics and now to secondary school faster than any other topic in mathematics. It owes this promotion to its generality of concepts and its all pervasiveness or unifying power of all the classical branches. It is also a capstone for the regular algebraic structures and geometric systems which are blended into algebraic geometry or geometric algebra as further study demands. So, the vector geometry of two and three dimensions as a model of vector spaces with their linear algebra is in every twelfth year or earlier syllabus of mathematical study. It is evidently in secondary school to stay.

9. The electronic computer has invaded all aspects of modern life, public, industrial, and private. In a short space of twenty years the study of the computer, its programming, and some numerical analysis have entered high school instruction in the U.S.A. to some degree. The lack of such provisions in European programs, presently in force or proposed, is partially explained by the cost of such instruction, but even more so by the failure of European culture to exploit this new technological instrument. In the immediate years ahead it appears that not

hundreds, but millions of persons will be directly or indirectly involved with the production, use and maintenance of computers, and the elementary mathematical ideas and thinking related to computers must become a part of secondary instruction for all students--not only those mathematically inclined.

10. While not evident from the syllabi which are still for the most part college preparatory-subject-matter-per-se oriented, but quite clearly discernible from political, social, and economic expressions of government, business, and the public at large, there is growing a great concern for mass education. The thinking in many countries is that for the major part of secondary education there should be a single curriculum for all students which would present the common knowledge all future citizens would need. This would supposedly constitute an education of equal opportunity for all. This certainly would be an admirable thing to do and would make mathematics specialists examine their subject from a social value orientation rather than being only subject matter centered.

There are other kinds of school mathematical study than that which has for its only purpose the elimination of the weak to select a strong elite university body of students. However the danger is, and in several countries this danger is recognized, that the common program becomes the only program to the neglect of our capable students. The essence of this trend lies in the fact that in the past our programs have been almost entirely dominated by preparation for college and presently there is now an awakening of the need to produce a program for the large mass of our youth which should be particularly centered on

their future needs.

Mathematicians have been studying their subject as to its nature and its uses, its possibilities and its limitations, and especially its place in the solution of human problems. The result, an explosion of mathematical knowledge, demands a reconstruction of the subject into a more efficient--unified--structured form. This new organization of mathematics, a mid-twentieth century development, has as its base sets, relations, and mappings on which are built algebraic and geometric structures, all of which have, beyond theoretical importance, valuable applications in all fields of investigation. Indeed, it is this present day conception of mathematics which has invaded almost every domain of human endeavor. For this reason the subject must be made known to every citizen, each according to his need, and each according to his ability and diligence to learn. The organization of the subject into a study to meet this challenge must be accomplished by a continued search for improved curricula.

EVALUATION ACTIVITIES OF SSMCIS: 1970-71

With three of the six SSMCIS courses in final form and the other three in various stages of development, the evaluation activities of SSMCIS from June 1970 to June 1971 were partly formative and partly summative in nature. That is, some activities were designed mainly to contribute to the improvement of the curriculum materials, and some were designed mainly to assess the effectiveness of the (more or less) finished product. As in the past, a large part of the formative evaluation of SSMCIS materials in 1970-71 was provided by (1) mathematicians and mathematics educators who, in the June Conference, the Summer Writing Session, and elsewhere, criticized the materials and made suggestions for improvement, and (2) teachers in the experimental schools, who reported on how the materials were going in their classes: the problems they were having, the problems their students were having, the topics that were going over well, and so on. This report covers the other major evaluation activities that took place during the year.

Evaluation of Achievement

Spring 1970 Examinations for Courses III and IV

Although the examinations taken by the experimental Course III and Course IV in the spring of 1970 were constructed and administered before the period covered by this report, they should be mentioned here. Each examination was designed to cover the major topics in the course. The examinations were to be used by the teachers in diagnosing each class's performance and by the SSMCIS writers in revising the Course III and Course

IV textbooks. Item analyses were prepared by the SSMCIS staff for use by the writers during the June Conference and the Summer Writing Session in 1970. Although of necessity there were only a few items on each topic, the item results did provide useful information for both teachers and writers. On the Course III examination, for example, students made an especially large number of arithmetic errors in calculating with coordinates and matrices. In Course IV, the performance of the students on items from the Sequences and Limits chapter helped confirm the decision to revise the chapter drastically.

