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The UCSMP: Translating Grades 7–12 Mathematics Recommendations into Reality

The University of Chicago's School Mathematics Project is developing curriculum to motivate middle-ability students.

Eighth grade students at Walt Disney Magnet School, Chicago, Illinois, use a balance beam to model the process of solving the equation 4B + 6 = 2B + 18 from the UCSMP Algebra.

Photographs by William R. Goes

In 1983 the Amoco Foundation gave the University of Chicago funding for six years to improve school mathematics in grades K-12. The result is the multifaceted University of Chicago School Mathematics Project, aimed at preparing students in the middle-ability range for the 1990s and beyond. The project has since received additional funding from the Carnegie Corporation of New York, the National Science Foundation, and the General Electric Foundation.

At the secondary level, the project has focused on designing and producing usable and effective materials for a complete mathematics curriculum for students in grades 7–12. This article outlines the curriculum development process and describes the motivation for the major features of the curriculum.

Recommendations and Reality

Among the many school reform reports published in 1983 were several that made specific suggestions regarding mathematics (National Commission on Excellence in Education 1983 and The College Board 1983). Since these recommendations largely mirrored views of mathematics educators and mathematicians in reports published between 1975 and 1980 (NACOME 1975, NIE 1975, NCSM 1977, NCTM and MAA 1977, NCTM 1980), the University of Chicago project has not created its own set of recommendations. Instead, it has attempted to translate existing ones into the reality of classrooms and schools.

These recommendations respond to two generally perceived problems in mathematics education in grades 7–12. The first is that high school graduates are not learning enough mathematics. Specifically:

1. many students lack the mathematics background necessary to succeed in college, on the job, or in daily affairs;

2. students do not get enough experience with problems and questions that require some thought before answering; and

3. many students terminate their study of mathematics too soon, not realizing the importance of mathematics in later schooling and in the marketplace.

These situations have given rise to recommendations to *upgrade students* by increasing graduation requirements and by improving students' problem-solving performance and their skills in arithmetic and algebra.

Upgrading is not as simple as some reports and remedies suggest. For instance, in the past few years, in response to the first and third problems, many states and schools have increased requirements for secondary school graduation. Yet in 1983, *before* many of these increases went into effect, the one million seniors who took the SAT had, on average, taken 3.62 years of mathematics; by 1985 the average had become 3.68 (Admissions Testing Program of the College Entrance Examination Board 1983, 1985). Thus, increases in requirements affect more non-college-bound students than those who will attend college. Consequently, students with a record of poorer academic performance are winding up in courses intended to provide preparation for college, courses in which they have little interest.

Furthermore, high school mathematics courses are characteristically among the most severely graded courses with the highest failure rates. To respond to the second problem by giving students harder questions would seem only to exacerbate the existing situation in which too many students experience failure.

The second general issue confronted in recent reports is that the school mathematics curriculum has not kept up with changes in mathematics and the ways mathematics is used in business, industry, and the marketplace. Specifically:

4. current mathematics curriculums have not taken into account today's calculator and computer technology;

5. students who do succeed in secondary school mathematics are prepared for calculus but not for the other mathematics they will encounter in college;

6. statistical ideas are seen everywhere, from newspapers to research studies, but are not found in most high school mathematics curriculums;

7. the emergence of computer science has increased the importance of a background in topics from discrete mathematics, which is not usually a high school focus;

8. mathematics is applied to areas outside the physical sciences as much as inside, but these applications are seldom found in textbooks; and

9. estimation and approximation techniques are important in all of mathematics, from arithmetic on, but have not been emphasized in the curriculum.

These situations have led to recommendations to update the curriculum. Updating the curriculum is also not easy to translate into reality, even if we ignore the usual difficulties in implementing any new content. Time is the omnipresent enemy. Even with the present curriculum, the pace of presenting new mathematics content is fast for average students. The content suggested in problems 4–9 cannot be covered in a couple of weeks or in a textbook chapter. To cover the additional topics in statistics and computing currently recommended by the College Board (1985) would take up to a full year. Some help comes from suggestions to delete certain paper-and-pencil skills that can be done more accurately and quickly by calculators and computers (CBMS 1983, NCTM 1984), but learning to deal with this technology takes time.

