Chapter 1: Rationale

Statement of the Problem

This study investigated the joint effects of two reforms that are beginning to have widespread impact on mathematics instruction in high schools throughout the United States and Canada. The first reform is adoption of a problem-centered mathematics curriculum initially designed to conform with the National Council of Teachers Mathematics' (NCTM's) *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). The second reform is adoption of a semestered block schedule.

Standards-based Curricula

In 1989, NCTM promulgated the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). The *Standards* called for mathematics classes to include less traditional teacher exposition and student practice, while increasing the amount of project work, group and individual assignments, and discussions between teacher and students and among students (NCTM, 1989, p. 10). The *Standards* reemphasized and strongly endorsed earlier statements by the NCTM that "problem solving must be the focus of school mathematics" (NCTM, 1980, p. 2; NCTM, 1989, p. 6). Later *Standards* documents (NCTM, 1991, 1993, 2000) provided a vision that was consistent with a problem-centered approach to mathematics instruction.

During the 1990s, researchers developed several new high school curricula specifically designed to conform with the vision described in the *Standards*. There has been considerable controversy about the worth of these new curricula ("An Open Letter to United States Secretary of Education, Richard Riley", 1999). Research to date has

generally shown that these new curricula tend to have positive effects on student achievement (Koedinger, Anderson, Hadley, & Mark, 1997; Huntley, Rasmussen, Villarubi, Sangtong, & Fey, 2000; Merlino, Wolff, & Tolbert, 2000; Webb, in press). Nonetheless, the evidence is not conclusive, as these studies have generally been small in scale, with the number of schools in each study ranging from one to six. Further, in all cases teachers using the new curricula have been volunteers, and in many of the studies the students have been volunteers as well. More research is needed, to determine whether earlier results can be replicated and to extend study of reform mathematics to situations where results cannot be attributed to a volunteer effect.

Block Scheduling

Over the last decade, block schedules have become increasingly popular in high schools throughout the United States and Canada. For example, in North Carolina, the percent of high schools using a block schedule grew from 1.6% in 1992-3, to 35% in 1994-5, to 64.8% in 1996-7, to 73.6% in 1997-8 (North Carolina Department of Public Instruction, 1999). Under a traditional high school schedule, each student typically enrolls in seven courses at a time. Each course meets daily for about 40-50 minutes over a 180-day academic year. In contrast, under the most common type of block schedule, the 4x4 or "semestered" plan, each student typically completes four courses in each semester. Each course meets daily for about 80-90 minutes over a 90-day semester.

Block scheduling has become popular among administrators for a number of reasons. School atmosphere tends to be calmer, and many schools have reported fewer discipline problems under a block schedule (Carroll, 1994a; Hackman, 1995; Meadows, 1995; Reid, 1995a, 1995b; Sessoms, 1995). With fewer classes per day, there are fewer

transitions, so students can spend more time in class instead of walking through hallways between classes. Moreover, some surveys indicate that both students and parents tend to prefer a semestered block schedule to a traditional schedule (Stevens, 1976).

Principals and teachers have reported that low-achieving students find it easier to focus on four classes at a time, instead of the usual seven (Alam & Seick, 1994; Averett, 1997; Carroll, 1994a; Reid, 1995a, 1995b). Also, under a semestered schedule, students have more opportunity to retake courses that they have failed (Reid, 1995a, 1995b; Stevens, 1976; Williams, 1985). Perhaps for these reasons, case studies indicate that failure rates usually decrease after a school switches to a semestered block schedule (Hottenstein & Malatestsa, 1993; Governor Thomas Johnson High School, 1995; Hackman, 1995; Reid, 1995a, 1995b; Schoenstein, 1995b).

Finally, in response to concerns about student achievement stimulated by publications such as *A Nation at Risk* (National Commission on Excellence in Education, 1983), many states and school districts increased the number of credits required for graduation (Porter, 1998). A block schedule makes it easier for principals to meet these requirements, as more courses per year are offered.

Despite the advantages cited above, there is reason to be concerned that changing to a block schedule can actually decrease student achievement, especially in mathematics. Block schedules have been used widely in parts of Canada since the 1970s, well before they became popular in the United States. A number of large-scale studies have investigated achievement effects of block scheduling in Canada (Raphael, Wahlstrom, & McLean, 1986; Marshall, Taylor, Bateson, & Brigden, 1995; Wild, 1998). They have

consistently reported that mathematics achievement under a semestered block schedule is lower than under a traditional schedule.

