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# A study of mathematics course sequence and student performance in mathematics in a block scheduled high school

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# A STUDY OF MATHEMATICS COURSE SEQUENCE AND STUDENT PERFORMANCE IN MATHEMATICS IN A BLOCK SCHEDULED HIGH SCHOOL

BY

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## DEDICATION

This dissertation is lovingly dedicated to Judy Moody, whose steadfast support, innumerable sacrifices, and belief in me made it possible to make this dream a reality. We end this journey as we began, as friends and partners. Who could ask for anything more?

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# ABSTRACT

## A STUDY OF MATHEMATICS COURSE SEQUENCE AND STUDENT PERFORMANCE IN MATHEMATICS IN A BLOCK SCHEDULE HIGH SCHOOL

by

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University of New Hampshire, May, 2001

The 1983 study of the condition of American Education, *A Nation at Risk*, brought a significant amount of attention to the way in which schools provided students with the skills necessary to be productive citizens. Many of the recommendations contained in *A Nation at Risk* focused on the perceived poor performance of American students when compared to their counterparts worldwide. The year after publication of *A Nation at Risk*, the National Commission on Time and Learning published *Prisoners of Time*, a report that called for the establishment of high academic standards for students and a major restructuring of the school day to provide more time for focus on providing students with additional time to focus on content area subjects. The additional time, it was proposed, would help our students to become more competitive with their peers internationally. These two powerful documents provided the fuel necessary to ignite

efforts to restructure the school day, particularly in high schools. While there have been several school restructuring initiatives, block scheduling has received much attention.

Block scheduling radically alters the way in which schools organize the instructional day for students and staff. The most prominent form of block scheduling is the 4X4 block, which results in ninety-minute classes four times per day for each of two semesters. Thus, students take eight courses during the school year, four during each semester. Under this model, students complete a year of work in half the time. One consequence of block scheduling is that students may experience significant gaps in sequential courses, particularly in mathematics and foreign language. The extent to which this gap affects student achievement in mathematics was the focus of this study.

# CHAPTER I

# GENERAL INFORMATION

## Purpose of the Study

The purpose of this study was to determine the impact of mathematics course sequencing on student achievement in mathematics in a block scheduled high school.

To date there is little empirical evidence to document the effect that block scheduling has had on student achievement. This research is intended to provide school administrators with a better understanding of how course sequencing and gaps in mathematics course enrollment in grades nine and ten impacts student achievement on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten assessment.

A comparative design was used to determine the relationship between course sequencing and student achievement in mathematics in a block scheduled high school. The course sequence and academic achievement level of students who have been involved in block scheduling for two successive years were examined.

In order to create two distinct groups for purposes of the study, students were identified as to whether or not they had participated in Algebra in grade eight. The achievement level of both groups, as measured by their performance on the New Hampshire Educational Improvement and Assessment Program mathematics assessment and their cumulative grade point average in mathematics, was used as the achievement variable throughout the study.

Participation in Algebra I at the eighth grade level provides students with an opportunity to participate in at least one additional higher level mathematics course prior to taking the end-of-grade ten assessment. Taking Algebra I in grade eight does not affect the three-course requirement for graduation; it is simply recorded on participating students' high school transcripts as a course without a grade. By distinguishing grade eight Algebra I students from their peers who did not take Algebra, two distinct comparison groups emerged: those students who had taken Algebra in grade eight and those who had not.

The results of this study will be useful to school administrators and guidance staff in determining whether students who participate in Algebra I in the eighth grade perform differently in their first two years in a block scheduled high school than their counterparts who do not take Algebra until the ninth or tenth grade. The information will be useful to guidance staff in advising students in the mathematics course selection process.

## Definition of Terms

Course Gap – Course gap is the amount of elapsed time between enrollment in one mathematics course and the next mathematics course, regardless of course sequence or level.

Course Sequence – Course sequence is the order in which a student enrolled in one mathematics course and subsequently enrolled in another, regardless of the elapsed time (gap) between those courses.

NHEIAP – The New Hampshire Educational Improvement and Assessment Program is the statewide assessment administered to all New Hampshire students enrolled in grades three, six and ten. Students in grade three are assessed in reading/ language arts, and mathematics. Students in grades 6 and 10 are assessed in reading/ language arts, mathematics, science and social studies.

New Hampshire Curriculum Frameworks – The NHEIAP is based on curriculum frameworks for each of the assessed subjects. The frameworks contain the specific proficiencies that each child is expected to know and be able to demonstrate on the annual assessment conducted at the end of grades three, six and ten.

NHEIAP Scale Score – Each student, school, district and the state are assigned a mean scale score performance rating based on the results of the NHEIAP. Scale scores range from 200-300 and correspond to specific proficiency levels: 200-239 Novice; 240-259 Basic; 260-279 Proficient; and 280-300 Advanced. Districts and schools are ranked according to their mean scale scores as determined by their three-year cumulative average of mean scale scores.

Block Scheduling – Block scheduling is a scheduling model that replaces the traditional seven-eight period high school day with any one of a number of alternative scheduling options, the most common of which is the 4X4 block schedule that has students participating in four 90-minute classes per semester twice per school year or the alternating block (A/B) schedule which results in students taking four classes each day, but on an alternating day schedule.

General Background Information

Educational innovations are, all too frequently, implemented without a great deal of thought about the long-term impact of the innovation on teaching, learning, and student achievement. Before implementation of a 4X4 block schedule at Salem High School, a set of evaluative criteria was established and approved by the Salem School Board. These criteria were specifically designed to be used in determining the effectiveness of block scheduling at Salem High School. One of the many factors considered in evaluating the success of block scheduling was the degree to which student achievement would increase because of block scheduling.

As a way of testing the anticipated increase in student achievement, this study attempted to determine whether course sequencing in mathematics, under a 4X4 block schedule, results in disparate student performance on the NHEIAP end-of-Grade Ten mathematics assessment. Developing a methodology to measure the influence of course sequencing on student performance was a major task of this study. The extent to which the anticipated results are valid may influence future scheduling practices in mathematics as well as other high school courses of study where the sequence in which students take a course(s) may impact their achievement on an independent assessment such as the New Hampshire Educational Improvement and Assessment Program, the Scholastic Aptitude Test or Advanced Placement Examinations.

This study has potentially significant implications for how block scheduled high schools schedule sequential courses as well as how such scheduling may inadvertently create gaps between courses that result in less than expected performance on independent assessments. The findings of this study will be useful to administrators and guidance counselors in block scheduled high schools as they develop and advise students about course offerings designed to result in improved student achievement and increased mean scale score performance on state and other similar assessments. This study will provide educational leaders with a data-gathering model and methodology that can be used to make key decisions about the impact of course sequencing on student achievement in a block-scheduling format.

The Salem School District adopted block scheduling for implementation at Salem High School in the spring of 1997. As part of the adoption process the Salem School Board agreed to accept the evaluative criteria proposed by the Block Scheduling Evaluation Committee. The approved evaluative criteria identified those factors that would be key indicators of the success of block scheduling and defined the methods by which the data would be collected, analyzed and reported annually to the school board and the community. The evaluative criteria were divided into three categories: Implementation Criteria, Effectiveness Criteria and Impact Criteria (Appendix A).

The first attempt to evaluate the effectiveness of block scheduling, using the agreed to evaluation model, met with mixed success. Incomplete quantitative data, delays in the development of survey instrumentation and a lack of a clearly defined process to sort and analyze data resulted in a limited evaluation. Therefore, there was little empirical evidence upon which the assertion that block scheduling positively impacted student achievement at Salem High School could be validated. Notwithstanding the lack of quantitative data about the success of block scheduling at Salem High School, there was a significant amount of qualitative data available gathered from a survey of parents, students, teachers and administrators. Information gathered through the survey was used to further refine and develop the block scheduling evaluation process.

From the beginning, concerns about scheduling in the 4X4 block format at Salem High School were expressed by staff, administrators and members of the Salem School Board (Appendix A). Major scheduling difficulties were encountered during the first two years of implementation, causing the focus of the annual evaluation to be more on student scheduling than on any other aspect of the agreed to criteria. These concerns were articulated in the staff questionnaire conducted as part of the block scheduling evaluation process (Appendix A).

Maintaining equitable class loads and offering a wide array of courses to meet student needs proved to be challenging during the first two years of block scheduling. While attempts were made to remedy the concerns being expressed by the board and the staff, mathematics and foreign language staff continued to voice their concern that student retention of instruction is impeded because of the 4X4 block schedule.[1]

While the total amount of time available for instruction in academic courses is approximately the same under the block schedule as it is in the traditional eight period day configurations, mathematics and foreign language staff continued to assert that they were unable to fully cover the prescribed curriculum in the block schedule as compared to the traditional seven period days. Because all coursework is completed in one semester in a block scheduled school, as opposed to over the course of a full school year in a traditional schedule format, the issue of retention of material by students takes on more significance in the eyes of the instructional staff.

For the teaching staff, the question of retention, breadth and depth of course content coverage becomes even more importat when students are tested by the state, such as is the case in Massachusetts, Iowa, Texas, New York, New Hampshire, California and Kentucky, among others. This is particularly true in those instances where students are tested on a broad range of standards and proficiencies, such as those articulated in the New Hampshire Curriculum Frameworks.

The NHEIAP mathematics assessment is a measure of individual student ability to apply mathematics in a variety of ways, yet some members of the faculty continue to express concern that block scheduling does not allow for the same depth of coverage of material as under a traditional schedule. Consequently, the amount of time between mathematics courses may decrease retention of material, particularly if the gap exists just before the administration of the state assessment. For example, it is possible under a block scheduling format, that students will have as much as an eleven month gap in mathematics courses prior to participating in the New Hampshire statewide assessment, depending on their choice of courses and the semester in which they take those courses during their freshman and sophomore years. The potential of such a large gap between mathematics courses presents a unique problem in that all tenth grade students are required to participate in a state assessment in mathematics at the end of the tenth grade regardless of the courses or the sequences of courses they take. This study seeks to measure the impact of course gaps on student achievement in mathematics and to provide possible solutions should the data analysis indicate that course gaps and/or course sequence negatively impacts student achievement in mathematics.

The New Hampshire Educational Improvement and Assessment Program assessment is administered annually to students in grades three, six and ten in all New Hampshire public schools. Grade three students are tested in Language Arts - Reading, Writing and Mathematics. Grade 6 and 10 students are tested in Language Arts – Reading, Writing, Mathematics, Social Studies and Science. The content of the New Hampshire Assessment is based on the New Hampshire Curriculum Frameworks for each of the tested areas. The curriculum frameworks are widely distributed and are available to all administrators and staff in the Salem School District.

The material in the K-12 Mathematics Curriculum Frameworks[2] is organized around eight strands: Problem Solving and Reasoning; Communication and Connections; Numbers, Numeration, Operations and Number Theory; Geometry, Measurement and Trigonometry; Data Analysis, Statistics and Probability; Functions, Relations and Algebra; Mathematics of Change; and Discreet Mathematics. Within each of these areas, one or more K-12 Broad Goals identify general expectations of what ALL New Hampshire students are expected to know and be able to do.

Following a two-year review process of national, state and local mathematics standards and curricula, the New Hampshire Curriculum Frameworks were adopted as the Salem School District curriculum in 1997. Therefore, instruction in each of the tested areas is expected to be taught in each grade and subject as indicated in the state curriculum frameworks. Consequently, the local curriculum reflects the standards and proficiencies assessed on the NHEIAP. Because the NHEIAP assesses skills acquired through the end-of-grade ten, it is important that students be provided opportunities to gain the mathematics skills and competencies required on the assessment. The extent to which this is accomplished through mathematics courses taken in grade nine and ten, the sequence in which students take those courses and the time between mathematics courses is addressed by this study (Appendix D).

## The Research Questions

To determine the impact of course sequence on student performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment, data will be gathered and analyzed to elicit answers to the following questions:

1. Does the sequence in which students participate in mathematics courses (regardless of course gap) result in disparate performance on the statewide mathematics assessment for students with similar characteristics?
   a. Does the amount of time (gap) between mathematics courses affect individual student performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment?
   b. Do students who take Algebra and Geometry closer to the administration date of the statewide mathematics assessment outperform those who do not?

c. Do students who participate in Algebra I in grade eight outperform those who do not take Algebra I on the end-of-grade ten statewide mathematics assessment regardless of the sequence of mathematics course that they take?

## Research Hypotheses

1. The sequence in which students enroll in courses in a block-scheduled high school will affect their Mean Scaled Score performance on the mathematics component of the New Hampshire Educational Improvement and Assessment Program.
2. Students who take Algebra I in grade eight will outperform tenth grade students who did not take Algebra I in grade eight on the NHEIAP mathematics assessment, regardless of their course sequence in mathematics.
3. Large gaps (long periods of time between courses) in mathematics instruction will result in lower Mean Scale Score performance on the mathematics component of the New Hampshire Educational Improvement and Assessment Program (NHEIAP) when holding initial achievement and grade level variables constant.
4. Students who participate in mathematics courses closer to the examination date of the NHEIAP will perform significantly better than those students who do not.

## Research Methodology and Data Analysis

In order to insure the integrity of the data collected for purposes of the study, the researcher reviewed each source of data to determine its validity and accuracy. All student records originally considered for the study were examined directly by the researcher. Individual student transcripts were reviewed to determine cumulative grade point averages. California Achievement Test Individual Student Record sheets were reviewed to ascertain the Mathematics Total stanine score for each student. The class record sheets containing the individual student Orleans-Hanna Algebra I Prognosis Test results were reviewed and subsequently recorded for use in the study. All data collected were maintained in a file and will be made available to Salem High School once the study has been completed.

## Significance of the Study

This study has major significance to the field of education in that it provides data about a relatively new school reform initiative that focuses on non-traditional scheduling practices in high schools. The researcher was unable to identify any comprehensive models for conducting such a study nor any papers, tests or dissertations that specifically focus on the impact of course gap on student achievement in mathematics on a state assessment.

# CHAPTER II

# REVIEW OF THE LITERATURE

## Literature Review

The ensuing literature review is used to establish the direction and scope of this study. The material contained in the literature review is organized as follows:

Setting the Stage for School Reform. This section reviews the impact of A Nation at Risk and Prisoners of Time as catalysts for school reform in America.

Block Scheduling's Emergence as a School Reform Initiative. This section examines the emergence of block scheduling as a major effort to restructure the school day as a means to improve school climate, culture and academic achievement.

Common Models of Block Scheduling. This section presents the most commonly used models of block scheduling.

Block Scheduling Goals. This section reviews the goals of block scheduling as presented by the most prominent researchers in the field of educational research on block scheduling.

The Impact of Block Scheduling on Student Achievement. This section addresses the issue of student retention of academic content and skills in block scheduled schools.

Course Gap as a Factor in Student Retention of Material. This section review the literature regarding student retention of academic material, and subsequent assessment of knowledge, when course gap is a factor.

Block Scheduling Critics. This section presents some of the arguments against block scheduling as a school reform.

Setting the Stage for School Reform

The American educational community was challenged by a bold statement included in the provocative report *A Nation at Risk*: "If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we well might have viewed it as an act of war" (National Commission on Excellence in Education, April 1983. p. 5). Characteristically, the education community did not respond to either statement in a way that adequately addressed the groundswell of concern that emerged following publication of *A Nation at Risk*. In addition to the assertion that American educational system was "mediocre," the report concluded that "declines in student performance are in large part the result of disturbing inadequacies in the way that the educational process is often conducted" (p. 18).

Increasing the productivity of students was one of the key findings of *A Nation at Risk*. Several of those findings have significance to schools considering restructuring their school day (p. 18). Among the findings reported to be part of the disturbing inadequacies of the American educational process were:

- Secondary school curricula have been homogenized, diluted, and diffused to the point that they no longer have a central purpose. In effect, we have a cafeteria style curriculum in which the appetizers and desserts can easily be mistaken for the main courses. Students have migrated from vocational and college preparatory programs to "general track" courses in large numbers. The proportion of students taking a general program of study has increased from 12 percent in 1964 to 42 percent in 1979.

- This curricular smorgasbord, combined with extensive student choice, explains a great deal about where we find ourselves today. We offer intermediate algebra, but only 31 percent of our recent high school graduates complete it; we offer French I, but only 13 percent complete it; and we offer geography, but only 16 percent complete it. Calculus is available in schools enrolling about 60 percent of all students, but only 6 percent of all students complete it.
- Twenty-five percent of the credits earned by general track high school students are in physical educational and health education, work experience outside the school, remedial English and mathematics, and personal service and development courses, such as training for adulthood and marriage.

