

Chapter 5: Summary and Conclusions

The overall purpose of this study was to investigate the joint impact on mathematics course-taking and high school algebra achievement of a semestered block schedule and a mathematics curriculum designed to conform with the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). The case of one particular school, Suburban High School, was examined in detail. 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.

Summary of Results on the Algebra Achievement Test

In the spring of 1997, eleventh graders at Suburban High school completed a three part Algebra Achievement test. The eleventh graders tested in the spring of 1997 had used a traditional schedule and traditional curriculum throughout Grades 9 through 11. They form a “Traditional” cohort that was contrasted with later “Reform” cohorts.

The testing was repeated in the spring of 2000 and the spring of 2001. Students tested in those years had used a semestered block schedule and the IMP curriculum throughout Grades 9 through 11. They comprise the two “Reform” cohorts who completed the Algebra Achievement test.

The Algebra Achievement test was comprised of three sub-tests. Test 1 measured achievement on understanding and solving applied algebra problems in context. Students had access to graphing calculators while completing Test 1. Test 2 measured achievement on algebra symbol manipulation without context or access to graphing

calculators. Test 3 was completed by students working in pairs. It measured their ability to solve a single, complex, open-ended, applied algebra problem.

Sixth-grade test scores were used as a covariate to control for prior student ability. Optimum Least Squares Linear Regression was used to investigate differences between students in the Reform cohorts and students in the Traditional cohort on Test 1 and Test 2. A Probit analysis was used to investigate differences between students in the Reform cohorts and students in the Traditional cohorts on Test 3. After controlling for prior ability, there is 95% confidence that the following three statements are simultaneously true:

1. On Test 1, the test of understanding and solving applied algebra problems in context, the mean score of students in the Reform cohorts differed from what would have been likely for the same students had they been in the Traditional cohort by between +1.3% and +9.3% correct. In standard deviation terms, this confidence interval was between +0.06 and +0.40 standard deviations. This was a statistically significant difference in favor of the Reform cohorts, as reflected by the fact that the Bonferroni-adjusted confidence interval contains only positive numbers, with the probable impact of being in a Reform cohort ranging from a very small positive effect to a moderate positive effect.
2. On Test 2, the test of symbol manipulation without context or access to graphing calculators, the mean score of students in the Reform cohorts differed from what would have been likely for the same students had they been in the Traditional cohort by between -9.4% and +0.6% correct. In

standard deviation terms, this confidence interval was between -0.36 and $+0.02$ standard deviations. This was a statistically non-significant difference, as reflected by the fact that the Bonferroni-adjusted confidence interval contains both negative and positive numbers, with the probable impact of being in a Reform cohort ranging from a moderate negative effect to a very small positive effect.

3. On Test 3, the test that required pairs of students to solve a single, complex, open-ended, applied algebra problem, the mean achievement of student pairs in the Reform cohorts differed from what would have been likely for the same pairs had they been in the Traditional cohort by between $+0.05$ and $+0.74$ standard deviations. This was a statistically significant difference in favor of the Reform cohorts, as reflected by the fact that the Bonferroni-adjusted confidence interval contains only positive numbers, with the probable impact of being in a Reform cohort ranging from a very small positive effect to a fairly large positive effect.

After controlling for prior ability, the average effect size of being in the Reform cohort on understanding and solving applied algebra problems (Test 1) was $+0.23$ standard deviations, enough to move a student who would ordinarily score at the 50th percentile up to the 59th percentile. The average effect size of being in the Reform cohort on algebraic symbol manipulation problems (Test 2) was -0.17 standard deviations, enough to move a student who would ordinarily score at the 50th percentile down to the 43rd percentile. The average effect size of being in the Reform cohort on a pair's ability to solve an extended open-ended applied algebra problem (Test 3) was $+0.40$ standard

deviations, enough to move a pair who would ordinarily score at the 50th percentile of all pairs up to the 66th percentile.

On Test 1 and Test 2, the effects of being in a Reform cohort appeared to be the same regardless of prior ability. That is, achievement of both high-ability and low-ability students appeared to respond in the same way to membership in the Traditional or Reform cohort. On Test 3, the picture was more complicated. For many pairs of students who took the test, a sixth-grade ability estimate was available for only one member of the pair. When all pairs with any ability estimate were included in the analysis, there appeared to be no interaction with prior ability. When only pairs who had two Grade 6 ability estimates were included in the sample, there did appear to be an interaction, with membership in the Reform cohorts having a more pronounced positive effect on students of lower ability. One possible explanation for the fact that applying differing definitions to measure prior achievement yielded differing results in the test of ability-by-treatment interactions is suggested by the fact that students with a missing measure on Grade 6 achievement were frequently those students who had not attended Suburban High School's feeder middle school. An innovative mathematics curriculum, *Visual Mathematics* (Foreman & Bennett, 1991) was in use at the feeder middle school. An explanation consistent with the data is that either *Visual Mathematics* or IMP was sufficient to enable high-ability students to do well on Test 3, with no value-added effect due to completion of both the visual mathematics and the IMP curricula. However, low-ability students did well only if they had utilized both *Visual Mathematics* and IMP. This explanation must be viewed as an hypothesis to be explored in a later study.

Schoenfeld (2002) noted that data analyzing the achievement effects of curricula designed to implement the *Curriculum and Evaluation Standards* (NCTM, 1989) are just beginning to become available. He stated that the data available so far seem to be converging on the following findings:

1. On tests of basic skills, there are no significant performance differences between students who learn from traditional or reform curricula.
2. On tests of conceptual understanding and problem solving, students who learn from reform curricula consistently out-perform students who learn from traditional curricula by a wide margin.