In contrast, anecdotal reports (Kramer, 1996), as well as some achievement data from North Carolina (Averett, 1994; North Carolina Department of Public Instruction, 1997) indicate that mathematics achievement may improve if a semestered block schedule is adopted at a school that implements instructional changes consistent with those called for by the NCTM *Standards* (NCTM, 1989). However, this possibility has never been systematically studied.

It is important to investigate how a semestered block schedule affects mathematics achievement at schools that are making substantial efforts to implement the reform called for in the NCTM *Standards* (NCTM 1989, 1991, 1993, 2000). As described below, there are three additional reasons to conduct further investigations of how block scheduling affects mathematics achievement.

First, research to date on block scheduling has often been confounded by a possible volunteer effect. Just as studies of *Standards*-based curricula compared achievement of teachers and students who volunteered to use the new curriculum to that of teachers and students who did not volunteer, so most studies of block scheduling have compared achievement at schools that voluntarily adopted a block schedule to achievement at schools that voluntarily maintained a traditional schedule. Data from North Carolina (North Carolina Department of Public Instruction, 1997) indicates that, *prior to the change*, schools that switched to a block schedule had systematically lower achievement than did schools that did not choose to switch. The volunteer effect may account for some of the discrepancies between results reported by the North Carolina

studies, which controlled for prior school-level achievement, and the Canadian studies, which did not do so.

Another reason to conduct further research about the affects of semestered block schedules on mathematics achievement is the need for better measures than have been used in past studies. Previous studies have used only a single measure of achievement, either a standardized test (Raphael, Wahlstrom, & McLean, 1986; Marshall, Taylor, Bateson, & Brigden, 1995) or a standard end-of-course exam (North Carolina Department of Public Instruction, 1997; Wild, 1998). Research comparing student learning under traditional mathematics instruction to student learning under *Standards*-based mathematics instruction has found that the results can vary, depending on what type of test is used to measure achievement (Wood & Sellers, 1996; Huntley, et al., 2000). Tests emphasizing procedures and symbol manipulation tend to favor traditional instruction, whereas tests emphasizing problem solving in context tend to favor reform instruction. It is important to conduct research that not only investigates the joint impact of a block schedule and a curriculum designed to implement the NCTM *Standards*, but also uses a variety of measures designed to test the strengths both of the traditional schedule/curriculum and of the block schedule/*Standards*-based curriculum.

Finally, it is important to investigate how a block schedule affects mathematics achievement at a site where course syllabi have been adjusted to fit the schedule, by spreading mathematics content over a larger number of courses. In the United States, students generally take a larger number of courses per year under a block schedule, with fewer total minutes allocated to each course. For example, a school might change from a traditional schedule offering each student six or seven courses per year to a semestered

block schedule offering eight courses per year (four each semester). Even though the total instructional time available is increased because students are spending fewer minutes walking through hallways between classes, each individual course has fewer allocated minutes of instruction than would an analogous course under a traditional schedule. Thus, one would expect it to be difficult for teachers to cover as much content per course under a semestered block schedule as they would under a traditional schedule. In fact, teachers have reported difficulty with content coverage under a block schedule (Usiskin, 1995; Sturgis, 1995). It should be noted that both Usiskin and Sturgis reported teacher experiences under an alternating-day block schedule, an arrangement in which students take eight classes at a time, each class meeting every other day. However, an alternating-day block schedule affects allocated classroom time in precisely the same way as does a semestered block schedule, so problems in content coverage would likely be the same for both types of block schedule.

Thus, under a block schedule less content can be covered per course than under a traditional schedule. However, more courses are available per year under a block schedule than under a traditional schedule. One solution may be to change syllabi when moving to a block schedule, so that the same content is covered over a larger number of courses (Harter, 1994; Kramer, 1996). Unfortunately, in most cases research on achievement effects of block scheduling has been conducted at sites where this approach has not been implemented. The one exception was a study conducted by Zhang (2000) for the North Carolina Department of Public Instruction. His study compared 214 schools that had adopted a 4x4 block schedule between 1995 and 1997 to 68 schools that had maintained a traditional schedule. He reported that, after controlling for race, socio-

economic status, and 1993-94 school level scores, students in the block scheduled schools outscored those in traditional schools on a state-mandated End-of-Course test in Algebra 1. Zhang attributed the improvement in part to the fact that some students in the 4x4 schools completed the End-of-Course test after taking "regular" algebra in a block semester, while others completed the test after taking Algebra IA and Algebra IB over two semesters.