The Commission presented several expectations that it felt were important for school and college graduates to possess. These expectations were defined in terms of the level of knowledge, abilities, and skills school and college graduates should possess as well as the time, hard work, behavior, self-discipline and motivation that are essential for high student achievement (p. 19). According to the Commission such expectations are expressed to students in a several different ways, several of which are:

- by grades, which reflect the degree to which students demonstrate their mastery of subject matter;
- through high school and college graduation requirements, which tell students which subjects are most important;

- by the presence or absence of rigorous examinations requiring students to demonstrate their mastery of content and skill before receiving a diploma or a degree;
- by the difficulty of the subject matter students confront in their texts and assigned readings.

Several notable deficiencies in the American education system were articulated to demonstrate the allegations made by the Commission that American schools were under-performing as compared to their international peers.

- The amount of homework for high school seniors has declined and grades have risen as average student achievement has been declining;
- In many other industrialized nations, courses in mathematics, biology, chemistry, physics, and geography start in grade six and are required of all students....;
- In 13 states, 50 percent or more of the units required for high school graduation may be electives chosen by the student.....; and
- "Minimum competency" examinations fall short of what is needed as the "minimum" tends to become the "maximum," thus, lowering educational standards for all.

Further reinforcing their focus on time as an important element in successful learning experiences for students, the Commission (p. 21) offered four disturbing facts about the use of time made by American schools and students:

- In many schools, the time spent learning how to cook and drive counts as much toward a high school diploma as the time spent studying mathematics, English, chemistry, US history, or biology;
- A study of the school week in the United States found that some schools provided students only 17 hours of academic instruction during the week and the average school provided about 22;
- A California study of individual classrooms found that because of poor management of classroom time, some elementary students received only one-fifth of the instruction others received in reading instruction; and
- In most schools, the teaching of study skills is haphazard and unplanned. Consequently, many students complete high school and enter college without disciplined and systematic study habits.

Effective use of the conclusions and recommendations included in *A Nation at Risk* could, conceivably, have led to the called-for improvements in the quality of education for all students in all schools across the country.

*A Nation at Risk* identified areas of concern of the current educational system and recommended four areas as needing immediate improvement: content, expectations, time, and teaching practices. Specific recommendations for improvement in each area were provided in the report. These recommendations were intended to be used as a blueprint for educational reform in America. As a result, "restructuring" and "reform" became the vehicles through which the alluded to decline in student performance could be remedied.

The call for action on the recommendations contained in *A Nation at Risk* required public support for education. While some may have questioned how supportive the public was in achieving the desired changes in the American education system, former President Ronald Reagan called for a renewed awareness of the need for public school reform in a May 1992 address to the National Academy of Sciences (p. 16). By increasing public awareness and "...I hope public action is -long overdue....This country was built on American respect for education....Our challenge now is to create a resurgence of that thirst for education that typifies our nation's history." Reagan, almost ten years after the publication of *A Nation at Risk*, was advocating public action in response to the perception that the American educational system was at risk.

Fifteen years following publication of *A Nation at Risk*, the recurring plea for expanded relationships between schools and their greater communities, including business and industry, remains at the epicenter of persistent calls for improvement in student achievement. These keys to effective educational reform were reinforced by the National Commission on Time and Learning: *Prisoners of Time* monograph (1994) which concluded in part that, "...certainly nothing will change as long as education remains a convenient whipping-boy by camouflaging larger failures of national will and shortcomings in public and private leadership" (p. 10).

While several educational reform initiatives have been undertaken since the publication of *A Nation at Risk*, the public education system in the United States continues to be the focus of much national attention; as evidenced by the prominence of this topic in the national debate conducted by the two major party nominees for the presidency during 1999-2000. This debate continued with the election of President George W. Bush in November 2000. President Bush proposed several educational reforms during his first week in office. The debate, which will certainly accompany those proposed reforms, is not likely to subside in the near future.

The proposed educational reforms are linked, to some degree, with several of the indicators of risk enumerated in *A Nation at Risk* (pp. 8-10) and continue to be the focus of public debate about the quality of the American education system and are illustrative of the seemingly slow progress in realizing real reform in education. Curriculum offerings, time for learning, instructional methodology and most prominently in recent years, assessment of student progress are at the epicenter of recent debate about the quality of education in America.

Development of national standards and assessment is the cornerstone of recently elected George W. Bush's educational reform proposal. Bush's educational reform package, presented during the first week of his presidency, includes national assessment in reading and mathematics as well as an accountability plan that would result in allowing parents of "under-performing" schools to transfer their children to other schools through the use of an educational voucher.

Educational leaders have much to accomplish if they are to improve our educational delivery system in ways that will improve student learning and achievement to the extent currently being advocated by local, state, and national leaders. New ways of thinking and doing will be required if progress is to be made.

As educational leaders continue to debate the effectiveness of educational reforms such as block scheduling, the debate over the overall quality of American education continues unabated. The continued focus on the condition of education may be due, in part, to the lack of empirical data to document the impact of educational reforms and their impact on teaching, learning and assessment of student progress.

*Prisoners of Time* (1994) criticizes American schools for their lack of action on restructuring the school day to maximize student learning. The Commission report asserts that "The boundaries of student growth are defined by schedules for bells, buses, and vacations instead of standards for students and learning" (p. 7). *Prisoners of Time* proved to be a catalyst for discussion of how schools structure themselves for maximum learning, particularly American high schools.

Block Scheduling's Emergence as a School Reform Initiative

Until only recently the seven/eight period day schedule has remained in place in high schools which were in existence thirty or more years ago. The effectiveness of this scheduling practice is to some degree as untested as alternative scheduling models currently being implemented in some high schools.

One of the major alternative scheduling models to emerge from the debate about school reform, particularly at the high school level, is block scheduling, the genesis of which, in its most recent configurations[3], can be traced back to a school reform and restructuring model developed in 1991 at Masconomet High School in Topsfield, Massachusetts. Named after Nicholas Copernicus the noted scholar and astronomer, the Copernican Plan was designed to change the structure of American high schools. (The

Copernican Plan, initially named the Renaissance Program, was initially implemented as a choice program, i.e., students could opt in or out of the program based on their individual learning plan, in collaboration with school staff and parents (Carroll , October 1994). The Copernican Plan, as it was proposed by Joseph Carroll, then Superintendent of Schools for the Topsfield, Massachusetts School District, was implemented at Masconomet High School in 1991 in an effort to provide students and staff with a variety of options for scheduling and teaching and learning.

The underlying concept of the Copernican Plan, as presented to staff and parents, was to provide longer class periods, fewer classes per semester, and less emphasis on so-called non-academic subjects. Carroll based his plan on the assertion that there was a need for dramatic change in school structure if the desired improvements in teaching and learning were to be realized. The Copernican Plan, it was believed, would give teachers greater control over the instructional environment in their school and in their classrooms, would provide teachers with more teaching time and less non-instructional time, and would encourage diversification of teaching methodologies and require students to be more actively engaged in their own learning (Carroll, 1987 p. 14). Additionally, the instructional plan proposed by Carroll was designed as a model for restructuring schools and for changing the way teachers, students, parents and administrators viewed the relationship between time and learning.

According to Carroll (AASA Online, 2000), an evaluation of The Copernican Plan conducted by Whitla, Bermperchat, Peronne and Carroll,[4] concluded that "Implementing a Copernican-style schedule can be accomplished with the expectation of favorable pedagogical outcomes" (Carroll, 1994, p. 28). The Copernican Plan, as it was proposed, had promise as a legitimate model for restructuring the school day to achieve a variety of purposes, not the least of which was the potential for students to maximize their own learning time through alternative scheduling.

However, despite the results of a follow-up study of seven high schools using Copernican models that noted, "while there were significant differences in the results under different models, each school benefited from the change, but the Copernican model did not survive the political culture in which it was conceived and implemented" (Carroll 1994, p. 28). As a result, Masconomet High School abandoned the Copernican plan after its second year of implementation for several reasons, not the least of which were political disagreements about the value of the new instructional plan (Carroll, 1992). The Copernican Plan, in spite of its demise in the Masconomet School District, stimulated the creation of a second generation of high school restructuring that has evolved into what is now commonly referred to as block scheduling.

## Common Models of Block Scheduling

Several variations of block scheduling have emerged since the Copernican plan was first introduced (Canady & Rettig, 1995, 1996, 1997, 1999; Edwards, 1993; Francka & Lindsey, 1995; Kruse & Kruse, 1995; Mistretta & Polansky, 19971997; Shortt &Thayer, 1997; Lybbert, 1998; Northeast and Islands Regional Laboratory at Brown University, 2000). There are several basic models that are more commonly used in high schools today.

4X4 Block Scheduling Plan

The 4X4 block plan divides the school day into four 90-minute periods with time provided for lunch and passing times. Each of the four blocks lasts for one semester (one-half of a traditional school year). Generally, teachers are required to teach three blocks and have one planning/preparation period usually equal to one block. Some variations of the 4X4 block require a "split-block" which accommodates the necessity of scheduling several lunch periods to accommodate the student population and to provide teachers with a mandated lunch period.

Table 1

Sample 4X4 Block Schedule

| FALL<br>Semester I | SPRING<br>Semester 2 |
|---|---|
| Course 1 | Course 5 |
| Course 2 | Course 6 |
| Course 3 | Course 7 |
| Course 4 | Course 8 |

Trimester Block Scheduling

In the trimester model of block scheduling students take two or three core courses each trimester over a 60-day period. As a result, the students complete six to nine credits per year.

Table 2

Sample Trimester Block Schedule

| Time | Trimester 1 (60 days) | Trimester 2 (60 days) | Trimester 3 (60 days) |
|---|---|---|---|
| Morning | Course 1 | Course 3 | Course 5 |
| Afternoon | Course 2 | Course 4 | Course 6 |

75-75-30 Block Schedule

The 75-75-30 block schedule is one in which students take three classes each for two 75 day terms followed by a 30-day intensive course or enrichment program. Placement of the 30-day period varies from school to school and may have two 15 day shortened courses in-between the 75-day courses.

Table 3

Sample 75-75-30 Block Schedule

| Fall Term (75 days) | Winter Term 75 days |
|---|---|
| Course 1 | Course 4 |
| Course 2 | Course 5 |
| Course 3 | Course 6 |

Alternative Day Plan (A/B)

The alternate day plan, or A/B plan, is organized into four periods per day, as in the 4X4 block schedule, but courses are offered on an alternating basis. Consequently, students take eight classes over a two-day period.

Table 4

Sample of Alternative Day (A/B) Block Schedule.

| Monday A-Day | Tuesday B-Day | Wednesday C-Day | Thursday B-Day | Friday A-Day | Monday B-Day |
|---|---|---|---|---|---|
| Course 1 | Course 2 | Course 1 | Course 2 | Course 1 | Course 2 |
| Course 3 | Course 4 | Course 3 | Course 4 | Course 3 | Course 4 |
| Course 5 | Course 6 | Course 5 | Course 6 | Course 5 | Course 6 |
| Course 7 | Course 8 | Course 7 | Course 8 | Course 7 | Course 8 |

Copernican Model of Block Scheduling

Students attend classes in large block of time over the course of 30, 45, 60, or 90 days depending on the selected format. Students may attend two two-hour classes each morning and then spend the afternoon in seminars or electives such as music, physical education or Advanced Placement classes. The time for afternoon classes is adjusted to meet the needs of the class and the topic being discussed.

The Impact of Block Scheduling on Student Achievement

Canady and Rettig (1995) frequently cited "experts" on block scheduling define the goals of block scheduling as follows:

Table 5

Copernican Plan Scheduling Model

| Time | Trimester 1 | Trimester 2 | Trimester 3 |
|---|---|---|---|
| AM | Course 1 | Course 3 | Course 5 |
| | Course 2 | Course 4 | Course 6 |
| PM | Seminars of Interest<br><br>Electives/Music/Physical Education, Advanced Placement Course(s) | Seminars of Interest<br><br>Electives/Music/Physical Education, Advanced Placement Course(s) | Seminars of Interest<br><br>Electives/Music/Physical Education, Advanced Placement Course(s) |

- Reduce the number of class changes and movements that large groups of students are required to complete during any one school day;
- Reduce the duplication and inefficiency reportedly documented in many high schools using the daily, single period high school schedule;
- Reduce the number of students for and with whom teachers must prepare and interact each day and/or each term;
- Reduce the number of classes and the accompanying assignments, tests, and projects that students must address during any one day or term;
- Reduce the fragmentation inherent in single-period schedules, a complaint that is especially pertinent to classes requiring extensive practice and laboratory work;
- Provide teachers with blocks of teaching time that allow and encourage the use of active teaching strategies and greater student involvement; and

- Allow students variable amounts of time for learning, without lowering standards, and without punishing those who need more or less time to learn (p. 12).

These goals for block scheduling serve as the foundation of recent efforts to expand educational reform, particularly as they relate to scheduling practices, across the United States. Canady and Retting (1995) contend that, "We must view a schedule not simply as a barrier blocking the path to school improvement, but as an untapped resource that can be drawn on to solve problems and implement needed programs (p. 29).

Canady and Rettig's view is consistent with the findings of *Breaking Ranks: Changing an American Institution* (1996) whose authors concluded that if American high schools are to adequately meet the changing needs of their students they will need to "develop flexible scheduling that allows for more varied uses of time in order to meet the requirements of the core curriculum" (p. 45). *Breaking Ranks* (1996) also called for a ... "redefinition or replacement of the Carnegie Unit[5] so that high schools no longer equate time with learning (p. 45).

Further strengthening the need to change the traditional model of most high schools is the contention that block scheduling provides for, among other things, more effective use of time, decreases class time, increases the number of course offerings, reduces the number of teachers with whom students have daily contact, reduces stress, improves school climate and allows teachers to use more process-oriented teaching strategies (Canady & Rettig, 1995, 1996, 1999; Edwards, 1993; Hottenstein, 1999; Kramer, 1997; Sturgis,1995; Watts & Castle, 1993).

Watts & Castle (1993) suggest that inflexible scheduling practices are inappropriately based on administrative and institutional needs as opposed to the needs of teachers and students. They offer five strategies for dealing with the dilemma of time in block scheduling (pp. 307-309):

1. Freed-up time. *Encourages the use of various interventions to break away from traditional views of scheduling of teachers' time.*
2. Restructured or rescheduled time. *Restructured time involves formally altering the timeframe of the traditional calendar, school day, or teaching schedule.*
3. Common time. *Designating specific time periods for individual teachers to prepare and plan.*
4. Better-used time. *Using the currently scheduled meetings and professional development activities more efficiently, for planning rather than for administrative or informational purposes.*
5. Purchased time. *Compensating teachers for additional job-related activities or securing para-professionals to perform non-teaching functions.*

Watts and Castle are supported in their contention that scheduling is a critical aspect of the reform movement by Canady and Rettig (1993, 1995, 1996) who propose that "...we must view the schedule not simply as a barrier blocking the path to school improvement but as an untapped resource that can be drawn on to solve problems and implement needed programs" (pp. 29, 310).

Scheduling practices in high schools were scrutinized. Kruse and Kruse (May 1995), studied high school schedules and believe that current scheduling practices "... have created a very narrow view of human learning, one focusing on recall and recollection, rather than thinking and learning" (p. 7). Student master schedules are more commonly built more around time and organization than on the assessment of the instructional needs of today's learners and the increasing expectations for improved student achievement (Kruse & Kruse, p. 6).

It is widely believed, as repeatedly reinforced in a review of the literature on block scheduling, that more time may be needed to evaluate the effectiveness of block scheduling as a legitimate and effective school reform. Decisions about how the instructional day is structured as well as the how that time is used and who is in control of it are equally important issues for future research on the effectiveness of alternative scheduling such as block scheduling.

Lammel (1996) admonishes that "exacerbating the effective use of traditional scheduling is the continued practice of having both teachers and students participate in six to eight instructional periods per day and asking professional teachers to deliver the curriculum, motivate students and assess 120-180 adolescent students at one time is ludicrous" (p. 5). He further adds to his indictment of the current configuration of high school schedules by pointing out the "ridiculousness" of the notion that a typical student can manage six to eight different courses and an equal number of adults every day of the school year.

In an effort to ascertain the status of school restructuring efforts, particularly block scheduling, Cawelti (1994) conducted a National Study of High School Restructuring in 1993. Of the 10,365 schools asked to complete a survey about restructuring efforts in their schools 3,380 schools responded (p. 5), 11% of the total. Of those responding, 12% indicated that block scheduling was in partial implementation stage and 61% indicated that they had no plans to implement block scheduling (p. 23). Based on the results of his survey, Cawelti concluded that, "The slow pace of change is likely to continue until there are more successful models of high schools that have been restructured and that see improved student learning" (p. 67).

One explanation as to why there is a lack of widespread adoption of block scheduling is offered by Sturgis (1995) who believes that the restructuring effort has no sponsor (p. 2), i.e., no university, governmental agency or foundation. Data about the effectiveness of block scheduling on student achievement are an important element for high schools to explore as they consider implementing, continuing or modifying block scheduling as a school reform initiative.