Finally, it is widely recognized that students do not read mathematics books and, thus, are not ready to learn mathematics on their own outside of school. This situation suggests that we need to change the character of math textbooks.

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School Mathematics Project Curriculum, Grades 7–12

The project's response to the problem of upgrading students is to develop courses for the average student—not for those who are mathematically inclined (as was the case with most of the new math curriculums of the late '50s and early '60s)—nor for the lowest achievers (as was the case with most of the back-to-basics curriculums of the '70s). The target population for project materials is perhaps best described as students who will graduate from high school but who are not advanced placement students in mathematics.

Characteristics of all project courses (Table 1) reflect the target population. The motivation in them often comes from real-world applications of mathematics (motivations seldom found either in new math or back-to-basics texts). Dealing with applications provides substantial and wide experience in problem solving. Skills are carefully selected to complement the applications and sequenced so that those needed by a wider populace (e.g., calculations of area and volume in geometry) are introduced early and reviewed frequently, while those needed simply for college-level courses (e.g., operations with rational polynomial expressions in algebra) are covered in a later year than is customary.

Confronting the problem of time, project members searched for room in the curriculum. We knew that eighth grade is a time at which many students are needlessly held back to wait for algebra in the ninth grade. Furthermore, there is a substantial gap between the difficult eighth grade algebra course offered to future advanced placement students and the typical course offered to most students. We hypothesized that many eighth graders would be ready for an average algebra course, even more ready for an algebra course of the type we might design, and still more ready if they were given a strong preparation in seventh grade. Studies of mathematics performance in other countries confirm this view (McKnight et al. 1985).

Our analyses of mathematics textbooks in use in the U.S. support this contention. In typical seventh and eighth grade texts, an average of only 20 percent of the first 200 pages contain *any* mathematics new to the student. (We counted anything as new content that was so indicated by publishers—even computer exercises or "calculator corners" that many teachers skip.) Only 30 percent of the pages of these entire books contain any new content. Thus, on the average, a teacher who conscientiously follows the book will introduce only one or two new bits of content a week. In contrast, about 70 percent of the pages of a typical algebra course contain content new to the student that year, so algebra teachers are introducing new material three or four days out of five. Many ninth graders are destroyed not by the content of ninth grade algebra, but because this is their first encounter with a mathematics course in which ideas are introduced at such a brisk pace. They do not possess the study habits necessary for success because they have been lulled to sleep in grades seven and eight.

We concluded that a curriculum to translate today's recommendations into reality must begin at grade seven at the latest, with algebra at grade eight. This spreads out the learning of traditional subject matter while offering room for newer content (see Table 2). Not all students are able to begin this curriculum at grade seven; preliminary testing has shown the first-year course to be appropriate for students who are at or above the achievement level of average seventh graders at the beginning of that grade regardless of age.

The general goal of the project's secondary curriculum is to prepare high school graduates with the mathematics most relevant to all citizens and to all college majors. Paralleling the breadth of mathematics found at the college level, the secondary curriculum includes substantial work with applications of mathematics in all years, statistics as an emphasis in the second and fifth years, computer access required in the fifth year and recommended in all other years, and attention to those mathematical topics basic to an understanding of computer science.

Today's mathematics textbooks contain very little reading. Students are forced to learn through the explanations of others, which goes against a primary purpose of schooling, namely, to teach students to learn independently. In contrast, all lessons in project textbooks contain reading to relate material from a lesson with previous content, to introduce examples, and to provide motivating information. Each lesson is followed by questions specifically covering that particular lesson. Suggestions to teachers strongly recommend that they frequently ask students to read and answer questions before giving explanations.