Spring 1971 Examination for Ninth Graders

Prior to the 1970-71 school year, all of SSMCIS's achievement testing had been conducted with the experimental classes only. Examinations were written for only those courses undergoing revision. Course III was published in final form in September 1970 and was being used in 1970-71 in several dozen schools besides the experimental centers. Since the ninth grade is a critical one for the SSMCIS program in many school systems, marking the transition from junior high to senior high, and since data had not yet been gathered on the achievement of SSMCIS students who were not in experimental schools, the SSMCIS staff decided to concentrate their evaluation efforts on a special examination to be given to ninth graders in the spring of 1971.

Letters were sent to the principals of schools--experimental and non-experimental--asking that their Course III students participate in a single 40-minute testing session sometime during the last month of school, at the teachers' convenience.

Testing materials and instructions were sent in mid-May to teachers in the more than 30 schools that agreed to participate. The teachers administered the tests and have returned them to us. Data analyses are under way.

To increase the information obtainable in a single testing session, three different examination forms were prepared. They were distributed more or less at random within each class. Each student took only one form. Form 1 was the Educational Testing Service's Cooperative Algebra I test. Admittedly while not appropriate to the content of Courses I to III, it will allow comparison of SSMCIS students' performance with established norms on a standardized measure of the knowledge of concepts from first-year algebra. Forms 2 and 3 were composed of items that, for the most part, were designed to cover content from the SSMCIS curriculum. Thirteen items in Forms 2 and 3 were taken from an algebra test given to ninth graders as part of the National Longitudinal Study of Mathematical Abilities (NLSMA). Data are available from NLSMA that will allow some comparisons of SSMCIS students' performance with that of groups of students who have been in various conventional and modern mathematics curriculum programs.

In designing Forms 2 and 3, the SSMCIS staff constructed a matrix having three rows--for Courses I, II, and III--and four columns--for Abstract Algebra, Linear Algebra, Geometry, and Probability (plus other miscellanea, such as Number Theory). The 50 test items to be written were distributed among the cells of the matrix so that they were divided 15, 15, and 20 across the three courses as listed, and 20, 7, 15, and 8 across the

four content areas as listed. NLSMA items were used in some of the cells, but most of the items were original. In addition to the 50 items from the matrix, and the remaining NLSMA items, a separate set of 18 items were written that tested students ability to deal with mathematical ideas in an unfamiliar set ing. All 18 of these items were put together at the end of Form 3.

Data from this special examination should provide information on how much Course III students recall of the material in Courses I, II, and III, how the SSMCIS students in non-experimental schools compare with SSMCIS students in experimental schools, how SSMCIS students compare with students who took the ordinary Algebra I course in the ninth grade, which topics in the SSMCIS program seem to be best understood by ninth graders, and so on. In a sense, the special examination will provide the first formal summative evaluation of a part of the SSMCIS program.

Evaluation of Attitudes

Any evaluation enterprise that pretends to be at all comprehensive should give some consideration to the assessment of attitudes. The SSMCIS staff has been interested in the attitudes of students in the program toward mathematics itself, toward their mathematics course, and toward their mathematics textbook. A Student Opinion Survey (SOS) was administered to students in the experimental classes at the end of the 1969-70 school year and was readministered in these same classes at the end of the 1970-71 school year. The SOS contains the following sections:

1. A list of chapter titles from the SSMCIS textbooks, with instructions to indicate which three chapters were "enjoyed

most" and which three were "enjoyed least"

2. A set of agree-disagree items on the student's opinion of his mathematics course and his mathematics textbook
3. Three semantic-differential scales dealing with attitudes toward mathematics in comparison to English, mathematics in relation to the student himself, and the student's mathematics textbook
4. A set of agree-disagree items dealing with attitudes toward mathematics in general, mathematics as a process, the difficulty of learning mathematics, and the place of mathematics in society; these items are from Aiken's Revised Math Attitude scale and three scales used in the International Study of Achievement in Mathematics
5. A set of open-ended items dealing with the student's textbook and his mathematics class.