In an effort to validate his claim that the lack of empirical data influences the sustainability of block scheduling, Sturgis (1995) collected data from twenty-seven high schools using block scheduling and found that only seven of the schools attempted to explore the impact of the restructuring strategy on student achievement. While some schools had begun to selectively collect and cite evidence of gains in student achievement, the data for Sturgis' study were drawn primarily from opinion surveys and not from a systematic and rigorous data-collection and analysis strategy (p. 3).

Cawelti and Sturgis' prediction that adoption of block scheduling as a school reform strategy would be slow is contradicted by the findings of (Rettig & Canady, 1996) who concluded as a result of their own independent study of block schedule schools, that

"..the pace in the growth of the number of schools has been dramatic" (p. 8). Canady and Rettig (1995) estimated that more than 50% of United States high schools were currently either using or considering some form of block scheduling (p. 8). While these findings might appear surprising when compared to the Cawelti study, it is important to note that Canady and Rettig do not present specific data that can be used to differentiate between schools actually employing block scheduling and those considering it as a model.

In 1996 the number of schools using block scheduling had increased to 50% (Shockey 1998, p. 4). Accounting for this increase is puzzling, given that the availability of research to document the impact of block scheduling on student achievement did not increase significantly between the time both studies had been conducted.

Whether or not the predicted increase in the number of schools employing block scheduling as anticipated by Canady and Rettig (1995) has been achieved is still unknown, primarily because there is no single source of data that identifies schools actually using, or intending to use block scheduling.[6] In addition, because the original 4X4 block scheduling model has been through several iterations, it is unclear whether or not respondents to surveys would be able to accurately answer in the same way they did in the original Cawelti survey.

A search of the Internet site specifically dedicated to block scheduling (http://www.blocklist@tc.umn.edu) does not provide data on the total number of schools currently operating under a block schedule.[7] The listserve frequently contains questions expressing concern from schools that are finding that their students are not meeting the anticipated academic achievement goals of block scheduling or that the specific configuration is not meeting the scheduling needs of the school. As a consequence, many of the questions on the block scheduling listserve focus on how to either redesign the block structure to address the problems that have arisen or how to return to the traditional seven or eight period per day schedule with minimal disruption to students already having been on block schedule for several years.

A review of the Block Scheduling Schools website (http://caeri.coled.umn.edu) listed 418 schools that had "self-identified" themselves as having adopted the block scheduling model. This does not indicate the growth rate anticipated by Cawelti based on his 1994 survey of schools considering the block scheduling model. The block scheduling listserve is dedicated to conversation and research about block scheduling and serves as a resource for those seeking information about that school restructuring effort.

A collection of articles about block scheduling, edited by Robin Fogarty (Fogarty 1996), contains a section by Joseph Carroll, the father of the Copernican Plan, which speaks directly to the importance of evaluation of block scheduling or similar school-day restructuring efforts as an integral component of the reform effort. Carroll (1994), refers specifically to the Copernican Plan as a model for educational reform such as block scheduling. The article reflects Carroll's perception that the major problem with most efforts to change schools is the failure to plan an evaluation as an integral part of the process and to evaluate student outcomes (p. 128).

Validating claims that block scheduling does, in fact, result in school improvement is critical to the successful implementation, expansion and continuation of block scheduling. Robinson (1996) proposed a series of research priorities for schools which focus on the necessity of validating educational innovations through appropriate research methodologies to achieve desired outcomes (pp. 17-69). Robinson addresses the need for educators to engage in meaningful dialogue and research about education initiatives, as part of the ongoing process of validating the impact of school reform. According to Robinson, "If we infuse a more reflective, analytic approach into all of our educational endeavors, we can renew a sense of confidence and hope in our nation's educational enterprise." He further states that, "Our nation has the capacity to mount the educational research efforts called for...efforts that meet rigorous, scientific standards and produce findings that are bold, useful, and responsive to important questions of the day."

Robinson's recommendations are contained in a report published by the U.S. Department of Education Office of Educational Research and Improvement in a monograph entitled *Building Knowledge for a Nation of Learners, A Framework for Educational Research 1997.* The report calls for new standards of research that focus on what works and why? Robinson (p. 12) advocates strongly for research of current educational initiatives as a means to improve the achievement level of American students.

> As we edge toward the new century teachers and other educational researchers need to pursue approaches that ask important questions, allow for sustained, responsible inquiry, recognize and accommodate complexity, and produce the kinds of knowledge that can improve results for all of our nation's learners.

While the capacity to conduct the educational research called for by both Canady and Rettig and Robinson and Cawalti exists, there is little evidence to indicate that schools and systems have conducted such research, or that there is sufficient momentum to conduct research as part of the exploratory, implementation and evaluation process of school reform efforts. In the literature review, it was clear that an interest in pursuing additional research about block scheduling emanates primarily from college and university staff and graduate students. Such an approach is contrary to the opinion of Robinson (p. 13) who advocates the position that research on educational initiatives must include classroom teachers and other practitioners.

The increasing number of unpublished doctoral theses on block scheduling indicates that this topic has received the attention of educational researchers and is likely to be the subject of further attention as block scheduling continues in the public spotlight. There is no indication, however, that classroom teachers are actively engaged in the process of scientifically based, systematic evaluation of block scheduling.

Block scheduling, as a recent school reform, is certainly not exempt from the requirement of sustained, responsible inquiry as proposed by Robinson and others and is one example of school reform that can be evaluated on several aspects simultaneously, both qualitatively and quantitatively. For whatever reasons, such has not been the case and consequently, schools considering block scheduling do not have access to sufficient empirical data upon which to base their decision to adopt, adapt, continue or discontinue block scheduling as a school reform initiative.

Multiple sources of data and the subsequent analysis of that data are essential elements in any effort to validate program effectiveness or ineffectiveness (Carroll 1994). Consequently, the need for comprehensive evaluation models is critical. While he does not directly attribute the failure to continue the Copernican Plan at Masconomet High

School directly to the lack of sufficient data to validate its success, Carroll alludes to the lack of such data as being a major contributor to the discontinuation of that initiative (p. 113).

Wyatt (September 1996) reported that teachers of block scheduled classes have found that they are forced to become better teachers. Where once they might make it through a 50-minute class period without significant planning, they know that they cannot continue to do that with a 90-minute period. Consequently, teachers must continuously examine and revise their instructional methodologies to accommodate the changing needs of their students (p. 18).

Block scheduling, without fundamental changes in instruction, is merely a continuation of the current high school program only in longer periods. If improving student learning and higher overall student achievement on a variety of assessments is the goal, then instructional practices, professional development and resource allocation must be adjusted to accommodate the changes.

## Course Gap as a Factor in Student Retention of Material

At the present time the most reported impact of block scheduling focuses on overall improvement on school climate, quality of the school day for both teachers and students, student attendance and discipline, increased graduation rates and student-teacher relationships (Adams & Salveterra, 1997; Canady & Rettig, 1991, 1993, 1995, 1996,1999; Edwards, 1993; Einder & Bishop, 1997; Irshmer, 1996; Watts & Castle, 1993). Data that measure the impact of block scheduling on student achievement are extremely limited.

As part of a five-year study of five high schools using block scheduling (Salvaterra & Adams, 1997) found that two schools that conducted pre-post investigations of Scholastic Aptitude Test scores and American College Testing Scores in math and verbal areas yielded no differences in reported scores during the two years of block scheduling as compared to the control group whose results were recorded while they were in a traditional schedule. The results of the Salvaterra and Adams study are consistent with those presented by Wasson High School, Colorado Springs, Colorado in 1995, after four years of block scheduling (Wasson High School Block Scheduling Internet page, October 15, 1997, http://www.wentworth.com). The Wasson High School SAT scores in verbal (455-428) and mathematics (493-482) declined and the ACT scores in verbal increased slightly (19.8-20.2) while the ACT mathematics scores declined slightly (20.1-20.0). None of these findings was considered significant and could not be directly attributed to block scheduling.

A study of the effects of block scheduling on a state mandated test of basic skills conducted by Veal and Schreiber[8] (September 1999) found that traditionally scheduled students scored significantly higher on the mathematics-computation skills section of Indiana Statewide Testing for Educational Progress than block and hybrid scheduled students (p. 5).[9] The analysis of data from the Veal and Schreiber study noted no effect in reading and language due to schedule type. However, the data did indicate that the traditionally scheduled students scored significantly higher on the mathematics-computations skills section of the (ISTEP+) than the block-scheduled students.

Based on their analysis of the data, Veal and Schreiber concluded that the traditional schedule seems better for the understanding and retention of mathematical-computational skills. While the findings were inconclusive in determining the actual impact of block scheduling on student mathematics achievement, they did provide some data that are instructive in the development of key questions about school structure and mathematics instruction and achievement in alternative scheduling configurations.

Whether or not the traditional schedule, despite the small gains made over those students involved in block scheduling, can be attributed to increased gain or losses in the mathematics component of the ISTEP+ is an unanswered question. While no differences in reading and language test scores were noted in the study, the data pointed to a possible negative influence of block scheduling on student achievement in mathematics.

A study by Cobb, Abate and Baker (1999) using junior high school students involved in block scheduling and traditional scheduling yielded similar results in mathematics. In this study eighth and ninth grade students using block scheduling were compared with a control group in a traditional setting. The block scheduling students were involved in that configuration for at least three semesters prior to their high school experience. The purpose of the study was to determine if block scheduling would increase student Grade Point Averages, result in higher scores on a standardized mathematics assessment, and increase student participation in higher level math courses at the high school level (p. 6).[10]

The findings of the Cobb et al study concluded, among other things, that the block-scheduled students performed significantly less well than their peers on the standardized mathematics test than students in the traditional schedule. The same students, however, had consistently higher grade point averages than students in the traditional schedule (p. 14). As with the Veal and Schrieber study, the need for further study and clarification is evident. The extent to which any gains in overall grade point averages or losses on the mathematics assessment can be attributed to schedule type is unclear.

Both the Veal and Schreiber and Cobb, Abate and Baker studies concluded that there is insufficient information to make substantive or conclusive inferences from their respective studies. In each case, the researchers call for more substantive investigation of the impact of block scheduling on student achievement. In addition, Cobb et al, call for a more intensive focus on comparing and analyzing the "block versus traditional" schedule as a means to determine the effectiveness of block scheduling as well as ways to modify block scheduling in ways that will best result in documenting the desired increase in student achievement (p. 14).

Using a methodology that compares block scheduling with a traditional scheduling model presents unique and interesting challenges for researchers, not the least of which is maintenance and retrieval of appropriate data that would allow for such comparisons. The lack of systematic organization of student data makes comparison with, and accounting for, the impact of other school reforms a difficult and daunting task.

There is minimal evidence upon which schools can document the direct impact of block scheduling on student achievement. However, there is an abundance of reports and studies that document its impact on school climate, student behavior, teacher behavior, discipline and other factors. Canady and Rettig, two well known experts in block scheduling, as evidenced by their numerous citations in the work of others writing and researching block scheduling, conducted a review of the current status of block scheduling in United States high schools (Canady & Rettig, AASA Online, pp. 1-2). Based on their review of available research of block scheduling, Canady and Retting made the following twelve findings:

- The two major types of block scheduling that have developed in high schools throughout the United States are the alternate-day schedule (A/B schedule) and the 4/4 semester schedule. A few schools have developed modifications of a trimester block, but that format is not common.
- Ample data support the fact that schools experiencing the most success with block scheduling involved teachers, students and parents in the decision to change the schedule.
- The majority of administrators, teachers, parents and students support block scheduling after at least two years of implementation.
- A block schedule changes the school environment positively, especially in the form of fewer disciplinary referrals to the office and less tardiness. In general, the school day becomes less stressful for both teachers and students.
- The A/B schedule is much easier to implement than a 4/4 schedule because the A/B schedule has fewer political and administrative problems.
- Few schools have successfully implemented a pure 4/4 block schedule in which students take four classes per semester, each running for about 1 1/2

hours. In most cases, schools using a 4/4 schedule have made modifications to accommodate year-long classes in band and Advanced Placement courses. The most practical adaptation involves using an A/B format embedded in the 4/4 schedule for such courses.

- For maximum student success, 4/4 schools should provide students with a balanced load of classes each semester.
- The 4/4 schedule provides greater instructional flexibility than the A/B format. In the 4/4 format students may repeat failed classes and still graduate with their class, and high achievers may complete eight sequential courses in mathematics or foreign language during four years of high school.
- Staff development is critical for successful implementation of any block scheduling model. Teachers must have multiple opportunities to develop active teaching strategies in their various disciplines. Lecturing for large amounts of time becomes a major problem with any block schedule.
- Whether block scheduling helps or hinders student achievement on standardized tests remains an open question. Many individual schools have reported gains. Larger studies in both Canada and the United States have reported conflicting results.
- Few schools to date have returned to the single-period schedule after adopting the A/B or 4/4 block. Only one of the 201 schools that implemented a block schedule in Virginia during the last nine years has returned to the traditional schedule.

- Evidence suggests that schools are most likely to move from an A/B schedule to the 4/4 model than they are from the 4/4 model to the A/B schedule.

Rettig and Canady's findings reinforce the fact that the answer to the question of whether or not block scheduling has a positive or negative effect on student achievement on standardized tests is largely an unanswered one. Consequently, the need for further research documenting the impact of block scheduling on student achievement remains an important task for educators and researchers.

Documenting the impact of course gap on student achievement, particularly in mathematics and foreign language courses, has not been widely researched. While teachers have frequently raised questions about this aspect of teaching, learning and student achievement, little empirical evidence has been provided to help clarify those issues and concerns.

Shockey (1998) examined the performance of students in two high schools who had been engaged in block scheduling for at least four years prior to the study. The study used both qualitative (teaching methodology) and quantitative (student mean scale scores on multiple assessments) to determine the effects of varying retention intervals on knowledge retention of Algebra II skills and concepts.

Shockey's findings indicate that students with a retention interval of zero months achieved significantly better on pre-post tests than students with retention intervals of eight or twelve months, "...all students, regardless of retention interval scored similarly on the end-of-course test in precalculus, with no significant differences among the three groups by retention interval' (p. 14). These initial findings indicate that course gap may influence pre-post test results, but not end-of-course examinations. The relationship between the pre-post tests and end-of-course examinations is important, particularly if pre-post tests are designed by teachers and measure the effectiveness of classroom instruction and end-of-course examinations are constructed outside of the jurisdiction and influence of teachers at the local level.

Shockey's study also focused on teacher methodology as a factor in ameliorating the impact of retention interval on student performance. The results of that component of the research study indicate that, "When teachers spend time reviewing the skills/concepts of the previous mathematics class, the effects of a lengthened retention (eight or twelve months) on knowledge retention are eliminated" (p. 14). Shockey found that teaching methodology, particularly in schools using the 4X4 block scheduling model, plays a significant role in how well students retain skills and concepts in mathematics.

While Shockey's research included a study of the impact of teacher methodology on student achievement in a block scheduled high school, it is important to note that the study investigated multiple factors contributing to student achievement under the block, including non-instructional factors, most notably assessment results. Consequently, the study is inconclusive with regard to the impact of teacher methodology on subsequent student achievement on an assessment conducted independent of the classroom, i.e., end-of-course examinations, which are fairly standardized and administered in all classrooms presenting a specific course of study.

Shockey's findings with regard to the impact of teacher methodology on student achievement is not surprising. Canady and Retting have repeatedly made this point in their numerous books and articles about block scheduling. It is very difficult to measure the impact of teacher efficacy on student learning. However, proponents of block scheduling believe strongly that changes in traditional teaching methods are an important aspect on adopting block scheduling (Adams & Salvaterra 1997; Canady & Rettig 1993, 1994, 1995, 1997, 1999; Gainey & Brucato, 1999; Queen, 2000). The Shockey, Veal and Schrieber and Cobb, Abate et al studies of the impact of block scheduling on student achievement indicate that student achievement is relatively unaffected by block scheduling, but that additional research is needed to validate, confirm or refute the original studies.

In a more recent study of block scheduling (Queen, 2000) the author points out the critical nature of teacher skill in adapting new instructional strategies to accommodate block scheduling. Queen and two of his colleagues provided a list of what they consider to be the most important skills for success in block scheduling (p. 219). Queen proposes, not unlike the findings of Shockey, Canady and Rettig, and Cawelti, that teachers must be able to be effective classroom managers, be adept at using a several instructional strategies within a block, and possess the skill to design and maintain an environment that allows for greater flexibility and creativity. Queen reported, among other things, that principals and professional developers have a significant role in ensuring that the desired change in teaching take place, through offering ongoing and appropriate training and monitoring of teaching and learning in their school.