The results of the Algebra Achievement test were broadly consistent with the findings reported by Schoenfeld, and lend weight to this emerging trend. It should be noted, however, that in the investigation which most closely paralleled the current study, Huntley, et al. (2000) found that while students using a reform curriculum tended to out-perform students using a traditional curriculum on understanding and solving applied algebra problems in context and on solving complex open-ended applied algebra problems, they tended to be less skilled at symbol manipulation without context or access to graphing calculators. In the current study, while the results were not statistically significant, students in the Reform cohorts did perform less well than students in the Traditional cohort on the test of symbol manipulation. A closer look at the specific questions comprising Test 2 indicated that at Suburban High School the advantage of the Traditional cohort on symbol manipulation appeared to be limited to performing well-practiced procedures on items presented in standard form. When items were presented in non-standard form, for example solving $\sqrt{9 + x^2} = 5$ for x , the advantage of being in the Traditional cohort disappeared.

The close look at specific items yielded one cautionary note to the generally positive results on the Algebra Achievement test for students in the Reform cohorts. Fluency in procedures such as translating a line graph to an equation, where students in

the Traditional cohort showed more skill, could be important to student learning in later mathematics or science courses. The new *Principles and Standards for School Mathematics* (NCTM, 2000), published after a decade of debate and consensus building among educators, mathematicians, and parents that followed promulgation of the earlier *Curriculum and Evaluation Standards* (NCTM, 1989) placed increased emphasis on procedural fluency. Further, fluency may aid future learning because effortless processing places fewer demands on conscious attention. Since a person can attend to only a limited amount of information at one time, ease of processing some aspects of a learning task gives the person more capacity to attend to other aspects of the task (Bransford, Brown, & Cocking 1999).

Summary of Results from the Transcript Analysis

The transcript analysis addressed the question, “Did students register in additional or more advanced mathematics under the IMP curriculum and semestered block schedule at Suburban High School than under the prior curriculum and schedule?” Complete transcripts for Grades 9 through 12 of students in the First Reform cohort were compared to complete transcripts for Grades 9 through 12 of students in two earlier cohorts at Suburban High School who had used a traditional schedule and mathematics curriculum throughout high school.

Under the semestered block schedule, more courses were available to students each year than under the traditional schedule, but each class lasted for fewer hours. The net effect of these schedule differences was that about one quarter of the students in the First Reform cohort enrolled in fewer hours of mathematics than would have been likely under a traditional schedule, and about three quarters enrolled in more hours of mathematics than they would have done under a traditional schedule. Of those who enrolled in more hours of mathematics, many enrolled in considerably more.

Students in the First Reform cohort were more likely to enroll in at least one advanced mathematics course than were students using a traditional schedule and curriculum. Further, among students who enrolled in at least one advanced mathematics class, students in the First Reform cohort on average enrolled in more hours of advanced mathematics. This reflects the fact that even though each individual advanced course met for fewer hours under the semestered block schedule, students in the First Reform cohort were more likely to enroll in several advanced mathematics courses than were students using a traditional schedule and curriculum.

Summary of Results Regarding Advanced Placement Courses

As the block schedule and IMP curriculum were implemented, a larger number of students enrolled in AP courses. In part, this was possible because a new AP statistics course was offered under the semestered block schedule. But improved AP participation is not explained by the new statistics course alone. Compared to students in previous years, among students who were enrolled in a semestered block schedule throughout high

and who used IMP as their core mathematics curriculum, a larger number of students enrolled in the most advanced AP mathematics course (Calculus BC), a larger number of students completed the Advanced Placement Calculus BC exam, and their scores on that exam were higher. In 2000-01, the first year in which all students had used the IMP curriculum and all students had been enrolled in a semestered block schedule throughout their years at Suburban High School, twenty students took the Advanced Placement Calculus BC exam. Eighteen of those students achieved a grade of 5 and two students achieved a grade of 4, for an average score of 4.9. That year, there were only seven other public schools in the United States where at least 20 students completed the Advanced Placement Calculus BC exam and achieved an average score of 4.9 or higher.

Interaction of the Semestered Block Schedule and IMP Curriculum

One potential positive effect of a semestered block schedule is to give students and teachers extra time for learning. Less time is spent walking through hallways, and more time is potentially available for studying course content. Nonetheless, previous research has found that when traditional pedagogical techniques and a traditional curriculum are used in the longer time blocks of a block schedule, student achievement in mathematics can suffer (Raphael, Wahlstrom, & McLean, 1986; Marshall, Taylor, Bateson, & Brigden, 1995; Wild, 1998).

The current study has found that at Suburban High School, when a curriculum designed to be consistent with the *Curriculum and Evaluation Standards* (NCTM, 1989) was implemented together with a semestered block schedule, achievement in algebra did not suffer. Students who used the IMP curriculum under a semestered block schedule were more proficient than students who used a traditional curriculum and schedule when asked to formulate mathematical models, to interpretation graphs and tables, or to work in pairs to solve an extended complex algebra problem. Students who used a traditional curriculum and schedule appeared to be advantaged only when applying well-practiced procedures that were presented in standard form.

Results from the Algebra Achievement test indicate that unless “achievement” is defined very narrowly, the semestered block schedule and IMP curriculum together did not harm and in fact improved algebra achievement of students at Suburban High School. Results from AP exam grades corroborate this finding. Students who utilized both the IMP curriculum and semestered block schedule were more likely than others to enroll in AP mathematics, and achieved significantly higher scores when they completed the AP examinations.