Zhang's study investigated algebra achievement at the time students had completed a particular curriculum, delivered either in the "regular" algebra format, or the Algebra IA/Algebra IB format. It did not control for the possible costs to other mathematics learning of spreading Algebra I over two courses. For example, did fewer students in the schools using 4x4 schedules complete Algebra 2, so that by the end of high school they knew less algebra than did students in the traditionally scheduled schools? The current study addresses this possibility in the case of one particular school, by testing all students at the end of eleventh grade. Thus, instead of asking how much algebra students learned in one particular course, it asks how much algebra students learned as a result of their high school program through Grade 11, taken as a whole.

Possible Synergies Between a Standards-based Curriculum and a Semestered Block Schedule

There is reason to suspect that a *Standards*-based curriculum implemented together with a semestered block schedule might have a more positive effect on student mathematics achievement than would either reform by itself. It has been conjectured that lecturing is less effective under a block schedule than under a standard schedule (Kramer, 1996). In contrast, the kinds of group work, in-depth investigations, and problem solving

emphasized by *Standards*-based curricula may actually be easier to accomplish in a longer time block than in the shorter periods offered in a traditional schedule (Averett, 1994; Meadows, 1995, Sturgis, 1995).

Thus, adopting a *Standards*-based curriculum may help compensate for a weakness of mathematics instruction under a block schedule (the relatively poorer results of lecture), while allowing the advantages of the schedule (more total instructional time, better school atmosphere) to positively impact student learning. The semestered block schedule may facilitate successful implementation of *Standards*-based practices such as increased group work, in-depth investigations, and problem-centered instruction.

Research Questions

This study compares the mathematics achievement of students using the reform-based *Interactive Mathematics Program* (IMP) curriculum within a semestered block schedule to the mathematics achievement of students learning a traditional curriculum within a traditional schedule. To narrow the scope of the problem, the primary research questions focus on students' knowledge of algebra. As noted by Huntley, et al. (2000), algebra has been at the heart of high school mathematics for many years, and high student achievement in algebra is generally seen as the hallmark of preparedness for advanced mathematical and scientific studies.

Student achievement data was collected at the end of Grade 11. It was assumed at the time of data collection that most students would have completed their algebra work by the end of eleventh grade.

The high school where this study was conducted used between class ability grouping. Under the block schedule/IMP curriculum the nature of this ability grouping

changed: under the new program, lower-level and higher-level classes used the same text, whereas previously they had used different texts. Also, the new curriculum affected the decision rules for assigning students to academic "levels" for mathematics instruction. Thus, this study's analyses examine both the main effects of schedule/curriculum on student achievement, and the interaction between schedule/curriculum and prior student ability.

Primary Research Questions

i. How do students enrolled in a reform-based curriculum and a semestered block schedule compare to students enrolled in a traditional curriculum and traditional schedule in their ability to solve algebraic symbol manipulation problems? Do the results of this comparison differ depending on students' prior ability?

ii. How do students enrolled in a reform-based curriculum and a semestered block schedule compare to students enrolled in a traditional curriculum and traditional schedule in their ability to interpret and solve challenging algebra problems presented in context? Do the results of this comparison differ depending on students' prior ability?

iii. How do students enrolled in a reform-based curriculum and a semestered block schedule compare to students enrolled in a traditional curriculum and traditional schedule in their ability to collaboratively solve and communicate their solution to a complex open-ended algebra problem? Do the results of this comparison depending on students' prior ability?

Secondary Research Questions

A semestered block schedule affords students the opportunity to take more mathematics classes during high school than they would under a traditional schedule. The curriculum being investigated by this study attempts to take advantage of this situation by covering fewer content objectives in each mathematics course, while expecting students to complete more mathematics courses during high school. However, the fact that students have the opportunity to complete additional mathematics courses does not necessarily mean that they will avail themselves of this opportunity. Actual student course-taking patterns are important to study both in their own right and because they will inform results discovered by the algebra achievement testing. The next two research questions address the issue of student course-taking.

iv. How did students enrolled in a reform-based curriculum and a semestered block schedule differ from students enrolled in a traditional curriculum and traditional schedule in the number of registered mathematics class hours by the end of Grade 12?

v. How did students enrolled in a reform-based curriculum and a semestered block schedule differ from students enrolled in a traditional curriculum and traditional schedule in participation in advanced courses, as measured by the number of registered hours in advanced mathematics classes by the end of Grade 12, by the number of students enrolling in Advanced Placement courses, and by scores on Advanced Placement tests?