Table 1
Secondary Curriculum
General Characteristics of Project Courses

To update content:	• scientific calculators required and exploited in all years • applications throughout • data handling, statistics, and probability given emphasis • mathematics needed for computer science interspersed
To improve performance:	• reading required • modified mastery learning sequence after each chapter • continual review within chapters, within years, and between years • multidimensional approach to understanding: skills, properties, uses, and representations

The Development Process

The process used to develop these materials has four major steps: planning, writing a pilot, formative evaluation, and summative evaluation. Each step takes roughly a year (Table 3). Project staff are involved rather obviously in each phase. For instance, they attend professional meetings and visit school districts to obtain information and guidance. Outlined here are the more formal ways in which school personnel (administrators, mathematics supervisors, and classroom teach-

Table 2
Secondary Curriculum
Special Characteristics of Project Courses

Year	Course Name	Special Characteristics
1	Transition Mathematics	Applied arithmetic, pre-algebra, and pre-geometry interspersed
2	Algebra	About 1/5 statistics interspersed, contrived word problems and complicated manipulations deemphasized
3	Geometry	Measurement formulas, coordinates, transformations first semester; proof second semester
4	Advanced Algebra	Graphic techniques and geometry emphasized; complicated manipulations deemphasized
5	Functions and Statistics with Computers	Content interspersed; computer access required 1 hour/week for class; 1 more hour/week for students
6	Pre-College Mathematics	Manipulative skills, pre-calculus, and mathematics needed for computers emphasized

ers) are involved.

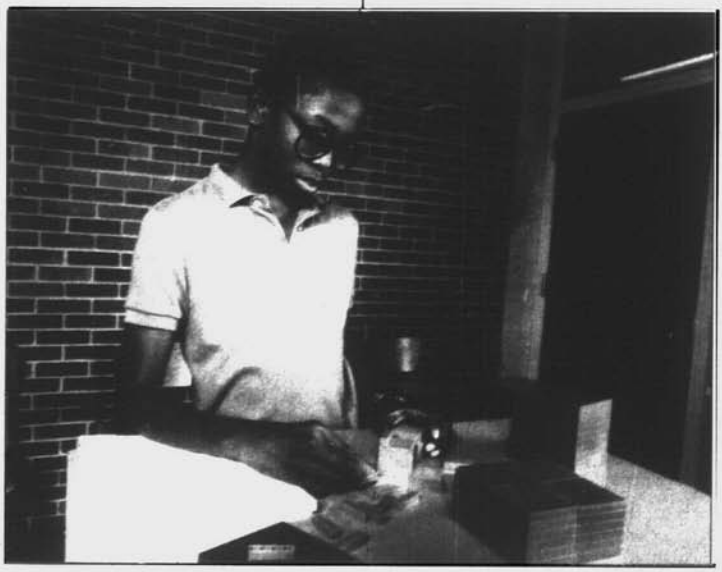
In the *planning* phase, each year we convene a full-day meeting of 20–30 school personnel to test whether ideas proposed by the project are reasonable and to come up with new strategies on particularly thorny issues. To date we have held three meetings, on the general themes of "Changing the Curriculum in Grades Seven and Eight," "Changing Standards in School Algebra," and "Functions and Statistics in Secondary School Mathematics." These meetings generate important information about sensitive points regarding implementation. For example, administrators have told us to be bold but to remember that our materials will be judged by old tests. Teachers have told us that the best existing software for doing manipulative algebra is not easy enough to use. At the most recent meeting, we were encouraged to go ahead with a plan to require computer access by classes and students in our fifth-year course, but not to change any content as a result! A bonus of these meetings is that almost everyone who attends later seems willing to become part of the testing program.

A curriculum project is judged by its materials. Because materials can be no better than their authors, we have taken great care to obtain the best authors available.[1] The algebra and advanced algebra writing teams were selected in a nationwide competition advertised in national newsletters. All respondents received an application that required them to edit a given lesson and to write a second lesson. We brought finalists to the university and evaluated them on their ability to plan with others and to write a lesson on the spot. It is noteworthy that 7 of the 11 members of these writing teams are teachers or supervisors below the college level. Authors of the other texts are all experienced textbook authors. Each project editor is an experienced secondary school mathematics teacher.