Descriptive data from the first administration of the SOS have been tabulated (see SSMCIS Technical Report 1 for an analysis of the data on the first section above) and were available to the SSMCIS writers in the summer of 1970. The major analysis, however, concerns changes in attitudes from the first administration of the SOS to the second and is just beginning.

Regents Examinations

In order that SSMCIS students in New York State may receive Regents credit for their courses, SSMCIS has received permission from the State Bureau of Mathematics Education to construct and use special examinations in lieu of the Tenth Year Mathematics and Eleventh Year Mathematics Regents examinations. Special

tenth and eleventh year examinations, together with sets of review questions, were constructed for June 1971. As more schools in New York State adopt the SSMCIS program, the task of constructing the special examinations will undoubtedly be taken over by committees of SSMCIS teachers. Ultimately, the State Department of Education may itself provide SSMCIS Regents examinations, should the number of participating schools warrant it. In the meantime, SSMCIS will continue to arrange the special examinations, with those examinations constructed thus far serving as examples for future efforts. The Supplementary complete report (see last page) contains a copy, with answers, of the SSMCIS special examination used in lieu of the Eleventh Year Mathematics Regents examination in June 1971.

College Board Examinations

One of the goals of SSMCIS has been to organize the secondary school curriculum more efficiently, so that much of the first two years of contemporary collegiate mathematics can be brought into the high school. The test of how well this goal has been met can only be made once all six courses are available and substantial numbers of students who have completed the course sequence are taking college mathematics courses. That time is still several years in the future, but SSMCIS has already taken some steps to smooth the transition between high school and college. A big question students (and their parents) have is whether participation in the SSMCIS program could adversely affect their chances of college entrance. They are usually convinced that the mathematics they are learning will stand them in good stead; what they are worried about is the

tests they will have to take.

During the 1970-71 school year, members of the SSMCIS staff met with members of the Mathematics Department of the Educational Testing Service (ETS), the organization responsible for the College Entrance Examination Board tests, to discuss ways of adapting the College Board mathematics testing program for SSMCIS students. The people at ETS were most cooperative. They want to encourage innovative curriculum programs, and they suggested a number of measures for assuring that students will not be penalized for their participation in SSMCIS. By special arrangement with ETS, the SSMCIS staff has examined the mathematics section of the Scholastic Aptitude Test. We have concluded that relatively few items deal with topics that are not treated at all in the SSMCIS curriculum. Perhaps one in eight items deals with a topic--such as the sum of the angles in a polygon--that is not given particular emphasis in the SSMCIS curriculum. Almost all items can be reasoned through without the knowledge of special facts and relationships. The extent of the SSMCIS students' handicap on the test is not known, however. ETS plans an investigation, beginning in the fall of 1971, in which the performance of the SSMCIS students on the Preliminary Scholastic Aptitude Test will be compared with the performance of others. Eventually the regular Scholastic Aptitude Test will also be used for comparison. We have also inspected the College Board's Level I and Level II mathematics achievement tests, and ETS has already begun a study of how SSMCIS students fare on the Level II test. which consider the more appropriate for them.

Should SSMCIS students be at a disadvantage on any of these examinations, the staff at ETS has discussed with us the feasibility of several plans, ranging from special scoring formulas to changes in the examinations themselves. Meanwhile, we are working closely with teachers and students in the experimental classes to make sure that no student will have his chances of attending a particular college jeopardized. Our experience thus far is extremely limited, but it leads us to expect that although an SSMCIS student may be at a slight disadvantage on certain mathematics tests, colleges will recognize the inappropriateness of the tests in his case and will count it an asset that he has been participating in this innovative mathematics program.

Questions of the articulation between the SSMCIS curriculum and college mathematics curricula will loom larger in the next few years as the first waves of SSMCIS students graduate from high school. Consequently, more of our limited resources for evaluation will be invested in this area, with a consequent reduction in the test construction activities that have been our major preoccupation to date. Put another way, more of SSMCIS's evaluation activities will be of a summative nature in the next year or so, and the biggest summative question of all is, what happens to the SSMCIS students in college?