The College Board (1998) found that students who complete a two-semester block-length Calculus BC course tend to score higher on the AP exam than do students who complete a traditional all-year course or students who take a one-semester course, so the current results may be partly explained by the two-semester format used under the block schedule. However, AP exam grades of students who took Calculus BC in the two-semester format and had used IMP as their core curriculum were significantly higher than AP exam grades of students who took Calculus BC in the two-semester format and had used a traditional curriculum. Thus, it appears that preparation using the IMP curriculum followed by studying Calculus BC in a two-semester block schedule format may have worked together to greatly improve student achievement.

The transcript analysis provides further evidence that together the semestered block schedule and IMP curriculum provided a considerable benefit to students at Suburban High School. While their algebra achievement by most measures improved, students in the Reform cohorts had considerably more time available to study mathematics topics other than algebra than did students using a traditional schedule and curriculum. In addition to studying the approximately two years worth of algebra and one year's worth of geometry that was completed in the traditional core curriculum, students studied a considerable amount of probability and statistics. Students in Academic Assisted and College Preparatory level courses completed two IMP modules devoted primarily to statistics: *The Game of Pig* and *The Pit and the Pendulum*. Together these modules are equivalent to almost half of a course under a traditional schedule. Students in Honors classes completed these same two modules, plus up to two additional modules that focused on probability and statistics (*Is There Really a Difference?* and *Pennant Fever*). Additional study in probability and statistics is integrated throughout the IMP curriculum. Also, as teachers have become more familiar with the IMP curriculum they have completed a larger number of modules with their students. In future years they expect to complete a larger number of the IMP probability and statistics modules.

Further, students in the Reform cohorts were more likely than students who used a traditional schedule and curriculum to enroll in advanced mathematics beyond the core requirements. These included courses in statistics or AP statistics, discrete mathematics, functional analysis, pre-calculus, Calculus AB and Calculus BC.

In summary, results of this study are consistent with the theory that mathematics achievement will improve at schools that implement a semestered block schedule while simultaneously replacing their core curriculum with the IMP sequence. At Suburban High school, by most measures students' achievement in algebra improved. This was true for both high- and low-ability students. Further, the very top students appeared to be better prepared to take advanced mathematics coursework. Also, while this study focused on algebra achievement and AP test exams, all students had considerably more exposure to probability and statistics than had been true under the traditional curriculum and schedule. Finally, many students had time to take more advanced mathematics coursework beyond the core curriculum than would have been possible under the traditional curriculum and schedule.

Limitations: Threats to Internal Validity

Threats to Internal Validity Attributable to Non-Random Group Assignment.

In a “true experiment” subjects are randomly assigned to treatment and control groups. If assignment is nonrandom, then the research design is referred to as a “quasi-experiment,” and the two groups investigated are commonly referred to as the “treatment” group and the “comparison” group (Krathwohl, 1993).

By this definition, the current study was a quasi-experiment. This increases the risk that there may have been pre-existing differences between students in the Traditional cohort and students in the Reform cohorts at the time they entered ninth grade. The two groups were chosen to be comparable in many ways. They lived in the same community. Many attended the same middle school and used the same middle school mathematics curriculum. They attended the same high school. Due to low staff turnover, they had many of the same teachers both in middle school and high school. Figuratively and in many cases literally, students in the Reform cohorts were the younger brothers and sisters of students in the Traditional cohort.

However, the possibility that some of the results reported here may have been due to a different experience in middle school mathematics class cannot be completely discounted. Both the Traditional cohort and the Reform cohorts used the *Visual Mathematics* curriculum (Foreman & Bennett, 1991) in middle school. However, the Traditional cohort was the first group at the school to use that curriculum. When an innovative program like *Visual Mathematics* is adopted, there is often an “implementation dip” resulting in lower achievement for the first few years (Busick & Inos, 1992; Fullan & Miles, 1992). The Traditional and Reform cohorts had similar scores on mathematics ability in sixth grade, but as Table 2 (see Chapter 3) shows the Traditional cohort had lower scores in seventh grade. As has been discussed in Chapter 3 of this study, this was likely due to a change in the test. Nonetheless, given the possible “implementation dip” the lower scores may have reflected a true difference in what was learned during middle school.

“History” could have affected results in other unknown ways. For example, the size of the junior class increased from 227 in 1996-97 to 279 in 2000-01. Perhaps there were other demographic changes that could have affected test results.

Other Threats to Internal Validity

There were other factors that could have affected achievement and were impossible to control. For example, the individuals teaching both calculus and pre-calculus changed in 1999-00, coincident with the arrival of the first largely-IMP group in the calculus class. Further, Suburban High School adopted a new Calculus textbook, *Calculus: Graphical, Numerical, and Algebraic* (Finney, et al., 1999). The Calculus teacher believed the new text was more in line with the evolving reforms in the AP Calculus curriculum. Together, the change in staff and text provide a possible alternate explanation for some of the success in the AP Calculus program. Various other staffing changes could have affected results on the Algebra Achievement test.

Every effort was made to keep the Algebra Achievement test a low stakes assessment. Teachers at Suburban High school did not review it carefully, and were unlikely to have identified specific topics on the test that they should teach. Nonetheless, the test was administered repeatedly over several years, so the possibility that some teachers unconsciously modified their instruction to accommodate material on the test cannot be completely discounted.