Queen points out that more recent studies of block scheduling have had similar results with regard to the impact of block scheduling on student achievement; no evidence has been made available that conclusively links block scheduling to increases in student achievement. It was noted, however, that the ability of students to take more classes, make-up failed classes and a resultant increase in graduation and attendance rates is a form of increase in student achievement. Whether or not increases in any of these areas can be directly attributed to block scheduling is open to debate.

While there is general agreement about the potential of block scheduling as an educational reform initiative, supporting the contention that it is a valid intervention that results in improved student achievement is difficult because of the insufficiency of current studies of block scheduling. There is, however, a significant body of evidence from self-reporting high schools using block scheduling,[11] that decreases in student discipline and improved school climate appear to be immediate results of block scheduling. Whether or not these results are sustainable over the long run has yet to be determined through comprehensive research studies.

In the Hottenstein study (1998) of 24 high schools in several states, the author found that there was an increase in both teacher and student attitude about block scheduling and that it had had a positive influence on school climate. In a subsequent article on block scheduling, Hottenstein (1998) presented a "six-step recipe" for successfully modifying time in school. The sixth step speaks to the necessity to maintain fair and constructive accountability for improved instruction and results. In this step, Hottenstein addresses the implications of research on block scheduling.

> Researchers are beginning to agree on several consistent positive trends connected to different types of block scheduling. If implemented properly, block scheduling can improve discipline, reduce stress, increase the

> capacity for academics, make the classroom experience more flexible and interactive, meet the educational needs of all students, provide more time for engaging the learner, create more opportunities for using technology and yield better quantitative results at the bottom line.

Hottenstein argued that if the non-academic components of block scheduling are properly designed and implemented, the academic components will improve as a result.

A study by Jenkins (2000), cited by Queen, found that there were "no significant differences in most subject areas among the types of instructional strategies used." According to Queen (p. 19), the Jenkins study is the largest study ever conducted on instructional strategies used in block scheduled and traditionally scheduled classrooms. Thus, importance of this findings of the study cannot be understated. Jenkins' findings point out that teacher instructional strategies had no impact in block scheduling and that those participating in the study report that they had insufficient or no training in adapting their instructional methods to accommodate the needs of block scheduling.

The results reported by Jenkins underscore the feelings of other researchers in block scheduling that, if block scheduling is to be successful, teachers must be provided staff development that will equip them with skills that will better meet the needs of their students under the new scheduling model (Canady & Rettig, 1993, 1995, 1996, 1997, 1999; Gainey & Brucato, 1999; Hottenstein, 1999; Irshmer, 1996; Kruse & Kruse 1995; Lybbert, 1998; Mistretta & Polansky, 1997; Wyatt 1996).

Queen's reflection on the success of block scheduling addresses the issue of retention of material from one level of a subject to the next as well as the impact of the need for extensive time required for independent study outside of school. While there are no studies that answer the question about the impact of retention of content under block schedule, Queen asserts that if the time available for instruction under block scheduling were used wisely, the question of retention would be moot. As evidence in support of this position, Queen cites the work of Skrobaracek and her colleagues that concludes that "...much instructional time is wasted in block scheduling if teachers fail to vary the learning activities and teaching strategies."

Canady and Rettig (1999) cite the work of Steven Kramer who, as a result of his extensive work with high schools using block scheduling, concluded that, "It seems safest to conclude that a gap in instruction may reduce recall of recently learned material, but it will probably have no long-term negative effects on student learning (p. 5). While Kramer's optimistic view of the potential impact of retention intervals or gaps in course sequence has not been widely tested, Canady and Rettig admonish schools considering block scheduling to be mindful of their opinion that, "If teachers do not change their traditional teaching strategies block scheduling will die, as did as similar instructional models of the 60's and 70's" (p. 205).

Lybbert (1998) recommends that schools have a maximum gap of one semester between courses in which it is believed that retention will become a barrier to successful learning (p. 33). On the other hand, Lybbert also believes that there is an inordinate amount of concern being directed as the issue of retention of material as a result of course sequence or retention interval. Lybbert contends that students under traditional schedules may experience similar learning gaps and that the concerns about retention of material in block scheduled schools is not justified (p. 34).

The issue of retention of learning has more to do with what is taught and how it is taught than the sequence or gap that may be experienced by students in block scheduled schools (Gainey & Brucato, 1999). The authors report that schools employing the 4X4 block scheduling model indicate that long-term retention of material is not a real problem, reinforcing the opinion espoused by Lybbert that too much attention is being paid to this aspect of block scheduling (p. 92).

Gainey and Brucato (1999) cite studies by Harvard University, National Training Labs, the U. S. Department of the Navy, the U.S. Department of Education and schools nationwide, that indicate that students do retain what they learn (p. 91). Their conclusions are based on several cognitive studies that concluded in part that "...the most significant loss of retention of learning occurs within the first few weeks after the end of a course. This occurs primarily in the loss of factual knowledge. After this initial period there is a leveling off in terms of retention" (p. 93).

Another study, referred to by Gainey and Brucato, found that even after a one-year gap in sequential courses, students still retained a little less than eighty percent of the material taught" (p. 92). Based on the evidence reviewed, Gainey and Brucato concluded that, "The empirical research and practictioner evaluation results support student learning and retention in the 4X4 ELT [extended learning time] scheduling. While the ability of students to retain information may decrease because of a gap in course sequence, retention of concepts and skills only decreases slightly" (p. 93).

Semb, Ellis and Aruajo (1993) conducted three experiments that measured student knowledge retention in college courses. The experiments tested the effects of several variables on long-term memory for knowledge learned in college classrooms including the degree of original learning, the tasks to be learned, characteristics of the retention interval, the manner in which the memory was tested, and individual differences of the learners (p. 305). The researchers concluded, based on the results of their experiments, that although the conditions for each experiment differed, the degree to which students originally learned material is an important determinant of how much they remember. Obviously, the author is connecting the relationship between teacher efficacy and instructional methodology and retention of student learning, a point which was also made by Shockey in her study of student achievement (p. 14).

In two of the Semb and Ellis experiments, which involved only college students, the retention rate for four months ranged from 75%-85% after four months and about 80% after eleven months (p. 309). The experiment results indicate that students remembered a great deal of what they learned in college courses (p. 314). These findings are important to the discussion of student retention of knowledge under the 4X4 block scheduling model, considering that the block scheduling model and the traditional college scheduling model are similar in design.

In a subsequent article by Semb and Ellis (1994) the authors report that evidence from numerous studies indicate that long-term retention of knowledge taught in schools is substantial (p. 253). Among the findings reported by Semb and Ellis were:

> (a) students retain much of the knowledge taught in the classrooms; (b) retention decreases over time as a function of the length of the retention interval but the forgetting curves for knowledge taught in school do not decline as rapidly as asympote[12] as low as the curves observed in traditional laboratory studies; (c) increasing the level of original learning

> differentially affects retention performance; (d) both instructional content and assessment tasks affect learning and retention, with one of the most consistent effects being that recognition tasks are retained at higher levels than recall tasks; (e) most instructional strategies that promote higher levels of original learning do not result in differentially better retention.

Semb and Ellis' studies conclude that students retain as much as 85% of what they have learned with the passage of as much as eleven months after the original learning. These initial findings may be indicative of the results of future research; however, each of the studies reviewed called for additional studies. Consequently, educators involved in refining or introducing block scheduling need to consider all of the available data on the impact of that educational reform initiative on student achievement.

This concept was reinforced by Irshmer (1996), in an article about block scheduled high schools in Oregon. Irshmer speaks to the need for ongoing evaluations and adjustments to block scheduling to ensure that schedules are serving, not impeding the learning process. Conducting such evaluation and adjustments based on appropriate research documenting the success of block scheduling, as recommended by Irshmer is at the core of any fair assessment of block scheduling as a means to improve student achievement.

## Block Scheduling Critics

Block scheduling, despite its recent popularity as a school reform, is not without its critics. Jeffrey Lindsay[13], a parent of children in a Wisconsin school district is a well-known critic of block scheduling. His prominence on the internet, along with his own discussion of the negative impact of block scheduling, is often accompanied by articles and citations of research bolstering his position. The site has provided much discussion and dialogue among proponents and opponents of block scheduling. Lindsay frequently provides provocative and challenging discussion about the impact of block scheduling on student learning and achievement and urges schools considering block scheduling to consider the negative impact of that effort on student learning and achievement.

Lindsay's criticism of block scheduling, as noted on The Case Against Block Scheduling web page dated July 7, 1997, focuses on the academic harm caused when students are expected to maintain their attention span for ninety-minute classes, retention of learned material when a gap in instruction is realized, and the perception that less time is spent on content in block scheduling schools. In addition, opponents of block scheduling, cited on Lindsay's block scheduling web page, refer to "scientific studies" that show academic harm directly related to block scheduling.

The studies cited by Lindsay, based primarily on Canadian studies conducted in British Columbia, allege academic harm due to block scheduling. The studies show either minor negative differences in performance on Provincial Examinations as a result of block scheduling or no improvement in academic performance that can be attributed to block scheduling. As is the case with other studies of block scheduling, the studies are inconclusive with regard to the impact block scheduling has on student achievement. Lindsay's criticisms of block scheduling, as well as the criticisms of others, should be considered by schools discussing block scheduling models. Such criticism often serves as a catalyst for the development of appropriate evaluation models that measure the desired outcomes of block scheduling.

## Summary

The literature review produced much thought-provoking, and often conflicting, data about the impact of block scheduling on student achievement. While schools currently employing block scheduling report varying degrees of success, specifically in non-academic aspects of block scheduling, there are very few empirical studies available to document any increase in student achievement, that can be attributed to block scheduling. This may be due to the fact that block scheduling is a relatively new educational reform and any long-term impact has yet to be documented.

While there are some schools that have used block scheduling for several years, many schools are just completing their initial experience with that non-traditional approach to scheduling. The reluctance to adopt or adapt block scheduling as an educational innovation may rest on the assumption that school leaders are unwilling to take the risks of such a dramatic change in the instructional delivery design without having an appropriate evaluation model available to validate the initiative. This assumption is not without merit and is illustrated by a lack of substantive research about the impact of block scheduling on student achievement.

As block scheduling continues to gain acceptance, new questions will arise about how teachers teach, and how students learn under the "new" conditions for teaching and learning. Educators will continue to struggle to answer the question about block scheduling and its impact on student achievement. Answers about the impact of block scheduling on student achievement will require strict research methodologies to document results and to maintain objectivity. This study is one step in that direction.

# CHAPTER III

# RESEARCH METHODOLOGY

## Purpose of the Study

The purpose of this research was to determine the impact of mathematics course sequencing (including course gaps) on student achievement in a block-scheduled high school.

## Research Questions

To determine the relationship between course sequence on student performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment, data will be gathered and analyzed to elicit answers to the following questions:

1. Does the sequence in which students participate in mathematics courses (regardless of course gap) result in disparate performance on the statewide mathematics assessment for students with similar characteristics?

    a. Does the amount of time (gap) between mathematics courses affect individual student performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment?

b. Do students who take Algebra and Geometry closer to the administration date of the statewide mathematics assessment outperform those who do not?

c. Do students who participate in Algebra I in grade eight outperform those who do not take Algebra I on the end-of-grade ten statewide mathematics assessment regardless of the sequence of mathematics course that they take?

## Hypotheses

The research questions were constructed to test the following hypotheses:

1. The sequence in which students enroll in courses in a block-scheduled high school will affect their Mean Scaled Score performance on the mathematics component of the New Hampshire Educational Improvement and Assessment Program.
2. Students who take Algebra I in grade eight will outperform tenth grade students who did not take Algebra I on the NHEIAP mathematics assessment, regardless of their course sequence in mathematics.
3. Large gaps (long periods of time between courses) in mathematics instruction will result in lower Mean Scale Score performance on the mathematics component of the New Hampshire Educational Improvement and Assessment Program (NHEIAP) when holding initial achievement, and grade level variables constant.
4. Students who participate in mathematics courses closer to the examination date of the NHEIAP will perform significantly better than those students who do not.

## Sample

This study includes data collected from the academic records of students at Salem High School, Salem, New Hampshire. Approximately half of the students selected for the study were enrolled in grade eight Algebra I, participated in the administration of the Orleans-Hanna Mathematics Test and subsequently enrolled at Salem High School. Subjects, because of the nature of the research, were not identified as individuals; consequently, no harm resulted to any subject involved in the study because of the research.

Students included in this study were identified as either having participated in Algebra I in grade eight or having participated in the general mathematics course in grade eight. Students were selected for participation in Algebra I based on several criteria:

(1) stanine score achieved on the Orleans-Hanna Algebra Prognosis Test;

(2) stanine score achieved on the Total Mathematics section of the California Achievement Test;

(3) teacher recommendation for participation in algebra in grade eight; and

(4) not having received a grade less than B in their grade seven mathematics course.

Once all students were identified as having met the minimum grade seven-mathematics course grade, they were allowed to take the Orleans-Hanna. All students take the California Achievement Test in grade seven. Additionally, mathematics teachers provided each student with a single number recommendation that was a three (low), six (middle) or nine (high). The teacher score, the Orleans-Hanna stanine score, and the

California Achievement Test stanine score in mathematics scores were summed to develop an Algebra I eligibility list.

Once students were sorted by their eligibility for algebra or mathematics, the number of open slots for algebra was determined. Because of staffing and course scheduling issues, the number of students wishing to participate in algebra generally exceeds the number of seats available; consequently, the number of seats available determines the actual number of participants. A cut-off point, at the level as close to the number of seats available, was established. Whether or not those students not selected for algebra, based on this selection criteria, would have been successful or not is the subject for further study.

Inspection of academic records and assessment results was conducted anonymously. For purposes of this research, student identification numbers were the only mechanism by which students were identified. No personal identification data is part of any report, chart, graph or narrative included in the study.

Only those students who were successively enrolled in grades eight through ten in Salem schools and who participated in the New Hampshire Educational Improvement and Assessment Program were included in this study. Consequently, while a large number of records were initially included in the research, only those students meeting the above criteria were reported. All others were excluded from the study.

## Sources of Data

The data used in this study included data collected from a review of the academic records of 639 students enrolled in grades nine and ten at Salem High School during the 1997-98 and 1998-99 school years.

In addition to data collected from individual student transcripts (student ID#, mathematics courses taken and Cumulative Grade Point Average), course enrollment rosters for grade eight students were reviewed to determine those students who participated in Algebra I at that grade and the score they attained on the Orleans-Hanna Mathematics Test. Individual Student Reports for the California Achievement Test were examined to determine the stanine score achieved in the Total Mathematics section of that assessment. Class Grouping Reports generated by the New Hampshire Educational Improvement and Assessment Program were reviewed to determine student mean scale score performance

## Measures

The measures used in this study included: (1) Individual student scale scores on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten assessment; (2) Stanine Scores on the Orleans-Hanna Mathematics Test; (3) Total Mathematics Stanine on the California Achievement Test; (4) the end of sophomore year individual student Cumulative Grade Point Average; and (5) student mathematics course history in grades nine and ten.

The *Orleans-Hanna Algebra Prognosis Test* (Orleans & Hanna, 1968) is designed to predict student achievement in first-year algebra. It is intended primarily for use during the term that precedes students' possible enrollment in algebra. The primary use of the Orleans-Hanna is to identify those students who may be expected to achieve success and those students who may be expected to encounter difficulties in an algebra course.

Stanine scores are normalized standard scores having a mean of five and a standard deviation of two and are expressed as a nine-point scale. The highest level of performance is expressed by stanine 9, and the lowest, by stanine 1. Stanine scores can be used to interpret student performance in terms of an appropriate reference group. For the purposes of this study, students Orleans-Hanna stanine score was useful in identifying potentially high achievers from potentially low achievers, i.e. grade eight algebra students from grade eight general mathematics students.

*The California Achievement Tests, CAT/5* (Macmillan/McGraw-Hill School Publishing Company) is a test series designed to measure achievement in the basic skills for kindergarten through grade 12. The subject areas measured are reading, language, spelling, mathematics, study skills, science, and social studies. Individual test records report performance on subsections as well as a total performance score for each subsection. Scores are reported as stanines, normal curve equivalents, and national percentiles. In order to maintain consistency between reporting student achievement, stanine scores on the Total Mathematics section of the CAT 5 were used in this study.

*The New Hampshire Educational Improvement and Assessment Program* is administered to all students at the end-of grades three, six and ten in New Hampshire schools. Students in grade three are assessed in English Language Arts and Mathematics. Students in grades six and ten are assessed in English Language Arts, Mathematics, Science and Social Studies. The assessments are based on challenging academic standards identified in the New Hampshire Curriculum Frameworks for English Language Arts, Mathematics, Science and Social Studies. Data about student performance are reported to schools, teachers and parents and include individual, school, district and statewide scale score performance in each assessed area. Scaled scores reported on the NHEIAP are an arithmetic average.