Note on Use of SSMCIS

In Bulletin 5, it was indicated that the SSMCIS texts have generated considerable interest among mathematics educators and mathematicians in this country and abroad (see Implementation

and Teacher Preparation, Bulletin 5). In 1970-71, in the United States, there were approximately 6,000 students using Course I, 4,000 students using Course II, 2,500 students using Course III and, 1,200 students using Course IV (which is available beginning September, 1971). Courses V and VI are now being studied by approximately 340 students in the Project's experimental schools.

A full report on the philosophy, content, construction, and evaluation of the SSMCIS mathematics program will be presented in Bulletin 7, scheduled for release in May 1972.

Appendix A

Sequence of Chapters

Courses I, II, III, IV, V, and VI

Course I

Chapter	Title
1	Finite Number Systems
2	Sets and Operations
3	Mathematical Mappings
4	Integers and Addition
5	Probability and Statistics
6	Integers and Multiplication
7	Lattice Points in a Plane
8	Sets and Relations
9	Transformations of the Plane
10	Segments, Angles, Isometries
11	Elementary Number Theory
12	The Rational Numbers
13	Some Applications of the Rational Numbers
14	Algorithms and Their Graphs

Course II

1	Mathematical Language and Proof
2	Groups
3	An Introduction to Axiomatic Affine Geometry
4	Fields
5	The Real Number System
6	Coordinate Geometry

7	Real Functions
8	Descriptive Statistics
9	Transformations of the Plane: Isometries
10	Length, Area, and Volume
Appendix A	Mass Points

Course III

1	Introduction to Matrices
2	Linear Equations and Matrices
3	Algebra of Matrices
4	Graphs and Functions
5	Combinatorics
6	Probability
7	Polynomials and Rational Functions
8	Circular Functions
9	Informal Space Geometry

Course IV

1	Programming in BASIC
2	Quadratic Equations and Complex Numbers
3	Probability
4	Circular Functions
5	Algebra of Vectors
6	Linear Programming
7	Sequences and Series
8	Exponential and Logarithmic Functions
9	Affine and Euclidean Spaces; Subspaces

Course V

1	Introduction to Continuity
2	More About Continuity
3	Limits
4	Linear Approximations and Derivatives
5	Properties of Derivatives
6	Linear Mappings, Simplex Method
7	Introduction to Integration
8	Probability
9	Applications of Derviatives

Course VI (June, 1971)

1	Infinity
2	Conics and Polar Coordinates
3	Some Transcendental Functions
4	Techniques of Integration
5	Applications of Probability

Booklets	
A	Algebra and Morphisms
B	Determinants, Matrices, and Eigen Values
C	Statistics

AVAILABILITY OF MATERIALS

For texts or Teacher Commentaries please direct all orders to:

TEACHERS COLLEGE PRESS
Teachers College, Columbia University
1234 Amsterdam Avenue
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UNIFIED MODERN MATHEMATICS

Course 1--2 parts	$3.25 per part
Course I--Teachers Commentary	5.25
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Course III--2 parts	3.25 per part
Course III--Teachers Commentary	5.25
Course IV--2 parts	2.50 per part
Course IV--Teachers Commentary (January 1, 1972)	3.00
Course V--2 parts (Available Fall, 1972)	2.50 per part

The following materials can be received without cost from:

SSMCIS, Box 120
Teachers College, Columbia University
New York, NY 10027

I. Bulletin 5

II. Report to the Office of Education regarding SSMCIS--Courses I, II, III

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Supplement to Bulletin No. 6

The Complete Report of Mathematics Instruction in European and Japanese Secondary Schools is issued as a paperback supplement to this Bulletin No. 6. Besides the European Report (125 pages) it contains a reproduction of the section on evaluation activities and a sample Regents examination with answers, an outline of the mathematical background for teaching SSMCIS, or any other contemporary mathematics curriculum, and an up-to-date report on SSMCIS activities.

This supplement is available from SSMCIS, for a prepayment of $1.00 a copy. Merely write for

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