While every effort was made to make testing conditions as comparable as possible for the three administrations of the test, once the block schedule was implemented it was not possible to replicate precisely the testing conditions that had occurred in 1997. Changes made in test administration due to lessons learned during the pilot study partly addressed this problem, but could not overcome it completely. For example, in 1997, students completed the Algebra Achievement test during their mathematics class. In 2000 and 2001, not all students were enrolled in mathematics at the time of testing, so they were administered the test in English classrooms, proctored by mathematics teachers. This meant that pairs completing Test 3 in the Reform cohorts were often from different mathematics classes, whereas in 1997 they had been from the same mathematics class. Due to fears that this difference in pairing might affect results, teachers in 2001 requested that students within each English class pair with someone who had been in their mathematics class. While there is no guarantee that all students complied with this request, many were reported to have done so. Concern that results on Test 3 may have

been due to the way students were assigned to pairs is mitigated by the fact that in 2001, when students were generally paired with partners from the same mathematics class, scores on Test 3 were even higher than in 2000 when no attempt had been made to replicate 1997 testing conditions by matching pairs within a mathematics class.

It should also be noted that only about 90% of eligible eleventh graders completed the Algebra Achievement test each year. Non-participants included some students who were committed to extra-curricular activities that conflicted with test administration times and students who were absent either because of illness or because they elected to skip the test. Had all students taken the test, results might have been different.

As described in Chapter 4, the decision to test students at the end of eleventh grade may have overestimated the achievement of students currently enrolled in mathematics class. A delayed test conducted at the beginning of twelfth grade may have provided a more realistic measure of how much of the algebra students learned by the end of eleventh grade was remembered and available for use in subsequent courses. Thus, the Algebra Achievement test as conducted may have biased results against students using the semestered block schedule, since a portion of them (28.7%) were not enrolled in mathematics class at the time of testing.

Finally, this study measured the overall effects of a semestered block schedule and the IMP curriculum on algebra learning throughout Grades 9-11. Under the Traditional schedule, approximately one-third of the students at Suburban High School enrolled in some form of second-year algebra in twelfth grade. The majority enrolled in Algebra 3/Trigonometry, a course mainly designed to review material they had previously studied, but some students were studying second-year algebra for the first time. Meanwhile, approximately one-third of the students in the Reform cohorts did not complete the core IMP sequence until twelfth grade, and thus had not yet had a full opportunity to learn the algebra content that was tested. Had the testing been conducted at the end of Grade 12, both groups would surely have known more algebra than they did at the end of Grade 11, and the results would have been different in unpredictable ways. It is particularly regrettable that most of the students in the Reform cohorts who were in Academic Assisted classes did not complete the core IMP sequence until twelfth grade, subsequent to the time of testing. Under the new program, Academic Assisted students were offered exposure to more sophisticated mathematics than had previously been the case, and it would have been desirable to measure the full effects of the program on this particular group.

Some Strengths of the Research Design

This study was designed to test the theory that implementing a semestered block schedule together with a *Standards*-based curriculum and adequate professional development and planning time would improve mathematics achievement. The study investigated a falsifiable prediction of that theory. While a research study conducted over several years at a school site is subject to inevitable threats to internal validity, two strengths in the design of the current study deserve mention.

First, there was no “selection bias” of the type that could have been caused by reporting on a site that was known in advance to have implemented a successful intervention. Rather, Suburban High School was selected as the site of this study because it was beginning to implement a program that theory predicted would lead to improved

achievement in mathematics. Data collection began in the spring of 1997, before any results were available to indicate whether or not the implementation would be successful.

Second, the measures of achievement used in this study were not designed with the IMP curriculum in mind. The Algebra Achievement test was designed to accomplish the purposes of this study, that is, to provide a fair yardstick which could compare the algebra achievement of students who had utilized a traditional curriculum to the algebra achievement of students who had utilized a curriculum designed to implement the *Curriculum and Evaluation Standards* (NCTM, 1989). But the test was not designed by the researcher or by anyone associated with the IMP curriculum. Rather, it was designed for a different study (Huntley, et al., 2000) and with a different curriculum in mind, Core-Plus. The secondary test of achievement used in this study, participation rates and scores on the Advanced Placement Calculus BC exam, was of course not designed by the researcher or anyone associated with the IMP curriculum. The other, non-test, measure of achievement reported in this study, student enrollment in mathematics classes and in advanced mathematics classes, was a natural measure of the impact of a reform program that has been used in studying other interventions (Gamoran, Porter, Smithson, & White, 1997).

The Nature of the Implementation at Suburban High School

In technical terms, this section could be entitled “limitations: threats to external validity.” It describes unique conditions at Suburban High School. Other schools that implement a semestered block schedule together with a *Standards*-based curriculum and adequate professional development and planning time will not necessarily get results similar to those that have been described here. The results at other schools might be better or worse because conditions unique to those sites will differ from conditions at Suburban High School. But the unique conditions at Suburban High School provide important lessons to be learned, so the current section provides new insights in addition to limitations.

Interaction of Community and Schedule

Historically, Suburban High School has been a high achieving school. There are many nearby college campuses, and the community puts a high value on education.

Traditionally, 90% of Suburban High School graduates enroll in 2- or 4-year colleges.

One teacher described the situation as follows:

We are a high-end community that values test scores, and math test scores especially. (Before adopting the block schedule) we used to have kids not take lunch in order to take more math and science. After we adopted the block schedule, students took more math. For some students, math became more enjoyable; for others, they wanted to take every mathematics course possible; and others had parents who said, “My child is going to take math every semester so they don’t forget it.”

Adoption of the semestered block schedule at Suburban High School led to a large increase in the number of mathematics classes students took. The school administration increased the minimum number of required classes from three to four, but the vast majority of students had already been taking four classes under the traditional schedule. Under the block schedule, most students increased their course taking to more than was required, enrolling in five or more mathematics courses over their high school career.