Previous authors have pointed out that, while a semestered block schedule might provide an opportunity for students to spend more time studying mathematics,

administrative policies can either enhance or impede this opportunity (Harter, 1994; Kramer, 1996). Such policies are essentially part of the "treatment," just as much as the mathematics curriculum and the format of the schedule itself. In addition to administrative policies, other aspects of the school and community could influence the way a semestered block schedule and the IMP curriculum affect student mathematics achievement and student enrollment in mathematics courses. If other schools are to learn from the experience at Suburban High School[1], special aspects of the school and community need to be described. The sixth research question addresses these issues.

vi. According to administrators and faculty who assumed critical responsibilities for implementing the shift to a semestered block schedule and reform-based mathematics curriculum, what school administrative policies and what unique aspects of the school and community affected mathematics course enrollment and mathematics achievement under the new schedule and curriculum?

Overview of Method

Research Opportunity at Suburban High School

This research project is part of an ongoing research effort that was begun during the 1996-97 school year by teachers at Suburban High School. Suburban is the only high school in a small school district located in a middle class suburb of a large U.S. city. During the 1996-97 school year, Suburban high school initiated a semestered block schedule for all ninth graders. In that same year, ninth graders were enrolled in IMP, as a phase-in of this new reform-based curriculum. Note that during this first year at

[1] "Suburban High School" is a pseudonym

Suburban High School, only ninth graders used IMP and the semestered block schedule. These students and their successors continued in this schedule/curriculum.

Testing the Traditional cohort. In order to assess their understanding of algebra, in the spring of 1997 all eleventh graders at Suburban High School completed an algebra test designed by the Core-Plus Mathematics Project. Core-Plus, like IMP, is a high-school curriculum designed to implement reform-based mathematics. Their algebra test was specifically designed to compare the effects of a *Standards*-based curriculum to

those of more conventional curricula. The test is organized into three parts. Part 1 emphasizes the ability to understand and solve algebra problems presented in context, as is typically emphasized by Core-Plus, IMP, and other reform curricula. Part 2 emphasizes problems typical of traditional mathematics curricula: context-free symbolic manipulations that call for transformation of algebraic expressions and solutions of equations and systems. Items in Part 2 were adapted from released ACT examinations and from items that commonly appeared on college placement tests. Part 3 requires collaborative work on a single extensive open-ended applied problem and is completed by students working in pairs. Items from Part 1, Part 2, and Part 3 of the Core-Plus assessment define the Algebra Achievement test for this study.

The eleventh graders tested in the spring of 1997 had used a traditional schedule and traditional curriculum throughout Grades nine through eleven. They form a "Traditional" cohort to be contrasted with later cohorts of students at Suburban High School who were taught using a semestered block schedule and the IMP curriculum.

Testing the Pilot cohort. As the ninth graders who had piloted the semestered block schedule and the IMP curriculum during the 1996-97 school year advanced through high school, they continued using the new schedule and curriculum. In the spring of 1999, when they were eleventh graders, this "Pilot" cohort completed the same Algebra Achievement test that had earlier been completed by eleventh graders in the 1997 Traditional cohort. A pilot study used this test data to compare how well students in the two cohorts (Pilot versus Traditional) understood algebra.

Unlike later cohorts of students at Suburban High School who used IMP exclusively, the Pilot students reflected a mixture of curricula: Honors students, who had begun studying traditional algebra while in eighth grade, continued using the traditional curriculum, while all other regular education students used the IMP curriculum.

Testing the first reform cohort. In the spring of 2000, eleventh graders at Suburban High School again completed the Algebra Achievement test. Students in this "First Reform" cohort had used a semestered block schedule and the IMP curriculum throughout high school. Since teachers already had experience using the IMP curriculum and block schedule with the pilot cohort, it is likely that by the time students in the First

Reform cohort were exposed to the new program their teachers had gotten past the "implementation dip" often experienced by major school reforms (Busick & Inos, 1992; Fullan & Miles, 1992). Also, lessons learned from the pilot study made it possible to ensure testing conditions for the experimental cohort were similar to those used for the Traditional cohort. For these reasons, it is reasonable to assume that a comparison of test scores of students in the First Reform cohort to those of students in the Traditional cohort will provide a fair indication of how a semestered block schedule, implemented jointly with the IMP curriculum, affected algebra achievement at Suburban High School.

Testing the second reform cohort. In the spring of 2001, eleventh graders at Suburban High School once again completed the Algebra Achievement test. Students in this "Second Reform" cohort again used a semestered block schedule and the IMP curriculum throughout high school. This study combines scores from the First and Second Reform cohorts to estimate achievement of students who used a semestered block schedule and the IMP curriculum, and to compare their achievement to that of students in the Traditional cohort.