Reporting scale scores for individual students, schools and school districts began in 1998. The NHEIAP scaled scores range from 200-300, with spans of scores corresponding to the four proficiency levels: Novice – 200-239; Basic - 240-259; Proficient - 260-279; and Advanced - 289-300. The NHEIAP Proficiency Level Report for each tested class was used to ascertain the individual mean scale score for each student included in the study.

For purposes of the research, the individual student scale score in mathematics was used as an independent variable to determine the impact of mathematics course sequence on student performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten assessment.

The individual student Grade Point Average was determined from a review of individual student transcripts. Grade point averages are based on a 0.0 to 4.0 point scale and are assigned based on grade performance in each subject taken by students. Once all course grades have been determined, they are summed and divided by the total number of courses to determine an overall grade point average for each student.

In order to effectively track the sequence of mathematics courses taken by students, each mathematics course offered to grades nine and ten students was assigned a unique two-digit code. The course code was subsequently utilized to sort the number of courses taken by each student as well as the specific course of studies for each group of courses in identified sequences. Any student who did not take a mathematics course that semester was assigned his or her own unique code. As with the course codes, the course gap code was used to assist in answering the research questions about the impact of course gap on student performance. Once all student course sequences were entered into the database, they were concatenated to form a string variable that identified all possible mathematics course sequences.

Each course sequence reflected each student's participation in mathematics courses over the four semesters of grade nine and ten. Since only three mathematics courses are required as a condition of graduation, some students choose not to fulfill their mathematics requirements until their junior or senior year. Therefore, while it normally might be expected that the maximum gap in mathematics coursework is five months, it could be as much as eleven months if students chose to delay taking mathematics course until their junior or senior year.

## Data Analysis

The research consisted of the comparison of the following data.

For purposes of statistical analysis of course sequence, each mathematics course offered during the ninth and tenth grade was assigned a unique course number. Included in the coding mechanism was a course number that identified the specific semester(s) when a student did not participate in a mathematics course. This code was important in determining the specific sequence of mathematics courses taken by students, the gaps that may have occurred between courses, and the impact that such gaps may have had on overall mathematics achievement. After all sequences were identified, the individual scale scores on the NHEIAP mathematics section was linked and averaged to determine which mathematics course sequence resulted in the highest means scale score.

Because 23 individual student scores on the California Achievement Test were unavailable, the NHEIAP mean scale score and the Grade Point Average were used to derive a predicted score on that instrument. The predicted score was determined using a linear regression methodology. The researcher used the Statistical Package for the Social Sciences (SPSS 9.0 for Windows) and Microsoft Excel to record, organize and analyze the data.

A record of all data and subsequent analyses was recorded consistently, including grades, NHEIAP Mean Scaled Scores in mathematics, Orleans-Hanna score, course sequence and end-of-grade ten cumulative grade point average. A methodology for insuring the integrity of data and interpretation of that data was developed before beginning the research. Following the conclusion of this study, the results will be provided to the Salem School District for its own use and distribution.

The research consisted of the collection and analysis of the following data:

1. Grade eight stanine scores on the Orleans-Hanna Mathematics Prognosis Test administered to students meeting minimum eligibility requirements for enrollment in grade eight Algebra I;

2. Mathematics course sequence and grade achievement for students enrolled in grades nine and ten during the 1997-98 and 1998-99 school years;
3. Individual student cumulative grade point average at the end of grade ten;
4. Total Mathematics stanine score on the California Achievement Test administered to grade eight students; and
5. Mean scale score on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment.

Standard statistical procedures were used to collect, organize and analyze the data. Table 6 illustrates the data collection spreadsheet used to record the specific statistical data required of the study.

The records of 639 students were reviewed. Of the original 639 students, 118 were eliminated from the study because they did not meet the minimum criteria of having attended grades eight through ten in the Salem School District. In most instances, students eliminated from the study had either entered the school district after grade eight, had withdrawn from the district prior to the end of grade ten, did not participate in the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten assessment or were enrolled in non-traditional mathematics programs that were not block-scheduled.

In an effort to maximize the total number of students included in the study, a multiple regression analysis was used to predict the California Achievement Test stanine score in Total Mathematics. The mean scores on the NHEIAP and the Cumulative Grade

Table 6

Sample Data Collection Worksheet

| Student ID# | YOG | OH Score | Gr. 8 Math Algebra I | CAT Stanine Score | Gr. 9 Sem. 1 | Gr. 9 Sem. 2 | Gr. 10 Sem. 1 | Gr. 10 Sem. 2 | NHEIAP Scaled Score | GPA |
|---|---|---|---|---|---|---|---|---|---|---|
| 112357 | 2001 | 8 | Gr. 8 Math | 6 | Alg. 1 | Geom. | No Math | Calculus | 256 | 3.26 |

Point Average were used as dependent variables to predict the unavailable scores on the CAT for 23 students included in the final analysis of data. (See Table 7.)

A review of the mathematics curriculum indicated that there was a similar sequence of mathematics courses offered to students during both of the school years included in this study. The sequence of courses offered during the four semesters varied somewhat depending on the course selections made by students at the end of grade eight and at the end of grade nine. As can be seen from the course sequence table, the number of courses offered remained constant during the period of this study. No new course additions were made to the schedule. Although there was some discussion about adding an Algebra I course that would run on a yearlong basis, as opposed to the block schedule, this course was not scheduled during the period of this study.

The mathematics course sequence for the 521 students selected for further consideration were concatenated to form a string variable which identified the specific mathematics courses and sequence of courses taken by each student. Additionally, the string variable identified the course gap(s) experienced by each of the participants. This methodology resulted in identification of fifty-two (52) variations of mathematics course sequences. (See Table 7.)

In an effort to achieve a reasonable level of statistical validity, only those course sequences with a minimum of nine students were selected for further analysis. This methodology further refined the study group to a total of 358 students and eighteen mathematics course sequences. For purposes of analysis, students were disagregated into two groups: Students having participated in Algebra I in grade eight and students having

Table 7

Possible Course Sequences

| Possible Course Sequences Grade 9 | | Possible Course Sequences Grade 10 | |
|---|---|---|---|
| Semester One | Semester Two | Semester One | Semester Two |
| Pre-Calculus* | Calculus* | Pre-Calculus* | Calculus* |
| Honors Geometry | Honors Algebra 1 | Honors Algebra 2 | Honors Geometry |
| Geometry | Algebra 1 | Algebra 2 | Geometry |
| Honors Algebra 1 | Honors Geometry | Honors Geometry | Honors Algebra 2 |
| Algebra 1 | Geometry | Geometry | Algebra 1 |
| Algebra 2 | Algebra 2 | Math 1, 2, 3 | Math 1, 2, 3 |
| Math 1 | Math 2 | Algebra 2 | Statistics and Probability* |
| Honors Algebra 2 | Honors Algebra 2 | | |

*Available on a limited basis to selected students.

participated in grade eight mathematics. Unique identifiers for each mathematics discipline were developed and used to calculate the specific course of study for each student.

The varying levels of each discipline were eliminated. Example: All Algebra, Geometry, Calculus, and General Mathematics are identified by a single code. (A = all Algebra courses, G= all Geometry courses, all Calculus courses and M = all general mathematics courses.) This strategy was employed to significantly reduced the number of course sequences taken by students over the four semesters of block scheduling included in this study. Because students were also identified as to whether or not they had participated in Algebra I or not in grade eight, the ability constant for performance was maintained throughout the statistical analysis. For each of the course sequences identified, the unique code identified the mathematics courses taken and those semesters when no mathematics course was taken.

The Cumulative Grade Point Averages represents the CGPA of all students participating in a specific sequence of courses. The New Hampshire Educational Improvement and Assessment Program Mean Scale Score represents the average of all mean scale scores in mathematics achieved by all members represented in a course sequence. In addition, the number of mathematics courses taken by members of each sequence is identified by those who participated in grade eight Algebra I and those who participated in Grade Eight mathematics.

The data were further refined to identify each course sequence by the number of courses taken and the number of course gaps identified in each sequence. This calculation was important to identifying the impact of course sequence and course gap on student achievement. Each of the subgroups (Algebra I students/Grade eight mathematics students) was identified and their cumulative grade point average, scale score on the NHEIAP and the number of mathematics courses participated in during the four possible semesters was reported and subsequently analyzed to answer the research questions. These data were used to determine which mathematics course sequences were most effective within each sub-group as well as to determine the relationship between course gap and student achievement, as measured by the NHEIAP scale score in mathematics and cumulative grade point average.

For purposes of determining the relationship between course sequence on students' performance, the course sequences were sub-divided into two categories: (1) all mathematics courses grouped as any course (X) and (2) all semesters where students did not take a mathematics course (N). This extrapolation of data resulted in six possibilities describing the course participation sequences identified in the study. See Table 8.

Table 8

Performance Summary by Control Group and Course Sequence

| Sequence: | Descriptor: |
|---|---|
| XNXX | Course-No Course-Course-Course |
| XNXN | Course-No Course-Course-No Course |
| XNNX | Course-No Course -No Course-Course |
| NXXX | No Course-Course-Course-Course |
| NXXN | No Course-Course-Course-No Course |
| NXNX | No Course-Course-No Course-Course |

Each of the course sequences was analyzed to determine the impact of course gap on student achievement for each of the two subgroups. The integrity of the two subgroups was maintained by identifying those students involved in Algebra I and those taking grade eight mathematics in the final analysis of data about the relationship between course sequence and student performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade-Ten mathematics assessment.

Because the nature of the data used in this study and the unique analysis required, exploratory techniques were utilized to sort and analyze the information. Conversion of some alphabetical data to numeric data and some numeric data to alpha characters was accomplished using both hand manipulation of data as well as the use of SPSS and Microsoft Excel spreadsheets. Subsequent to the exploratory analysis, appropriate inferential statistics were applied to determine significant differences between groups.

An analysis of variance (ANOVA) was used to determine the relationship between performance on the NHEIAP and course sequence, course gap and cumulative grade point average in mathematics.

## Limitations

1. Although the findings of this study provide implications for further study, the use of only one block -scheduled high school prohibits generalizing the results on any large scale.
2. The study did not account for variables such as teacher efficacy, student attention to studies and other environmental and instructional factors that may influence student performance in mathematics.

3. The instrumentation required involved data about a large group of students and may be impacted by the accuracy of the data as maintained over the period being addressed by the study.

4. Since the study is not experimental, it therefore lacks controls inherent in more sophisticated designs.

## Summary

This chapter has sought to articulate and illustrate the methodology used in this study. The research questions and hypotheses were presented and used to explain the data-collection methodology and analysis. The design of each instrument used to collect and analyze data was presented and described. The study population was defined as were the reasons for selection of participants in the study. The treatment of the quantitative data was presented and examined. The next chapter will provide results of the analysis of the data.

# CHAPTER IV

## ANALYSIS OF DATA

This study sought to assess the relationship between mathematics course taking patterns (i.e., course sequencing) and student achievement in a block scheduled high school. In this chapter, an analysis of the data gathered from a review of the academic records of 639 students in a block scheduled high school is presented.

Of the original 639 student records reviewed, the number of students included in the analysis of data totaled 521 students. Students eliminated from further consideration were those who (1) had not attended the eighth-tenth grade in the Salem School District, (2) did not participate in the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment, (3) had incomplete academic records, or (4) were enrolled in non-block scheduled classes such as self-contained mathematics courses. The number of students included in the final analysis of data totaled 358, representing 56% of the original records screened for consideration.

Following the paring of students based on the above criteria, students were sorted by their mathematics course sequence in grades nine and ten, during the 1998-99 and 1999-2000 school years. This process resulted in the identification of 52 mathematics course sequence variations having enrollments as low as one and as high as 47. For purposes of statistical analysis, course sequences with fewer than nine students were eliminated from further inclusion in the study. Based on the minimum enrollment parameter of at least nine students per mathematics course sequence, the final number of sequences included in the study was eighteen, representing a total of 358 students.

Each mathematics course sequence was assigned a course code which identified each course as well as the sequence in which each course was taken. Each mathematics course sequence was assigned a four letter code that identified the specific course sequence in abbreviated form (e.g., Algebra, No Course, Geometry, Algebra II = ANGA). Table 9 displays the course sequence variations.

For purposes of analysis of the impact of course sequence on performance on the New Hampshire Educational Improvement and Assessment Program mathematics assesssment, courses were not leveled, i.e., Algebra = all Algebra courses, G = all Geometry courses, C = all Pre-Calculus courses, and M = all General Mathematics courses (generally referred to as Math 1, 2 and 3). Where N is indicated, no mathematics course was taken during the semester.

Each of the mathematics courses listed in Table 9 was available to students in grades nine and ten during the 1998-99 and 1999-2000 school years. Block scheduling had been in effect at Salem High School for two years during the 1998-99 school year and for three years during the 1999-2000 school year. As a consequence, all of the students represented in this study had participated in mathematics courses in a block scheduled format.

Table 9

Mathematics Course Sequence and Course Codes

| Mathematics Course Sequence | Sequence Code | No. Students Sequence |
|---|---|---|
| Algebra-No Math-Algebra-Geometry | ANAG | 12 |
| Algebra-No Math-Geometry-Algebra | ANGA | 21 |
| Algebra-No Math-Geometry-No Math | ANGN | 23 |
| Algebra-No Math-Gen. Math-No Math | ANMN | 10 |
| Algebra-Algebra-No Math-Geometry | AANG | 38 |
| Geometry-No Math-Algebra-Calculus | GNAC | 9 |
| Geometry-No Math-Algebra-No Math | GNAN | 14 |
| Geometry-No Math-No Math-Algebra | GNNA | 18 |
| Gen. Math-No Math-Gen. Math-Gen. Math | MNMM | 9 |
| Gen. Math-No Math-Gen. Math-No Math | MNMN | 19 |
| Gen. Math-No Math-No Math-Gen. Math | MNNM | 13 |
| No Math-Algebra-Geometry-Algebra | NAGA | 23 |
| No Math-Algebra-Geometry-No Math | NAGN | 41 |
| No Math-Algebra-No Math-Geometry | NANG | 47 |
| No Math-Geometry-Algebra-No Math | NGAN | 20 |
| No Math-Geometry-No Math-Algebra | NGNA | 20 |
| No Math-Gen. Math-Gen. Math-No Math | NMMN | 9 |
| No Math-Gen. Math-No Math-Gen. Math | NMNM | 11 |

Table 10

Mathematics Course Participation Rate by Number of Courses

| Grade 8 Math Course | # Students 2 Math Courses | % of Total | # Students 3 Math Courses | % of Total |
|---|---|---|---|---|
| Algebra 1 | 79 | 87% | 12 | 13% |
| Grade 8 Math | 226 | 85% | 41 | 15% |

The content of each mathematics course offered during the study remained constant and no additional mathematics course were offered. Although some discussion took place about the structure of Algebra I and Math 1,2, & 3 courses, no modifications were implemented. Minimum performance requirements in prior mathematics courses were articulated in the Salem High School Progam of Studies for entry level courses in Algebra I, Geometry and Pre-Calculus and Math 1.

Algebra I-Grade of C or better in 8th grade math; Grade of B+ or better in Math 1

Geometry–Grade of C- or better in Algebra I; Grade of B or better in Math 3.

Pre-Calculus–Grade of C- or better in Algebra 2 and Geometry.

Math 1–No prerequisites

Math 2–Passing grade in Math 1 or Algebra I

Math 3 – Passing grade in Math 2

Prerequisites, in the form of minimum performance expectations in other mathematics courses, made students either eligible or ineligible to participate in higher level courses only if they met or exceeded those prerequisites. One of the minimum graduation requirements at Salem High School is the successful completion of at least three math courses.

Block scheduling offered students an opportunity to take a maximum of four mathematics courses prior to participation in the New Hampshire Educational Improvement and Assessment Program mathematics assessment, which is conducted during the middle of May each school year in grades three, six and ten. See Table 10 for a breakdown of number of courses taken by grade eight math course group.

Course gap is defined as the length of time that elapsed between enrollment in one mathematics and enrollment in any subsequent mathematics course. For purposes of this study, gap was defined as whether or not a student participated in a mathematics course during the NHEIAP mathematics assessment administration semester.

Students who enrolled in a mathematics course during the semester that the NHEIAP is administered ($n = 337$) outperformed those students who did not enroll in a course during the examination period (no gap NHEIAP = 241.8, SD =19.07, $n = 84$; no gap mean NHEIAP = 247.6, SD = 19.03, $n = 153$), but this result was not significant. Among students who took Algebra I in grade 8, taking a course in the semester in which the NHEIAP is administered did not make a difference in mean scale scores on the NHEIAP. Finally, students who took general mathematics in grade 8 demonstrated a statistically significant difference in NHEIAP scale score performance (no gap NHEIAP 242.6, SD 17.06, $n = 255$; gap NHEIAP = 236.2, SD 16.4, $n = 145$; $t = 3.59$, df-398, $p = .000$).