The risk that a different community might react very differently to implementation of a semestered block schedule is not merely a theoretical possibility. Gruber and Onwuegbuzie (2001) conducted a similar study in a very different community in rural Georgia, and the results were vastly different. The nearest college to this high school was a 30-mile drive. Although a college preparatory track was available to students, many students on the college preparatory track have traditionally gone on to work or into the military after graduating from high school rather than enrolling in a 2- or 4-year college. Historically this high school required students to complete four units in language arts and three units each in math, science, and social studies in order to graduate. When they adopted a semestered block schedule in 1997-98, the requirements were not changed and the core curriculum was not modified. Teachers continued to use the traditional text they had used previously, covering the same content in each course despite the fewer hours available per course under a semestered block schedule. Also, new academic courses such as statistics or discrete mathematics were not introduced. Students had the option of enrolling in a larger number of academic classes under the semestered block schedule, but they generally did not. Instead, they enrolled in vocational classes, in forestry, or in two semesters of band. The major change in academic course-taking patterns was among students who failed a course. Under the prior scheduling system, those students would have been scheduled to re-register and complete that course again during summer school. Under the semestered block schedule they were able to complete a second enrollment in these same courses during the school year. As a result, the high school eventually eliminated its summer school program (personal communication, authors, April 20, 2002).

Under these conditions, Gruber and Onwuegbuzie (2001) noted that mathematics achievement appeared to suffer after the school adopted a semestered block schedule. Between the spring of 1997 and the spring of 2000, mathematics scores on the Georgia High School Graduation Test fell by a statistically significant .52 standard deviations. These data reflect only three years of the block scheduling, so this drop in tests scores may in part be due to an implementation dip (Busick & Inos, 1992; Fullan & Miles, 1992). Nonetheless, the large decrease is cause for serious concern.

Thus, in communities that differ in academic emphasis and parental education from Suburban High School, adopting a semestered block schedule may not lead to

students enrolling in an increased number of mathematics courses. They may enroll in the same number of courses, with each course lasting fewer hours and covering less content than it had previously. As a result, achievement could suffer.

Schools adopting a semestered block schedule cannot presume that students will enroll in more academic courses in general, and more mathematics courses in particular, simply because more courses are available each year. Instead, existing courses need to be restructured to fit the new schedule. The core curriculum needs to be spread over a larger number of courses, and administrative policies need to be implemented to ensure that students enroll in them. New academic courses need to be created for students wishing to pursue advanced coursework beyond the core curriculum. These things were done at Suburban High School. Such policy changes are probably even more important for schools in less mathematics-oriented communities who are adopting a semestered block schedule.

Planning Time and Professional Development

It was the original intent of this study to investigate the impact of a semestered block schedule and a reform curriculum at a site where teachers had available a considerable amount of planning time and a considerable amount of professional development. This was the case at Suburban High School. It needs to be emphasized that the research literature provides strong evidence that without the planning time and professional development, positive results like those at Suburban High School are unlikely to be realized (Canady & Rettig, 1995; Kramer, 1997a).

Modifications to the IMP Curriculum

Teachers at Suburban High School did not implement the IMP curriculum as intended by its authors. Instead, they made three important changes.

First, they did not follow the IMP authors' recommendation that mathematics be taught in heterogeneous classes. Instead, they maintained three separate "levels" of IMP classes: Academic Assisted, College Preparatory, and Honors. Each level utilized the IMP curriculum, but completed modules at different rates. Over four Integrated Mathematics courses, students in lower-level classes completed less than four complete IMP textbooks. It is the belief of teachers at Suburban High School that despite completing fewer modules, students in the Academic Assisted classes studied much more advanced mathematics than they had done under the traditional program.

Previous research indicates that the approach to ability grouping taken at Suburban High School may be a good one. Gamoran, et al. (1997) studied "transition" courses in California and New York that were designed introduce lower ability students

to college preparatory mathematics, often by teaching the college preparatory content over a longer period of time. They reported that the programs were generally successful. Further, two of the “transition” classes originally in their study had used IMP, but according to the authors the IMP classes were dropped from the study because initial examination of results showed them to be outliers in instruction and achievement. When contacted to provide details about the IMP classes, the authors indicated that test scores in those classes had been sufficiently high so that they skewed the overall results of the study (personal communication, Smithson, 2001).

Despite the support provided by Gamoran et al.’s (1997) article for using IMP as was done at Suburban High School, the authors of IMP have made a strong case for utilizing the curriculum in heterogeneous classes (Alper, et al., 1997). Whether doing so would have affected the results at Suburban High School cannot be answered by the data provided by the current study.

A second change made to the IMP curriculum at Suburban High School may have affected achievement on the Advanced Placement calculus exams. The school continued to use a pre-calculus course, to be taken after completing IMP and before taking calculus. It was the intent of IMP’s authors that students could take calculus immediately after completing the fourth IMP textbook (Green, 2000), or even simultaneously with the fourth textbook (Fendel, Resek, Fraser, & Alper, 1997). Teachers at Suburban High School debated whether completing all four IMP textbooks was sufficient preparation for Calculus. One teacher commented that before studying calculus, students who had completed the traditional core sequence of algebra 1, geometry, and algebra 2 needed an intervening course to reflect on the math they’d learned and see why things are working, to “see the forest for the trees.” Similarly, she felt that after completing the four IMP texts, students still needed that intervening “reflection” course before enrolling in calculus. Other teachers disagreed with the need for such a course. In the end, they decided to keep the pre-calculus course, which utilized the UCSMP text *Precalculus and Discrete Mathematics* (Perissini, et al., 1992). In part, this decision was based on the fact that they could afford to do so, given the extra number of courses students could take under the semestered block schedule. The combination of four IMP courses, followed by pre-calculus, followed by a two-semester sequence of Calculus AB and Calculus BC has certainly achieved spectacular success at Suburban High School. Whether similar success could have been achieved without the intervening pre-calculus course cannot be answered by the current study.