Data Analyzed

In order to answer the research questions, this study analyzed six types of data:

1. Scores from the Algebra Achievement test;
2. Mathematics achievement tests administered prior to high school, used as a covariate to compare relative prior ability of students using the Traditional and Reform programs.
3. Student transcripts;
4. Course syllabi, textbooks, and other documents used to teach mathematics at the school;
5. School system documents, including annual testing reports and annual school profiles;
6. Qualitative data from key informants at the Suburban High School.

Analysis of Algebra Achievement tests. This study compared tests taken by the Traditional cohort of eleventh graders at Suburban High School who had completed a traditional mathematics curriculum within a traditional seven-period per day schedule, to those taken by two Reform cohorts of students who attended the same school three and four years later, completing a reform-based mathematics curriculum within a semestered block schedule.

Transcript analysis. This study analyzed student transcripts to see whether mathematics course taking changed under the new schedule and curriculum. It compared Traditional to Reform students on three measures: total number of hours registered in mathematics courses, number of hours registered in advanced mathematics, and number of students enrolled in Advanced Placement courses.

Document analysis. This study reviewed annual "school profiles" published by the Suburban High School to determine the number of students each year taking Advanced Placement exams administered by the College Board, as well as to determine student grades on the Advanced Placement exams they took.

This study also analyzed course syllabi published by the school. Combined with the transcript analysis, these documents provided insight regarding students' opportunity to learn the key topics evaluated in the Algebra Achievement test.

Key informants. If other educators are to learn from Suburban High School's experience, it is important to understand not only the nature of the new schedule, curriculum, teaching methods, and syllabi, but also how course taking changed and why. Therefore, this study examined the administrative or counseling policies that influenced course-taking decisions. Interviews with key informants, combined with the transcript analysis, provided data to answer these questions.

Definition of Key Terms

Advanced Mathematics Classes: The term "Advanced Mathematics Classes" refers to classes for which material traditionally covered in Algebra 1, Geometry, and Algebra 2 is a prerequisite.

Alternating-day or A/B block schedule: A semestered block schedule contrasts with an A/B block schedule, in which students take 8 classes at a time, each class running 80-90 minutes every other day.

Constructivism: A constructivist theory of knowledge is characterized by two basic principles: (a) learners actively construct knowledge through interaction with their surroundings and experiences, and (b) learners interpret these occurrences based on

existing knowledge and their rendering of the experienced observations and actions (Noddings, 1990).

Implementation Dip: A period commonly seen in successful change initiatives, where individuals have given up old practices, but not yet mastered new and potentially more effective practices that they have adopted. During this period, student performance may go down, only to be followed by later improvements (Fullan & Miles, 1992; Busick & Inos, 1992).

IMP: The Integrated Mathematics Program (IMP) curriculum authored by Fendel, Resek, Alper, and Fraser (1997) is published by Key Curriculum Press. IMP was one of five reform-based high school mathematics curricula whose development was funded by the National Science Foundation. The IMP curriculum is built around complex, open-ended problems. It emphasizes in-depth understanding of mathematical concepts and techniques. IMP promotes students' active role in the classroom, working together in teams, talking with each other about mathematics, and making oral and written presentations about challenging problems.

NCTM *Standards:* Originally, the National Council of Teachers of Mathematics published three *Standards* documents. Only the first of these, the Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989) was available at the time Fendel, Resek, Alper, and Fraser began developing IMP. Unless otherwise specified, this is the document referred to by the term NCTM *Standards*. (Note: the other *Standards* documents (NCTM, 1991, 1993) are compatible with the Curriculum and Evaluation Standards and with the general vision of IMP. So are the Principles and Standards for

School Mathematics (NCTM, 2000), recently published to update the original *Standards* documents.)

Quasi-Experiment: A research design in which treatment and comparison groups are formed by some means other than random assignment (Krathwohl, 1993).

Retention Interval: The gap in time between when a student studied mathematics content, and when the student was tested on knowledge of that content.

Semestered or 4x4 Block Schedule: Under a "semestered block schedule," also called a "4x4 block schedule," high school students take four classes at a time, and each class lasts one semester. In general, such classes run about 80-90 minutes a day.

Situated Cognition: A "situated cognition" theory of knowledge is characterized by the principle that the activity in which knowledge is developed and deployed is not separable from learning and cognition. Rather, it is an integral part of what is learned (Brown, Collins, & Duguid, 1989)