The *writing/pilot* phase is based on the philosophy that, whenever possible, all materials should be taught first by their authors or surrogates of the

Table 3
Development Schedule

Course	Planning	First Draft/Pilot	Revision/Formative	Revision/Summative
1983–84	Transition Mathematics	Transition Mathematics		
1984–85	Algebra Advanced Algebra		Transition Mathematics	
1985–86	Geometry Functions and Statistics with Computers	Algebra Advanced Algebra		Transition Mathematics
1986–87	Pre-College Mathematics	Geometry Functions and Statistics with Computers	Algebra Geometry	
1987–88		Pre-College Mathematics	Advanced Algebra Functions and Statistics with Computers	Algebra Geometry
1988–89			Pre-College Mathematics	Advanced Algebra Functions and Statistics with Computers
1989–90				Pre-College Mathematics



An eighth grade student at the Walt Disney Magnet School uses a concrete model of coordinates to picture multiplication, an approach used in UCSMP Algebra.

authors. In this way, as many as possible of those who revise the materials have the benefit of firsthand classroom experience. The actual logistics have differed from course to course. *Transition Mathematics* was written and then taught by its author and one other teacher. The first drafts of *Advanced Algebra* and *Algebra* were written during the summer, then edited and piloted during the next school year. The writing of *Geometry* and *Functions and Statistics with Computers* began about four months before the beginning of the year in which they were piloted.

After the pilot, the original authors or editors revise the materials. Then comes a *formative phase*, in which materials are tried with "typical" teachers. Evaluators closely study those teachers and their classes. They meet periodically at the university to discuss materials, so schools participating in this phase must be within commuting distance of Chicago. The purpose of the formative phase is to learn as much as possible for the second revision, which takes place during the following summer.

The *summative evaluations* planned for the first three years of this curriculum are major national studies. For example, the 1985–86 evaluation of *Transition Mathematics* involved over 2,000 students from 35 schools in 10 states. In this stage, schools provide names of pairs of teachers willing to teach either project or their usual materials; to avoid the "interested teacher" variable, we randomly decide who teaches which. In both formative and summative evaluations, we interview students, teachers, and administrators, observe classrooms, administer pre- and post-tests, and make results available to the public.

At the time of the summative evaluation, our materials are available for general use. We hold a conference each fall at which users and prospective users can find out the latest project news, share ideas, and comment on our work. The conference provides us with guidance and other information even from schools not in our formal studies.

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Alone But Promising

From the 1984–85 formative evaluation of *Transition Mathematics*, we found that students using this text held their own with arithmetic skills and far outstripped their counterparts in readiness to study either algebra or geometry. The formative evaluation teachers responded positively to the materials, the reading in them, and the use of calculators, but they had the benefit of being directly involved with us. As I write this (September 1986), the test results from the summative evaluation of *Transition Mathematics* are being processed, and we expect to have data to report by early 1987. We are pleased that several districts in our study have adopted these materials for large student populations.

Still, we are often asked if our work isn't pointless. What happened to all those projects of the '60s? We respond that virtually all commercial textbooks of the '60s are out of print. A project textbook should not be expected to have a longer life than a commercial textbook with a sales force behind it. Also, if the curriculum currently in schools were an experimental curriculum being tested, we would be forced to pronounce it a failure for many students.

We think the project is affecting efforts in many states and on many fronts to improve the mathematics curriculum. Our materials demonstrate that some of the recommendations of national commissions can be implemented. Project test items have been sought by states and school districts who wish to evaluate students on newer content. A number of major publishers have sent representatives to our meetings (we use their input, too), and before long we hope to see some effect of our work in commercially published materials.

When we began our work in 1983, we expected to learn of other projects of the same size and scope; to date we are alone. We feel pressured to perform the seemingly impossible: to de-

velop a curriculum that is immediately implementable, fully uses the latest widely available technology, and prepares students for success in the future. We hope that the University of Chicago School Mathematics Project will spawn other large-scale efforts to improve the mathematics curriculum in schools. Mathematics is too important today to the average citizen who must deal with numerical information and to the person who must use mathematical techniques on the job to allow them to leave school with insufficient preparation.□

1. Course leaders include John McConnell (Glenbrook South High School, Glenview, Illinois); Arthur Coxford (University of Michigan); Sharon Senk (Syracuse University); James Schultz (Ohio State University); and Rheta Rubenstein (Renaissance High School, Detroit, Michigan).

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