A third modification to the IMP curriculum by the teachers at Suburban High School was the use of complementary materials. This modification is less important than the other two, because the materials were not used extensively for students in the First and Second Reform cohorts. Mathematics teachers at Suburban High School described the development of the complementary materials as follows. For the first two years they were utilizing the IMP curriculum, teachers sometimes made their own work sheets and

used traditional problems as warm ups. In the summer of 1999, teachers responded to the concern of some parents who wanted to see more traditional texts coming home by more formally integrating into their program the algebra 1, geometry, and algebra 2 textbooks that had been in use before the adoption of IMP. They prepared a list of specific problems from the algebra 1, geometry, and algebra 2 textbooks that are matched to specific IMP modules and could be used for enrichment or reinforcement, as needed. Today, these specific problems are sometimes used as homework assignments and sometimes used in class. Because students in the First Reform cohort were entering eleventh grade and students in the Second Reform cohort were entering tenth grade at the time the formal complementary materials were prepared, the materials did not have as much impact on students completing the Algebra Achievement test as they have had on students in subsequent cohorts. Nonetheless, it is possible that achievement results would have been different had these complementary problems not been utilized. Huntley, et al. (2000) provided data indicating that similar complementary materials may have had a positive achievement effect on students utilizing the Core-Plus curriculum.

Visual Mathematics

Most students in either the Traditional cohort or the Reform cohorts had utilized the curriculum Visual Mathematics (Foreman & Bennett, 1991 in middle school. Teachers at Suburban High School believed that the middle school curriculum had a very positive impact on student achievement. The Visual Mathematics curriculum is also an unusually good match to the problem-centered approach used by IMP. Further, there is some indication in the data from Test 3 that previously low-achieving students who had used both the Visual Mathematics curriculum in middle school and the IMP curriculum

in high school showed large improvements in their ability to solve an extended, open-ended algebra problem, but that either curriculum alone was insufficient. Thus, it is possible that results would be different at a high school whose students had experienced more traditional instruction in middle school.

Use of the Visual Mathematics curriculum may have affected not only students' preparation for using IMP, but also the readiness of teachers to implement the IMP curriculum. Before adopting IMP, high school teachers had worked extensively with middle school teachers who had implemented the *Visual Mathematics* curriculum, attending professional development that supported use of the Visual Mathematics curriculum for three consecutive summers. As one Suburban High School mathematics teacher put it, "IMP was easy for most of us to adopt since we were already far along the change continuum by the time we had to make a choice." Thus, it is possible that previous experience with the *Visual Mathematics* middle school curriculum enabled the high school teachers to teach the IMP curriculum more effectively. Results might have been different had this not been the case.

A Strong Grass Roots Leader

Mrs. Sullivan played a key role in changing the mathematics program at Suburban High School. Since 1984, she had served jointly as mathematics supervisor for the school district and as high school mathematics department chair. In that position, she had been involved in hiring new mathematics teachers at both the middle school and the high school and had chosen candidates whose teaching philosophy was broadly compatible with what was eventually outlined in the NCTM *Curriculum and Evaluation Standards* (NCTM, 1989). She arranged high quality professional development over many

consecutive summers, first for the *Visual Mathematics* curriculum and then for the IMP curriculum, and convinced both middle school and high school mathematics teachers to attend the professional development. To build support for the new curricula, she organized parent education nights, and rallied key stakeholders within the community. At various times during the early years IMP was being utilized, she made arrangements to have a reduced teaching load so that she could mentor teachers learning to utilize the new curriculum.

Since leaving Suburban High School in 1999, Mrs. Sullivan has worked with other school districts implementing IMP, Core-Plus, and other curricula designed to implement the *Curriculum and Evaluation Standards* (NCTM, 1989). She believes that those schools who were most successful also had strong grassroots leadership supporting the new program. A Suburban High School IMP mathematics teacher who took a leave of absence from Suburban High School to mentor other schools using new curricula, confirms this opinion. Commenting, based on her experience at Suburban High School and elsewhere about what is need to make a program successful, she noted:

First of all, a grass roots leader in the math department who has a vision and a drive to do the best thing for students regardless of the criticism that inevitably comes from those who do not wish to change. I say grass roots because I think there has to be a leader within the department, a department head or a strong teacher. If it comes from upper administration as a whole it does not seem to work, at least not well or quickly. (Mrs. Sullivan) was the impetus for the change; at first in the middle school, and then as we prepared for Block she led us through the change to IMP.

Unusually Strong Mathematics Teachers

The mathematics teachers at Suburban High School were unusual in a number of ways. They were proactive in designing a mathematics program they believed would benefit their students. Almost all the mathematics teachers at the high school in the mid-

1990s attended professional development to learn about the new middle school curriculum their future students were using, even though they themselves would not be teaching that curriculum. When the high school decided to adopt a block schedule, they searched for a curriculum they thought would match the schedule. Upon identifying the IMP curriculum, they then adapted it to fit the needs of their school and their community. In addition to making the changes described in the previous section, teachers at the school believe they were the first in the nation to adopt IMP school-wide, rather than as an alternative program operating in parallel with a traditional curriculum. Since adopting IMP, most teachers have attended four summers of intensive training in use of the curriculum. The teachers have continued to make changes to their courses, gradually adding modules to course syllabi as they have become more familiar with the program, and adapting and refining the complementary materials they use with the program. It is unclear whether the combination of a semestered block schedule and a Standards-based curriculum could have been successful at a school with a less assertive and professional group of mathematics teachers.