# Results

## Mathematics Course and Mathematics Achievement

Table 11

NHEIAP Math Scores by Grade 8 Mathematics Course

| Grade 8 Math Course | n | NHEIAP Scale Score - Math | Standard Deviation |
|---|---|---|---|
| Algebra I | 121 | 263 | 15.13 |
| Grade 8 Math | 399 | 240 | 17.10 |

An independent samples t-test was conducted to test for significant differences between those who took math in grade eight and those who took general math (see Table 11 for descriptive statistics). The results indicate a statistically significant difference (t=13.19, df=519, p=.000). This difference of 23 points on the NHEIAP corresponds to an effect size of nearly one and one half, which is of substantial magnitude. This difference is consistent with the disparity in end of grade 10 cumulative grade point averages for both groups (3.39 for algebra group, 2.75 for general math group).

The significant difference on end of grade 10 NHEIAP (and to an extent, GPA) scores between those students who took algebra in grade eight and those who did not prompted course sequence analyses to be conducted separately for the two groups (i.e., grade eight algebra students and grade eight general math students).

## Course Sequence and Math Achievement: Grade Eight Algebra I Students

Course sequences were compared among the students in the sample who took Algebra I in grade eight. Course sequences that did not serve at least 6 students were dropped. Six distinct course sequences emerged, which accounted for nearly three-quarters (89/121) of all students taking algebra in the eighth grade.

Average math scores by course sequence yielded few differences among the "high ability" students (i.e., students who took grade eight Algebra I). Regardless of their mathematics course sequence, students who took Algebra I in grade eight scored similarly (well) on the NHEIAP end-of-grade ten mathematics asssessment (see Table 12). The range of scale scores on the NHEIAP for the Algebra I group was 251-268. A one-way analysis of variance (ANOVA) found no statistically significant differences among mean math scores.

Table 12

Grade Eight Algebra I Students' NHEIAP Scale Score by Course Sequence

| Course Sequence | n | NHEIAP Scale Score – Math | Standard Error | NHEIAP Scale Score Proficiency Level |
|---|---|---|---|---|
| ANNG | 6 | 251.67 | 6.6 | Basic |
| GNAC | 12 | 266.50 | 3.99 | Proficient |
| GNAN | 15 | 262.27 | 2.79 | Proficient |
| GNNA | 18 | 268.67 | 3.02 | Proficient |
| NGAN | 18 | 265.78 | 3.24 | Proficient |
| NGNA | 20 | 260.80 | 2.78 | Proficient |
| Total | 89 | 263.80 | 1.41 | Proficient |

Course Sequence and Math Achievement: Grade Eight General Math Students

A total of thirteen different course sequences emerged for students taking a general math course in eighth grade. These thirteen sequences accounted for two-thirds (267/399) of the grade eight general math students, similar to the analysis above. Only those course sequences which served at least nine students were included here.

A one-way ANOVA found statistically significant differences among these "lower ability" students (F = 10.28, df = 12,254, p = .000). See Table 13 for mean scores by course sequence. The range of scores for this group on the NHEIAP was 221-253, representing minor ovelap between the highest achieving students in the "lower ability" group and the lowest achieving students in the "higher" ability group.

Table 13

Grade Eight Mathematics I Students' NHEIAP Scale Score by Course Sequence

| Course Sequence | n | NHEIAP Scale Score – Math | Standard Error | NHEIAP Scale Score Proficiency Level |
|---|---|---|---|---|
| MNNM | 14 | 230.79 | 2.45 | Novice |
| ANGA | 22 | 252.55 | 3.68 | Basic |
| ANNG | 32 | 243.31 | 2.18 | Basic |
| NAGA | 23 | 253.04 | 4.20 | Basic |
| NAGN | 30 | 241.67 | 2.49 | Basic |
| NANG | 47 | 243.57 | 1.55 | Basic |
| AGNA | 6 | 249.33 | 8.01 | Basic |
| ANAG | 13 | 246.62 | 4.73 | Basic |
| ANGN | 28 | 242.47 | 1.96 | Basic |
| ANMN | 11 | 236.18 | 2.95 | Novice |
| MNMN | 20 | 223.30 | 2.72 | Novice |
| NMMN | 11 | 221.09 | 3.44 | Novice |
| NMNM | 10 | 226.00 | 3.01 | Novice |
| Total | 267 | 240.98 | .98 | Basic |

The results of the ANOVA indicate a greater degree of variability and overall lower mean scale scores among grade eight general mathematics students and their peers who took Algebra I in grade eight. These differences can readily be seen in Table 14.

Table 14

High School Algebra Sequence-General Mathematics Sequence NHEIAP MSS Comparison

| HS Algebra Course. Sequence | HS General Math Course Sequence | Mean Difference | Standard Error | Significance (exact *p* level) |
|---|---|---|---|---|
| ANAG | | | | |
| | NMMN | 23.32 | 4.78 | .026 |
| | NMMN | 25.52 | 5.50 | .049 |
| ANGN | | | | |
| | MNMN | 19.27 | 3.93 | .024 |
| ANGA | | | | |
| | MNNM | 21.76 | 4.59 | .038 |
| | MNMN | 29.25 | 4.15 | .000 |
| | NMMN | 31.45 | 4.96 | .000 |
| | NMNM | 26.55 | 5.12 | .011 |
| ANNG | | | | |
| | MNMN | 20.01 | 4.69 | .009 |
| | NMMN | 22.22 | 4.86 | .039 |
| NAGA | | | | |
| | MNNM | 22.26 | 4.55 | .000 |
| | MNMN | 29.74 | 4.11 | .000 |
| | NMMN | 31.95 | 4.92 | .000 |
| | NMNM | 27.04 | 5.09 | .007 |
| NAGN | | | | |
| | MNMN | 18.37 | 3.88 | .002 |
| NANG | | | | |
| | MNMN | 20.27 | 3.59 | .002 |
| | NMMN | 22.48 | 4.50 | .019 |

Sheffe post hoc tests indicated several significant differences among pairs of course sequences. Table 14 illustrates the pairs of course sequences yielding significant differences in performance between students having participated in grade eight mathematics, and subsequently taking the algebra or general mathematics course sequence in grades nine and ten. The comparison used the NHEIAP mean scale score for each course sequence as the dependent variable and grade eight mathematics course sequence and high school mathematics course sequence (algebra or general mathematics) as independent variables.

## Analysis of Data

Although this study was designed to address specific research questions, the nature of those questions necessitated exploratory techniques of analysis. For instance, early in the study, it was discovered that there were distinct differences in the performance between students who took Algebra I in grade 8 and students who took general math in grade eight. These differences prompted separate analyses for both groups. Separating these two groups made methodological sense, too, because these groups also differed in initial mathematical ability. Entrance into Algebra I in the eighth grade requires a certain (high) level of math aptitude not shared by all eighth graders.

One of the threats to the internal validity of causal-comparative studies is the "subject characteristics" or "non-comparability" threat, i.e. the extent to which subject characteristics not accounted for in the study may confound the outcome. Thus, separating the groups in these "high" and "low" initial ability groups was a first step toward controlling for this non-equivalence threat.

An analysis of covariance (ANCOVA) using the California Achievement Test Total Mathematics stanine score to control for eight grade math ability was conducted to test for differences among these course sequence groups. NHEIAP scale scores represented the dependent variable. Even after covarying on the CATMAT, the main effect of course sequence was statistically significant (F = 5.797, df = 12, p = .000). Table 15 presents the scale scores by course sequence, adjusted for scores on the CATMAT.

Table 15

NHEIAP Scale Scores When Covarying on Eighth Grade CATMAT Scores

| Course Sequence | n | NHEIAP Scale Score | Standard Deviation |
|---|---|---|---|
| MNNM | 15 | 231.27 | 9.03 |
| ANGA | 23 | 252.09 | 16.99 |
| ANNG | 38 | 244.63 | 13.14 |
| NAGA | 24 | 253.75 | 20.02 |
| NAGN | 33 | 242.30 | 14.27 |
| NANG | 50 | 245.36 | 13.31 |
| AGNA | 6 | 249.33 | 19.62 |
| ANAG | 13 | 246.62 | 17.04 |
| ANGN | 28 | 242.57 | 10.38 |
| ANMN | 11 | 236.18 | 9.78 |
| MNMN | 20 | 223.30 | 12.18 |
| NMMN | 11 | 221.09 | 11.40 |
| NMNM | 10 | 226.00 | 9.52 |

Post hoc comparisons were conducted to identify all significantly difference pairs of course sequences. The results of this comparison are reported in their entirety in Appendix F.

The pairwise comparisons reported in Appendix F suggested that there could actually be two course sequence "tracks" within the grade eight general math group. One track could be construed as a delayed algebra track (ANAG, AGNA,ANGA, NAGA); the other, a continued general math track (MNMN, NMMN).

One hundred and seven of the grade eight general math students were collapsed into these two "track" groups and mean NHEIAP scores were computed. The delayed algebra track group (251.4, SD = 18.2) outperformed the continued general math group

(223.4, SD = 11.25) by 28 NHEIAP points. An independent samples t-test indicated a statistically significant difference between the delayed algebra and continued general math tracks ($t = 8.863$, df 105, $p = .004$). The difference of 28 NHEIAP points corresponds to an effect size of well over one and one half.

The result above indicated that the delayed algebra group outperformed the continued general math group on the end of grade 10 assessment. However, prior to attributing these score differences to the course sequence, it would be important to control better for initial (or eighth grade) math ability and perhaps even overall academic ability. In other words, differences in end of grade 10 math scores are likely not entirely attributable to differences in course sequences—these differences could be confounded by varying levels of subject characteristics, such as initial math ability and cumulative GPA. In fact, significant differences exist between the two groups on the eighth grade California Achievement Test (6.26 vs. 3.85, $t = 7.25$, $df = 105$, $p=.000$) and on cumulative GPA (2.74 vs. 1.94, $t = 7.03$, $df = 105$, $p = .000$).

A multiple regression analysis was performed to determine the unique explanatory contribution of being in one or the other of those tracks. After partialing out the explained variance from the CATMAT ($R^2 = .279$), the tracking variable explained an additional 16% of the variance in NHEIAP scores. This is a modest contribution at best, but nonetheless is suggestive that one or another of these tracks influences scores on the NHEIAP.

# CHAPTER V

# SUMMARY, DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

## Introduction

This chapter begins with an overview of the study, including the research questions and methodology. A summary of the study's major findings is also presented. The chapter examines conclusions drawn from the analysis of data and focuses on the effect of course gap and mathematics achievement within a 4X4 block schedule, the impact of mathematics course sequence and achievement in mathematics between students who took Algebra I in grade eight and students who took general mathematics (grade eight math) in grade eight, and the differences in their performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment. Finally, recommendations arising from the findings of the study are presented.

## Overview of the Study

Salem High School adopted the 4X4 model of block scheduling beginning with the 1997-1998 academic year. The 4X4 block schedule replaced the traditional eight period day, which had been in place since 1967 and resulted in students taking four courses during each of the two semesters of the school year. This schedule allowed students to take eight Carnegie Units per year, as compared to the five to seven courses generally taken under the eight period day schedule. Under the 4X4 block scheduling model, students complete courses in eighteen weeks by taking four ninety-minute classes each day for a semester. In addition to the ninety-minute block scheduled classes, a limited number of non-block scheduled classes were available. Some of these courses were scheduled for one quarter and others were scheduled for a full year. None of the mathematics courses included in this study was quarter or full-year courses.

Before adopting block scheduling, Salem High School staff and administrators conducted research on block scheduling, visited block scheduled schools and provided numerous professional development opportunities for staff about how to teach in the block. Following approval by the Salem School Board, a comprehensive set of evaluative criteria was developed to measure the effects of block scheduling on a variety of factors, on of which was student achievement (Appendix A).

One of the continuing issues raised by mathematics teachers at Salem High School was that mathematics instruction in the 4X4 block scheduling format does not allow for depth of content coverage. While the actual amount of time available for instruction in block scheduled classes is equal to the time previously available in the yearlong eight-period day, teachers argued that attendance procedures, review of homework, announcements and other non-teaching tasks cut the time available down to a degree that it impacted their ability to cover all of the content necessary for students to achieve the course goals. Further, teachers argued, because of the increased length of classes, the actual time available to delve into complicated mathematical concepts, using teaching methodologies adapted for block scheduling, is hindered by block scheduling. This argument is consistent with those expressed by the staff of other block scheduled schools, not only in the area of mathematics, but in science and foreign language as well.

The debate over how block scheduling effects student achievement continues unabated. This study was conducted to provide additional data to document the impact of 4X4 block scheduling on student achievement in mathematics.

## Demographic Data Analysis

Student data included in the study were calculated and reported for the (a) California Achievement Test (CAT5) Total Mathematics stanine score; (b) the stanine score on the Orleans-Hanna Mathematics Achievement Test; (c) cumulative grade point average at the end of grade ten; (d) mathematics courses and course sequence in grades nine and ten; and (e) mean scale scores on the mathematics component of the New Hampshire Educational Improvement and Assessment Program (NHEIAP).

## Research Questions

The following research questions were addressed by this study:

1. Does the sequence in which students participate in mathematics courses (regardless of course gap) result in disparate performance on the statewide mathematics assessment for students with similar characteristics?
    a. Does the amount of time (gap) between mathematics courses affect individual student performance on the NHEIAP?
    b. Do students who take Algebra I and Geometry closer to the administration of the statewide assessment outperform those who do not?

c. Do students who take Algebra I in grade eight outperform those who do not take Algebra I on the end-of-grade ten mathematics assessment, regardless of the sequences of course they take?

<u>Discussion of the Research Questions</u>

Student data were collected, sorted and analyzed to determine the effect of course sequence on student performance on the New Hampshire Educational Improvement and Assessment Program End-of Grade Ten assessment in mathematics. Students selected for the study were identified as either high achieving, those who took Algebra I in grade eight, or low achieving, those who took grade eight mathematics. This distinction was necessary to maintain consistency in data analysis and reporting and because it was expected that high achieving students would outperform their counterparts in the low achieving group in ways that would skew the results. This expectation was proven correct as the data were analyzed. Consequently, the results more accurately reflect the performance of the two distinct groups of students involved in the study.

Some additional information emerged from the analysis of data that are important to student participation in mathematics courses in a block scheduled high school. Under the traditional eight-period day, students were required to take at least three mathematics courses over the course of four years. This meant that students would have had at least three full year courses in mathematics. Under the block schedule, it is possible, and perhaps likely, that they can complete the same requirements in as little as one and one-half school years. This may have implications for student performance on statewide assessments as well as the Scholastic Aptitude Mathematics Test. Among the findings of this study were:

- Regardless of grade eight mathematics course (Algebra I or Grade Eight Math), the majority of students (Algebra I 87%, Grade Eight Math 85%) took only two mathematics courses during the four semesters examined as part of this study.
- The percent of students not taking a mathematics course during the semester in which the NHEIAP is administered was only 35%.
- The percent of students not taking a mathematics course during the assessment period was lower than each of the other three semesters included in the study. Semester 1: 51%, semester 2: 48% and semester 3: 44%.

It is apparent that students entering grade nine, in a 4X4 block schedule, were less likely to participate in a mathematics course during their first semester, regardless of their grade eight mathematics course.

Students identified as low-achieving were less likely to take a mathematics course upon entering grade nine (56%) as compared to the high achieving students (46%). The mathematics course participation rate for the first semester of grade ten yielded the opposite result. Almost half of the high achieving students (49%) did not participate in a mathematics course in the first semester of their sophomore year as compared to 38% of the low achieving students. During the second semester of grade nine, low achieving students non-participation rate for mathematics courses was 48%, the rate for high achievers was 47%. Low achievers non-participation rate for the second semester of grade ten was 37% and the high achiever's non-participation rate was 33%. These findings are important to any discussion of scheduling of mathematics courses in a 4X4 block scheduled high school and will be further addressed in the recommendations section of this chapter.

Course Sequence Effect on Student Achievement

The analysis of the thirteen mathematics course sequences selected for more intensive study (Table 13) yielded significant differences in student performance on the NHEIAP. High achieving students outperformed low achieving students in the mathematics component of the NHEIAP in the significant pairwise comparison of each schedule sequence. Students who participated in Math 1, 2 and 3, or any combination of these courses, performed at the Novice level on the NHEIAP, with a range of mean scale scores on that assessment of 226-253. (NHEIAP scale scores range from 200-300). The range of performance for high achieving students was 251-268, placing them in the Basic (240-259) and Proficient (260-279) categories on the NHEIAP. Some low achieving students were able to exceed the minimal level of performance of the high achievers; however, the overall performance of high achievers significantly outdistanced that of low achievers (Tables 14 and 15).