Collegial Mathematics Department

Both the principal and mathematics teachers at Suburban High School emphasized the fact that a major factor in the mathematics department's success was the ability of teachers in the department to work well together. Other schools trying to replicate the results of the current study may need to pay attention not only to developing the skills of individual mathematics teachers, but also to developing a collegial atmosphere in which mathematics teachers can build on one another's strengths.

Time to Prepare for the Change

After the high school administration decided to adopt a semestered block schedule, and before it was implemented, teachers at the school were given a year to prepare for the change. One teacher described the importance of this planning year as follows:

We were given a year to prepare for the change and our department, with Mrs. Sullivan's direction, did do our homework. Every in-service day was spent collaborating about what do we want our students to be able to do mathematically and how are we going to get them there. Then we looked at the curriculum that was available and chose IMP.

Without a year to plan, teachers at Suburban High School may not have been able to make the changes that appear to have contributed to the success of their mathematics program under a semestered block schedule.

Elements of Community Support

With strong support from the district superintendent and assistant superintendent, Mrs. Sullivan had implemented the Visual Mathematics curriculum at the middle school, beginning in 1991-92. Subsequently, both the superintendent and assistant superintendent left the district, so most of the impetus for change at the high school came from Mrs. Sullivan and other teachers there. By the time they began to consider IMP, a series of parent nights and similar events had organized a degree of community support for the Visual Mathematics curriculum. Further, mathematics test scores had improved at the middle school, and some community members perceived the improvement as being due to the use of Visual Mathematics. Finally, when the high school faculty was considering how to adapt their mathematics curriculum to meet the needs of a semestered block schedule, Mrs. Sullivan arranged a meeting with a group of mathematics professors from nearby colleges who were also parents of children attending the high school. This group strongly endorsed the adoption of an integrated curriculum,

and it was a member of this college group who first suggested that the high school consider utilizing IMP. The support of an influential group of local parents with strong education credentials helped counter vocal opposition to the new program that was expressed by other groups within the community.

Use of Multiple Measures

This study has confirmed the repeated finding of many investigations going back at least to the NLSMA reports prepared by the School Mathematics Study Group in the 1960s: Mathematics achievement is a multidimensional phenomenon. More recent 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. This means that studies reporting changes in “mathematics achievement” can be highly misleading, unless they provide a detailed description of precisely what was tested in their measure of “achievement”. It is possible to construct a test that will favor almost any program, so long as the test covers only the specific skills at which that program excels.

The current study used an assessment containing three very different measures of mathematics achievement and found that results differed depending on the measure. Further, considerable insight into what students did and did not learn was provided by a detailed examination of student responses to specific questions within each of the measures. Given the controversy that has surrounded reform mathematics programs like

IMP, it is particularly important for researchers reporting results to explain just what they measured, and whenever possible to use multiple measures that will assess a range of student abilities.

Synergy of IMP and the Semestered Block Schedule

The current study was designed to investigate the joint effects of a semestered block schedule and the IMP curriculum, at a site where sufficient planning time and professional development were available to make it likely these changes would be implemented effectively. Results of the study cannot be attributed to either the curriculum or schedule alone. Rather, it is the impact of both together that appears to have achieved positive results.

Regarding a semestered block schedule, there is considerable evidence based on anecdotes, observations, and surveys that successful implementation requires changes in teaching style, changes in curriculum, and changes in the support given to teachers. The majority of achievement research to date has been conducted at sites where few if any of these changes have been made. The result has usually been equivocal or negative effects on mathematics achievement.

This is the first study that investigated mathematics achievement a site at which all of the research-recommended changes had been implemented. While the mathematics teachers at Suburban High School were engaged in extensive planning to adapt their program to the needs of the semestered block schedule even before they decided to utilize IMP, the adoption of IMP made it much easier for them to modify course content and instruction in a way that fit the new schedule. One possible reason so much other research has been conducted at sites that did not make the recommended changes when

adopting a semestered block schedule is that, absent a reform curriculum, such changes may be difficult or impossible to implement.

The result of the implementation was a very positive effect on student mathematics learning. Students in the Reform cohorts had a somewhat different, but generally more flexible and stronger profile of algebra knowledge than did students in the Traditional cohort. Students had more opportunity to study probability and statistics, to study other mathematics beyond the core curriculum, and to enroll in Advanced Placement classes. The two-semester course in Calculus BC that was possible under a semestered block schedule was particularly successful, as measured by student performance on the AP Calculus BC examination.

Regarding IMP, there has been considerable controversy about the worth of that curriculum. In particular, Wu (2000) and others have accused the curriculum of inadequately preparing students to study advanced mathematics. They have labeled the program as providing insufficient drill, insufficient support for the teacher in guiding students to abstraction and generalization of ideas, and insufficient emphasis on mathematical precision. In contrast, the authors view the curriculum's problem-centered approach as a likely vehicle for empowering students as mathematical thinkers with a deep understanding of underlying concepts (Alper, et al., 1997). In particular, the curriculum might help to overcome the problem of "inert knowledge" described by Bransford, et al. (1989), and thus might better prepare students for future learning.

As implemented at Suburban High School, there was some limited evidence that the curriculum's lack of drill resulted in less automatic or fluent operation on procedures, as Wu (2000) predicted. However, the advantage students in the Traditional cohort had

in performing procedural operations appeared to be “inert.” When symbol manipulation problems were presented in anything other than the standard format, students in the Reform cohorts were as likely to solve them as were students in the Traditional cohort.

Students who used the IMP curriculum had higher achievement on items requiring formulation of mathematical models, interpretation of tables and graphs, and cooperative work with a partner to solve an extended, open-ended problem involving linear equations. It should be noted that the success of learning algebra under IMP may have been due in part to the longer time blocks under a semestered block schedule, which could perhaps support IMP’s style of investigations.

Students who had utilized the IMP curriculum seemed particularly well prepared for studying calculus. After studying Calculus BC under a two-semester format they scored significantly higher on the Advanced Calculus BC exam than had students who used a traditional curriculum and studied Calculus BC under the same format. Although alternate explanations cannot be ruled out, this result is consistent with the hypothesis that algebra concepts might be less “inert” if they are learned using IMP materials instead of a traditional curriculum.

As can be seen from the previous paragraph, this study provides direct evidence regarding the validity of concerns about IMP’s ability to provide students a firm technical foundation for pursuit of more advanced work in mathematics or science (Wu, 2000). The experience at Suburban High School provides strong evidence that students who complete the IMP curriculum can have an excellent technical foundation to pursue advanced study in mathematics or science.

It should be noted, however, that after completing the IMP sequence students at Suburban High School did complete a pre-calculus course before enrolling in calculus, just as students using the traditional core sequence had done. Some teachers at Suburban High School believed students would not have been as successful at calculus without the intervening course. Given that the IMP sequence uses four texts, versus three for the traditional sequence, without the extra courses available under a semestered block schedule it would have been difficult or impossible for many students to have completed IMP, then completed pre-calculus, and still have had time for calculus. Whether forgoing the pre-calculus course would have negatively affected students' achievement in calculus cannot be determined from the current study.

Mrs. Sullivan, the former mathematics supervisor at Suburban High School noted that one of the goals teachers hoped to achieve by adopting a reform curriculum was “to get our mainstream kids, not just our top level kids, to enroll in advanced mathematics courses.” There is some research evidence that utilizing the IMP curriculum can indeed motivate students who wouldn't otherwise do so to study advanced mathematics (Webb, in press). While the IMP curriculum may have motivated some students to enroll in advanced courses, the semestered block schedule provided extra opportunities for them to do so. Again, the current study cannot separate the effects of the two interventions. Together, they did accomplish the goal of increasing mainstream students' participation in advanced mathematics classes. Overall, the proportion of students enrolling in at least one advanced course beyond the core curriculum increased from 48% in traditional cohorts to 58% in the First Reform cohort. This was true despite the fact that students in the First Reform cohort had to complete four core courses before they were able to study

more advanced mathematics, compared to three core courses for students in the traditional cohorts. Further, the proportion of students studying Advanced Placement classes swelled, due mainly to the large number of students interested in Advanced Placements statistics. About 13% of the students in the First Reform cohort enrolled in the Advanced Placement statistics course.

According to one study, the success of teachers at Suburban High School in encouraging mainstream students to study advanced mathematics courses may have had a strong impact on their students' future. An investigation of longitudinal data from the High School and Beyond survey reported that one of the strongest predictors of whether an individual would successfully earn a bachelors is the highest level of mathematics he or she completed in high school. 62% of students who completed trigonometry in high school went on to completed a bachelor's degree, versus only 39.5% of students whose highest course was algebra 2 (Adelman, 1999).

Future Research

There is more research to be done at Suburban High School. When they were in twelfth grade, some students in the Traditional cohort completed two blocks of items from the National Assessment of Educational Progress (NAEP) focusing on geometry and on probability and statistics. Students in the First Reform cohort completed the same items, and students in the Second Reform cohort are scheduled to do so this year. These items will be scored and analyzed, to provide a picture of differences between cohorts in knowledge of geometry and probability and statistics. Also, standardized tests administered by the state in which Suburban High School resides will be analyzed, to provide another view of how the curriculum and schedule have affected achievement.

It is more important, however, to extend the current study to other and contrasting sites. A particularly useful study would be to implement a similar program at an historically under-achieving high school. Block schedules, when implemented correctly, are purported to have particularly positive effects on schools with discipline problems, and to be particularly helpful for low achieving students (Kramer, 1997a). Further, there is general agreement both among proponents of the IMP curriculum and among those who have opposed some of its implementations that IMP is likely to be particularly effective for students who have historically been disaffected from mathematics (Alper, et al., 1997; Wu, 2000).

Most importantly, the experience at Suburban High School has demonstrated that a semestered block schedule, when properly implemented, can provide students the opportunity to take a larger number of advanced mathematics courses than they would otherwise. When implemented together with the IMP curriculum, previously reported negative side effects of a semestered block schedule on student mathematics achievement were prevented and even reversed.

Adelman (1999) in reviewing data from the High School and Beyond longitudinal study found that the highest level mathematics course completed in high school was a strong predictor of whether or not a student would eventually be able to complete a bachelor's degree successfully. Adelman's study was correlational so it is unclear whether providing a student with more opportunity to study advanced mathematics will truly improve his or her prospects later in life but it is a possibility. Given the current emphasis on educational opportunity for all, as reflected in the such documents as the *Principle and Standards for School Mathematics* (NCTM, 2000) and the *No Child Left*

Behind Act of 2001 (U. S. Department of Education, 2002) such a possibility is certainly worth pursuing. Implementing a semestered block schedule together with IMP or a similar curriculum is a promising vehicle for increasing all students' opportunity to study advanced mathematics.