The comparison of mathematics course sequence and scale scores on the NHEIAP mathematics assessment (Table 11) indicated a greater degree of variability and lower mean scale score for the course sequences of low achieving students when compared to those of high achieving students, as well as significant differences in scale score performance between students taking Algebra and Geometry and students taking only

Math 1, 2, and 3. Students who took Algebra (Including Algebra I and II) during the second semester of grade ten outperformed their high achieving peers on the NHEIAP. Students who took an Algebra-Geometry-Algebra course sequence (including all levels of Algebra and Geometry) outperformed other high achievers on the NHEIAP.

The results of the analysis of mathematics course sequence indicate that the sequence in which students participate in mathematics courses in the 4X4 block schedule impacts their scale score on the NHEIAP mathematics assessment. For high achieving students, the range of mean scale score performance for individual mathematics course sequences (243-268) places them in the Basic category of the assessment. For low achieving students, the range of mean scale scores for individual mathematics course sequence (221-253) places them in the Novice category of the mathematics assessment (Tables 13 and 14).

For high achieving students there was no significant difference in mathematics scale score on the NHEIAP because of their having taken a mathematics course during the semester when the assessment was administered. The mean scale score for high achieving students taking a mathematics course in the second semester of grade ten (262) was similar to that of students not taking a mathematics course during that semester (263). Overall, the high achieving students performed at the Proficient level of the NHEIAP, regardless of their mathematics course sequence and irrespective of any gap in their mathematics course sequence.

Data on low achieving students, however, indicated that participation in a mathematics course in the semester that the NHEIAP mathematics assessment is administered made a difference in scale score performance on that assessment. Students who took a mathematics course during the second semester of grade ten outperformed their peers who did not. The mean scale score for students taking a mathematics course in the second semester of grade ten was 243 (Basic) as compared to a mean scale score of 236 (Novice) for low achieving students who did not take a mathematics course in the second semester of grade ten, the semester during which the NHEIAP is administered to all grade ten students.

The relationship between cumulative grade point average (CGPA) for both the high and low achieving students indicates that students who participated in general mathematics in grade eight had a lower CGPA (2.75) than their peers who participated in Algebra I in grade eight (3.60).

## Results

### Research Question 1:

Does the sequence in which students participate in a mathematics course (regardless of course gap) result in disparate performance on the statewide mathematics assessment for students with similar characteristics?

The sequence in which students participate in mathematics courses in a block scheduled high school impacts their performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment if those students did not take Algebra I in grade eight or Algebra and Geometry in grades nine and ten. Students who took Algebra I in grade eight (high achievers) significantly outperformed students who did not take that course on the NHEIAP regardless of any course gap that existed. Students who did not take Algebra I in grade eight (low achievers) and did take Algebra I closest to the administration of the NHEIAP mathematics assessment outperformed those who did not take Algebra during the semester during which the assessment was administered.

Research Question 1a:

Does the amount of time (gap) between mathematics courses affect individual student performance on the New Hampshire Educational Improvement and Assessment Program End-of-Grade Ten mathematics assessment?

The analysis of data that examined course gap did not result in any significant difference in performance on the statewide mathematics assessment between high achieving and low achieving students that could be attributed directly to course gap. Consequently, there was no statistically significant relationship between course gap and performance on the NHEIAP mathematics assessment.

For high achieving students the data indicated that those students not taking a mathematics course in the semester that the NHEIAP was administered outperformed their other high achieving peers on that assessment. Low achieving students taking Mathematics 1, 2 and 3 in grades nine and ten performed slightly better than their low achieving peers taking other combinations of mathematics courses on the NHEIAP. This finding may be attributed to course gap, but was not sufficiently significant to generalize the results to other low achieving students who took any combination of Algebra and Geometry courses. Low achieving students taking any combination of Algebra and

Geometry, regardless of course gap, outperformed the Mathematics 1, 2 and 3 students on the NHEIAP.

Research Question 1b

Do students who take Algebra I and Geometry closer to the administration date of the statewide mathematics assessment outperform those who do not?

Analysis of the six mathematics course sequences of high achievers selected for further study, revealed a relationship between when students last took algebra and their subsequent performance on the NHEIAP. High achieving students who took algebra closer to the statewide mathematics assessment outperformed their high achieving peers who took Geometry during the second semester of grade ten. When accounting for course gap and course sequence, the Algebra-No Course-No Course- Geometry (ANNG) sequence students had a mean scale score of 269 (Proficient) on the NHEIAP. (Table 4.5)

The mean scale score for low achieving students taking Algebra and Geometry closest to the administration of the NHIEAP mathematics assessment was 253 (Basic) as compared to a mean scale score of 241 (Basic) or all other course sequences of low achieving students (Table 13). As was the case with high achieving students, the mean scale score for low achieving students taking Algebra during the second semester of grade ten, was higher, than students not taking algebra during the second semester of grade ten. For low achieving students taking algebra during the assessment period, the mean scale score was 253 (Basic) as compared to a mean scale score of 235 (Novice) for all other mathematics course sequences of low achieving students. For students taking only Mathematics 1, 2 and 3, the means scale score results were even more dramatic. Those students not taking either algebra or geometry in grades nine or ten had a mean scale score of 225 (Novice) on the NHEIAP mathematics assessment.

Research Question 1c:

Do students who participate in Algebra I in grade eight outperform those who do not take Algebra I on the end-of-grade ten statewide mathematics assessment, regardless of the sequence of mathematics courses that they take?

Students who took Algebra I in grade eight (high achievers) outperformed students who did not take Algebra I in grade eight (low achievers) in every area investigated by this study: cumulative grade point average, course sequence, course gap and NHEIAP scale score performance in mathematics. The mean cumulative grade point average for all students involved in the study was 3.39 for high achievers and 2.75 for low achievers. Mean scale scores on the NHEIAP mathematics assessment was 263 (Proficient) for high achievers and 240 (Basic) for low achievers.

The analysis of course sequences for both groups yielded similar results, Algebra I grade eight students outperformed non-Algebra I students with the exception of low achieving students who took the No Course-Algebra-Geometry-Algebra (NAGA) sequence. The mean scale score for this mathematics course sequence was 253 (Basic) as compared to the lowest scoring course sequence for high achievers, Algebra-No Course-No Course-Geometry (ANNG). This sequence yielded a mean scale score of 232 (Basic). Notably, the ANNG course sequence students took only two mathematics courses, compared to the three courses taken by the NAGA sequence of low achievers. The ANNG group had a one year gap between the first and last math course taken, while the

NAGA sequence students had no gap between courses and took Algebra during the assessment semester. This finding is consistent with previously reported data that pointed out the differences in mean scale performance by both high achieving and low achieving students who took algebra during the second semester of grade ten.

## Conclusions

### Course Sequence, Course Gap and NHEIAP Mean Scale Score Performance

The sequence in which students participate in mathematics courses, including course gap, in a 4X4 block scheduled high school, results in disparate performance on a statewide mathematics assessment for students with similar characteristics, is consistent with the predicted outcome (Hypothesis 1) to a limited degree. While it was anticipated that course sequence would affect both groups of identified students, high achievers and low achievers, the results were inconsistent between groups. The high achievers, regardless of course sequence and course gap, had no significant differences in performance on any of the characteristics included in the study, but most notably cumulative grade point average and mean scale score on the NHEIAP. The sequence in which high achieving students took mathematics courses did not affect their grades or their performance on the statewide mathematics assessment. For low achievers, the sequence in which they took mathematics courses, their cumulative grade point average and their mean scale score on the NHEIAP was dramatically affected by the genre of mathematics courses taken; i.e., Mathematics 1, 2, and 3 or Algebra and Geometry. Students taking Algebra and Geometry outperformed the general mathematics track students significantly, regardless of course sequence or gap.

This finding has major implications for mathematics course instruction in a block scheduled high school as well as for how well students are prepared as they enter high school. Clearly, students who entered Salem High School with no or limited background in algebra and who subsequently did not take algebra in grades nine and ten, performed at the lowest proficiency level on the NHEIAP (Novice). If the desired result is for all students to achieve at, at least, the Basic level of performance on the statewide assessment there is a need for action with regard to mathematics course structure, methodology, sequence and course gap for students considered "low achieving" as they enter high school. For students who took Algebra I in grade eight, there was no evidence that would validate a claim that the sequence in which they participated in mathematics courses in high school, or the gap between courses, negatively affected their performance on the statewide assessment.

Course Gap and NHEIAP Mathematics Assessment Mean Score

The prediction (Hypothesis 2) that students who take Algebra and Geometry closer to the administration of the statewide assessment in mathematics would outperform those who do not was disproved for high achieving students because no causal relationship could be found between course gap and performance on the NHEIAP. Low achieving students taking Mathematics 1, 2 and 3 performed lower on the NHEIAP than their low achieving peers taking other combinations of courses. Attributing the differences in performance among low achieving students on the statewide mathematics assessment based on course gap is not justified based on the data analyzed in this study.

Recency of Algebra I and Geometry Courses and NHEIAP Scale Score Performance

The prediction (hypothesis 3) that students who take Algebra and Geometry closer to the administration of the statewide mathematics assessment would outperform those who did not yielded an interesting result. For high achieving students, the sequence in which they took algebra or geometry courses resulted in a difference in performance on the NHEIAP. Students who took an algebra course closer to the examination date had higher scale scores on the NHEIAP than those students who took geometry closer to the examination date. Low achieving students who took an algebra course during the second semester of grade ten outperformed those students who did not.

This finding is important to the scheduling of mathematics courses in a block schedule, particularly since students who took algebra closer to the examination date outperformed students who did not. An additional consideration is the dramatically significant poorer performance of students who did not take algebra or geometry in any of the four semesters preceding the statewide mathematics assessment.

The Impact of Grade 8 Algebra I and NHEIAP Scale Score

The prediction (hypothesis 4) that students who participate in Algebra I in grade eight would outperform those who do not take Algebra I at that level on the statewide mathematics assessment, regardless of course sequence, was proven to be accurate. Regardless of course sequence, including course gap, the cumulative grade point average and NHEIAP scale score of grade eight Algebra I students were significantly higher than those of students who did not take Algebra I in grade eight.

This finding is significant in that it points to the importance of preparing students for the rigorous expectations of the statewide assessment in mathematics. Clearly, students who came to Salem High School with grounding in Algebra I outperformed students who did not have that course in grade eight. Additionally, many of the students entering grade nine did not subsequently enroll in either an algebra or a geometry course during the four semesters before the administration of the mathematics assessment. The low achieving students who did elect to take algebra and geometry in grades nine and ten, were not as competitive on the NHEIAP as those students who took algebra in grade eight. There is more than sufficient reason to examine scheduling practices, course content and student guidance procedures to address the issues raised by this study.

## Recommendations

This study added significantly to the growing body of research on the impact of 4X4 block scheduling on student achievement in mathematics. It is one of the few studies that identified mathematics course sequence and course gap as factors potentially affecting student achievement on a statewide mathematics assessment. This study therefore, has implications for 4X4 block scheduled high schools and future research.

Based on the findings of this study the following recommendations are made for further research and mathematics course scheduling and content in a 4X4 block scheduled high school.

1. Longitudinal studies of student achievement in mathematics in a 4X4 block scheduled school are needed. While there have been several studies that have addressed this important aspect of the impact of block scheduling on student achievement in

mathematics, the results have been inconclusive. While some studies (previously cited in this study) have shown gains in student achievement in mathematics in block scheduled schools, other have shown losses or no change due to block scheduling. The proposed studies should be comprehensive and conducted in schools employing block scheduling for at least four years, so that the data collected will be more broadly reflective of students' total high school experience with block scheduling.

2. Examination of student performance on the statewide assessment in mathematics should be expanded to include data about their performance in mathematics before high school, i.e., grades, course content, length of course, teaching methodology. The results of the study concluded that students who did not take Algebra prior to or in high school performed significantly lower than their counterparts who took Algebra one in grade eight or in grades nine or ten. This is an important issue for the administrator responsible for the scheduling of mathematics courses and the sequence in which those courses are scheduled.
3. Studies of the content of mathematics courses offered to grades nine and ten students should be conducted to determine if the content of those courses is consistent with the skills and competencies assessed by the statewide assessment. The study concluded that students who took general mathematics courses (Math 1, 2 and 3) in grades nine and ten performed significantly lower than their peers on the statewide mathematics assessment as well as in their cumulative grade point average. The implication that course content and expectations of the statewide assessment are dissonant needs clarification. If students are required to participate in a statewide

mathematics assessment, it is not unreasonable to expect some consistency with mathematics course offerings with the statewide curriculum frameworks for mathematics, specifically, those skills and proficiencies that all grade ten students are expected to know and be able to demonstrate on the assessment.

4. Studies of mathematics instruction and content of instructional materials in mathematics should be conducted at the middle level to determine alignment of that curriculum with the high school mathematics curriculum. Such a study should provide high school mathematics teachers with information about the preparedness of grade nine students for Algebra and Geometry and assist in the construction and scheduling of courses designed to meet more effectively the needs of the learners as they prepare for the statewide mathematics assessment.

5. Studies to determine the efficacy of teachers in delivering the skills and competencies required in the statewide mathematics curriculum frameworks should be conducted. Because there may be significant differences in the content of mathematics textbooks and other resources purchased and utilized prior the adoption of the state frameworks for mathematics, it would be prudent to determine the level of familiarity with and acceptance of these frameworks on the part of teachers of mathematics. Ensuring congruence between teaching methodology and mathematics frameworks is critical to student achievement on the statewide assessment; consequently, observations of teacher performance should include this aspect as part of the evaluation process.

6. Studies to examine alternatives to the 4X4 block model for some mathematics courses need to be conducted. As schools gain more experience with the 4X4 block scheduling

model, they come to understand that time is the most critical issue in student learning. With that understanding comes a responsibility to examine scheduling practices to meet more effectively the needs of students. Several alternative models, such as extended learning time (ELT) and varying learning time(VLT), have been proposed as accommodations that can be made within the 4X4 block schedule, while still maintaining the overriding objective to provide more intensive learning experiences and opportunities for students. Some of the proposed models address the needs of low achieving students and allow for full-year mathematics courses of increasing difficulty, while providing a more significant grounding in the basics of Algebra and Geometry.

7. Examination of the amount of time and resources allocated to teacher professional development in the area of block scheduling is recommended. Much of the research on block scheduling points to the need for initial and ongoing exposure to professional development designed to provide teachers with skill in providing the alternative instructional methodologies required under the 4X4 block schedule. Without frequent opportunities to increase professional competency the probability of the success of block scheduling diminishes.

8. Investigation of the various mechanisms used to collect, record, and analyze and report student achievement data is recommended. The collection of student data, both current and historic, about student achievement is important to any study of the success of block scheduling. Schools interested in documenting progress on educational initiatives should investigate effective, efficient, and user-friendly data management systems to record, sort and analyze data for use by teachers,

administrators, parents and school boards as they seek to validate the investment of time energy and resources. Without such resources, the ability to document change effectively is significantly hampered.

9. Extension of the study of student achievement to include all students and all subjects is recommended. Mathematics is only one of the academic areas cited as in need of research to document student achievement in the 4X4 block scheduling format. It would be prudent to conduct further studies to determine the achievement level of students in other subjects as well as mathematics.

10. Restricting the study of block scheduling and student achievement to block scheduled schools is recommended. Comparing the performance of block scheduled schools and non-block scheduled schools has proven to be a difficult and non-productive endeavor. Because the 4X4 block schedule and the traditional seven to eight-period day model are so diverse, it is very unlikely that any fair comparison of student performance can be made. It would be more productive to look at the long-term impact of block scheduling on student achievement and to base changes to schedules, teaching, and allocation of resources on the results of that analysis. Because there are many factors affecting student learning and achievement, it is unlikely that any comparison of block scheduling and the former traditional schedule would yield useful results. Comparing "apples to apples" seems to be a more effective way of assessing block scheduling.

11. Examination of the efficacy of continuing a general mathematics curriculum (Math 1, 2 & 3) in a 4X4 block scheduled high school is recommended. The data regarding the

performance of general mathematics track students in grades nine and ten indicate a significant disparity in performance when compared to students who took Algebra in grades nine and/or ten. Some of this disparity was explained by initial ability, but a good portion was explained by mathematics course sequence "track." Students in the general math track performed at the Novice level on the statewide math assessment regardless of course sequence or course gap. The extent to which this disparity in performance can be attributed to the 4X4 block schedule is subject to further research.

12. A review of the mathematics course content at middle level schools is recommended to ensure that each student entering high school is sufficiently prepared to demonstrate those skills and competencies required on the statewide mathematics assessment. It is clear, based on a review of the mathematics curriculum frameworks and the content of the statewide assessment, that Algebra and Geometry skills are required if students are to perform (as a minimum expectation) at the Basic level on the NHEIAP. Students who do not participate in either of these courses in grades nine and ten demonstrated that they were unable to successfully meet the minimum level of performance. Ensuring that all students enter grade nine with at least pre-algebra skills may be a positive step in improving the overall performance of students on the statewide assessment.

13. A study of performance by gender on the statewide assessment is recommended. Although an analysis of gender was not included as a part of this study, it would be helpful to schools in analyzing mathematics course content to have some data about

the differences in performance, between males and females in mathematics courses in a 4X4 block scheduled school.

## Summary

Block scheduling appears to be increasing in popularity across the United States. This major change, if it continues at the current rate, will mean that a majority of schools will be employing some form of block scheduling during the next five years. That possibility is reason for continued focus and research about the effectiveness of block scheduling on student achievement. While this study did yield some important information about student achievement in mathematics, more extensive research in this area as well as in other areas of the curriculum will be required if the model is to be deemed appropriate and effective for raising the academic achievement level of all students. Even though many studies point to the success of block scheduling on students behavior, attendance, and school climate, there is insufficient evidence to declare it a success as a model for all high schools.

END NOTES

[1]Three Annual Reports on Block Scheduling have been presented to the Salem School Board. In each of those reports staff continue to voice their concern about the impact of block scheduling on mathematics achievement under block scheduling as opposed to the traditional seven period day.

[2]The K-12 Mathematics Curriculum Framework is distributed to each school and school district in New Hampshire and is the basis from which the New Hampshire Educational Improvement and Assessment Program assessments in Language Arts Reading, Mathematics, Science and Social Studies are constructed.

[3]The Encyclopedia of Educational Research credits Robert Lynn Canady as the pioneer of parallel block scheduling as early as 1985. Canady's intention was to modify the schedule of mainstream teachers with the schedule of "specialists" in an effort to maximize learning time. These alternative scheduling practices, not unlike the flexible modular schedules of the 1960's and 1970', did not catch on a long-term solution to resolving problems associated with increasing student achievement.
5 The Masconomet Regional High School Renaissance Program: The First Implementation of the Copernican Plan, the Final Report of the Harvard Evaluation Team, 1992.

[4]The Masconomet Regional High School Renaissance Program: The First Implementation of the Copernican Plan, the Final Report of the Harvard Evaluation Team, 1992.

[5]Carnegie Unit(s) A measurement used in traditional high schools to determine how much coursework a student has completed. Students need roughly 20 Carnegie Units to graduate; one unit is equal to a traditional 50-minute class taken several times per week (usually five) throughout the school year. A one-semester course is usually worth one-half of a Carnegie unit.

[6]While the Veal and Schrieber study was conducted in a middle school, the scheduling practices used were similar in design to a block scheduled high school.

[7]The Indiana Statewide Testing for Educational Progress ( ISTEP+) is a statewide test of basic skills that all students in grades 3, 6, 8 and 10 have to take. All 10th graders are required to take all three sections of the ISTEP+ test in reading, language and mathematics.

[8]The Iowa Test of Basic Skills (TAP version) was used in the study. Scores in reading, mathematics and written expression sections were used as the dependent variable. Student cumulative grade point average and attendance rate were also used to construct the experimental and control groups.

[9]The Internet has become an electronic communications vehicle for schools using block scheduling to communicate with other schools either using block scheduling or contemplating moving to block scheduling. The block scheduling listserve has become a place to share information with anyone interested in this reform effort. A review of many block scheduling sites reveals that there is little empirical research available to document the impact of block scheduling on student achievement.

[10]Asympote, a straight line that continually approaches a curve, but does not meet it within a finite distance (Scott Foresman Advanced Dictionary).

[11]Jeff Lindsey's web site The Case Against Block Scheduling can be accessed at http://www.jefflindsay.com/Block.html.

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APPENDICES

# APPENDIX A

Plan for Evaluating

Block Scheduling

at

Salem High School

Developed by the
Salem High School Block Scheduling
Evaluation Planning Committee

and
Martha Williams, Consultant
Center for Resource Management, Inc.

March, 1997

# Plan for Evaluating Block Scheduling at Salem High School

## INTRODUCTION

On November 8, 1996, the Salem School Board unanimously approved the implementation of block scheduling at Salem High School for the 1997-98 school year. Their decision culminated several years of study and deliberation about how to restructure the high school to provide students with a richer and more intensive academic program aimed at ensuring that all students achieve high standards.

In October, 1996, Salem School District contracted with the Center for Resource Management, Inc. (CRM) to assist in the development of an evaluation model that could be used throughout the district to evaluate programs and organizational changes. Because of the impending implementation of block scheduling, the evaluation process was developed in collaboration with a committee of high school staff. This Block Scheduling Evaluation Committee met throughout the fall and winter to develop the evaluation model and plan for block scheduling, presented in this document. Upon approval, the model will be piloted with block scheduling, refined as needed, and then submitted as a generic evaluation process that can be used by other district and community groups to evaluate other programs and organizational changes.

The Committee identified several stakeholders@ for the evaluation process C individuals and groups who have an interest in the effectiveness and impact of block scheduling. These stakeholders include:

X The Salem High School faculty and staff;
X Salem High School students;
X Parents of current and future students;
X The Salem School Board;
X The SAU administrators (Superintendent and Assistant Superintendent);
X Members of the community;
X Employers of Salem High School students;
X Post-secondary institutions attended by Salem High School students; and
X The broader education community in New Hampshire and elsewhere.

The evaluation process is designed to assist these stakeholders as they seek information and evidence about this important change in the structure of the high school program. The Committee encourages all parties to maintain a posture of inquiry, objectivity, and continuous improvement so that the promise of block scheduling can be realized in Salem as it has in many other communities.

This proposed Evaluation Plan includes the following elements that were developed by the Block Scheduling Evaluation Committee working with Martha Williams of CRM:

Evaluative Criteria: These are the criteria that will be used to evaluate block scheduling. The criteria represent the anticipated benefits of block scheduling, or what it would look like and what would be happening if it worked well. The criteria also address the potential drawbacks of block scheduling that need to be identified and overcome if they occur. The Evaluative Criteria were drawn from several sources, including:

X The work of the Restructuring Committee, whose members studied block scheduling and recommended its implementation at Salem High School;
X The literature on block scheduling found in education publications and reports;
X The work of the Block Scheduling Evaluation Committee.

**Sources of Evidence:** For each evaluative criteria, the Committee identified sources of evidence, or data, that would indicate the extent to which each criterion is being met. While not all of these sources are readily available, or easily obtained, they are offered for consideration as the evaluation process unfolds.

**Evaluation Methods:** Methods for collecting data from the various sources are included to facilitate evaluation planning and implementation. Strong consideration was given to ensuring that these methods: 1) would produce meaningful and credible data; and 2) could be implemented within the resources (time, funds, access) available.

**Evaluation Activities:** Specific steps to be taken by various parties to implement the proposed Evaluation Plan. Where such activities can not be predicted, and where alternative approaches should be considered, questions are included.

As this important effort goes forward, there is a need for a specific group to be charged with the responsibility of overseeing implementation and evaluation. Several members of the Evaluation Planning Committee have agreed to participate in the next phase. Representatives of other stakeholder groups should also be invited to participate.

## OVERVIEW OF KEY EVALUATION CONCEPTS

Evaluation is a systematic process for asking and answering questions about activities that have been undertaken to achieve specific objectives. Evaluation is also a way of thinking -- of being clear about desired results and reflective about how various strategies, practices, and arrangements are leading toward those results.

Evaluation is often thought of as an end of the line activity; something that occurs separate from planning and implementation. However, evaluation should play an important role in designing, developing, planning, implementing, and refining programs and activities. Good evaluation helps articulate the values and assumptions on which the activity is based, and helps to anticipate issues and considerations related to implementation.

Evaluation can fulfill the following functions:

1) Help foster an inquiry process by engaging stakeholders in formulating and answering questions about the activity;

2) Help stakeholders focus on the values that are the reason for implementing the activity -- why the activity is worth doing;

3) Define the intended results in observable, measurable terms;

4) Guide day-to-day decisions and actions;

5) Enable progress toward results to be tracked;

6) Provide information for ongoing planning and improvement;

7) Document and verifies results.

8) Assist in communicating with stakeholders.

When we undertake a new activity, we do so to achieve a result that we and others value. We assume that if the activity (or program, approach, structural arrangement, etc.) is implemented, the result we value will be achieved. Those opposing the activity may not value the same result, or they may have different assumptions about how to achieve the valued results. Prior to implementing the activity or change, the evaluation process helps to clarify these values and assumptions.

In education, we operate from one central and universal value that is the foundation for all that we do: student learning and achievement. This result is the overriding mission of education. From this value, we then make numerous assumptions about what will lead to improved student learning and achievement. Our thinking goes something like, If we use a different text book, or reading program, or instructional strategy, student learning will improve. Sometimes our assumptions have several layers: If we improve the climate of the school, students will feel safer and more valued, which will increase their readiness to learn. Or, if we provide teachers with new skills and instructional strategies, they will be more effective, and students will develop higher level skills.

Some of the assumptions we make have been substantiated through research and evaluation activities, the results of which are reported in the professional educational literature. Our assumptions may have come from the experience of teachers who work with students every day, and who, over time, have determined what works. Other assumptions remain untested. They may have been true in another setting, but not true in the present setting.

The chain of assumptions related to an activity, such as block scheduling, are the basis for identifying evaluative criteria. In block scheduling, as with many other educational strategies, success depends on much more than changing the scheduling; e.g., doubling the length of periods from 45 to 90 minutes and having students take four courses. Success C the results we anticipate and value C depends on a wide range of factors, among which is the important factor of how teachers and students use the additional instructional time.

A central task of the evaluation design process is to define the criteria upon which the activity will be based. These are called evaluative criteria, or sometimes indicators of what the activity looks like, and what indicates progress, if it is being implemented as planned, making progress toward the desired results, and, ultimately, achieving those results. These are the three types of evaluative criteria: implementation, effectiveness, and impact, or outcome criteria. They are defined as follows:

X Implementation Criteria: The strategies, practices, materials, arrangements, roles and responsibilities, communication, etc. that are used in carrying out the activity.
X Effectiveness Criteria: The extent to which implementation is effectively leading toward the desired results.
X Impact Criteria: The extent to which the intended outcomes of the activity are being achieved by the intended beneficiaries. We refer to this set of criteria as the so what? criteria.

The Evaluative Criteria established for Salem High Schools Block Scheduling initiative were developed by the Evaluation Planning Committee through several rounds of identification and review. They are listed below. It is important to note that the first year of implementation, evidence of the impact criteria being met should not be expected. There could be positive evidence related to these criteria, or even negative evidence. In either case, caution should be exercised in attributing these results to block scheduling. A change as complex as block scheduling will take several years to produce solid results. In the meantime, evidence of the implementation and effectiveness criteria being met should be present.

## EVALUATIVE CRITERIA FOR BLOCK SCHEDULING

### Implementation Criteria

1. There is a clear plan for implementing block scheduling; the plan spells out what will be done, how it will be done, when, and by whom.
2. Policies related to block scheduling have been established and approved.
3. The roles and responsibilities of teachers, administrators, specialists, students, etc. have been spelled out.
4. An Implementation Oversight Group has been designated; they have a clear charge and procedures for operating.
5. The evaluation process is being implemented as designed.
6. Communication between and among all stakeholders is occurring.
7. Time has been allocated to work on the curriculum to align it with the NH frameworks.
8. The Superintendent's Academy in the summer provides time for curriculum development related to block scheduling.
9. Staff development is focused on teaching strategies that are effective in the block scheduling format.
10. Planning periods of at least the same length as before (90 minutes) are available for teachers to work together.

### Effectiveness Criteria

#### <u>Teachers and Teaching</u>

1. Teachers are using a variety of instructional methods, learning activities, grouping structures, etc. to deliver the curriculum.
2. Teaching methods accommodate the different learning styles of students.
3. Teachers implement the classroom modifications in Individual Education Plans.
4. The student/teacher ratio has decreased.
5. The total number of students taught by each teacher has decreased.
6. Interdisciplinary planning and coordination have increased.
7. Teachers perceive the school to be a more positive, stimulating learning environment. Teachers perceive the school to be a more positive professional working environment.
8. Teachers believe that block scheduling enhances their teaching.

9. Teachers believe that block scheduling enhances student learning.
10. Teachers believe that block scheduling enhances the achievement of standards included in the NH Curriculum Frameworks and the 13 Graduation Standards.

1. Teachers professional development goals focus on improving instructional strategies.
2. Teachers feel more relaxed and creative.
3. Planning and preparation may take more time, but teachers have more time to do it.
4. Students who need more time to learn have the time.
5. The teachers role is shifting to that of facilitator of learning.
6. The library is used more extensively than before.
7. Teacher attendance has improved.
8. Teachers want to continue to implement block scheduling and improve its effectiveness.
9. There are more opportunities for acceleration, remediation, and individualization.

<u>Central Office, Parents, School Board, and the Community</u>

10. Parents have positive attitudes about the impact of block scheduling on their children.
11. The School Board is enthusiastic and supportive of block scheduling.
12. The Central Office, parents, the school board, and community are allowing the school to implement block scheduling fully and refine it prior to deciding whether to continue or not.
13. The Central Office is allowing the high school staff the latitude to implement and refine block scheduling.

<u>Students</u>

14. More students are able to take 1st choice courses and electives.
15. More students participate in extra-curricular activities due to an increase in optional courses taken.
16. Students are more actively involved in learning.
17. The number of student-initiated activities has increased.
18. Personal interaction with teachers has increased.
19. Students are making meaningful connections between schoolwork and their on lives.
20. Students are beginning to do better on critical thinking problems.
21. Students can apply knowledge rather than just spitting it back.
22. Student writing is improving.

23. Students perceive the school to be a more positive, stimulating environment.
24. Students believe that block scheduling positively contributes to their academic and career goals.
25. The occasional lack of continuity (e.g., a course taken during first semester not followed up on until a year later) does not negatively impact student learning. Impact Criteria

Non-Academic Student Outcomes

26. Attendance has improved .
27. The drop-out rate has gone down.
28. The graduation rate has increased.
29. Disciplinary problems in classrooms have decreased.
30. Discipline referrals have gone down.
31. Tardiness has decreased.
32. Class cuts have decreased.

Student Learning and Achievement

33. Grade Point Averages have increased.
34. Students are more focused on career clusters.
35. More students are taking electives and participating in internships.
36. Students are earning more credits over the four years of high school.
37. Course failures have decreased.
38. More students are taking AP courses.
39. AP test scores have improved.
40. More students are on the Honor Roll
41. More students are receiving High Honors.
42. There are fewer course failures.
43. Students are being accepted into challenging colleges.
44. The quality of writing in writing samples is improving.
45. More students pass the writing sample the first time.
46. Results on the 10$^{th}$ grade assessment have improved.
47. SAT percentile rank has remained the same or improved.
48. More special education students are achieving passing grades in their academic classes in the mainstream.

Other Criteria

49. Other school systems view Salem as a model of effective implementation of block scheduling.

## DATA COLLECTION METHODS

Several data collection methods will be used to produce evidence related to the evaluative criteria above. These will include:

1. Surveys of:
    - Teachers
    - Parents
    - Students
    - Specialists
    - Administrators

2. School Board interviews
3. Student Performance Study Using *Socrates:*
    - Incorporate Student and Teacher Survey Data
    - Import Test Data (NHEIAP, SAT, CAT)
    - Writing Sample Holistic Scores
    - Non-Academic Indicators

## NEXT STEPS

4. The School Board will review, discuss, and make recommendations or approve the evaluation design.
5. The Oversight Committee will be established and will be oriented to the evaluation process and the evaluative criteria.
6. A detailed Evaluation Plan will be developed, including data collection instruments.
7. Documentation activities will begin in the fall of 1997, including a baseline survey of teachers, specialists, administrators, and students.

# Appendix B

## Salem High School Block Scheduling Data Collection Matrix

| Evaluative Criteria / Data Sources | Factual Descriptions | Teacher Surveys | Parent Surveys | Student Surveys | Specialist Surveys | Admin. Surveys | School Board Interviews | *Socrates* |
|---|---|---|---|---|---|---|---|---|
| IMPLEMENTATION CRITERIA | | | | | | | | |
| 1. There is a clear plan for implementing block scheduling; the plan spells out what will be done, how it will be done, when, and by whom. | X | | | | | X | | |
| 2. Policies related to block scheduling have been established and approved (grading, GPA, graduation requirements, attendance, etc.). | X | X | | | | X | | |
| 3. The roles and responsibilities of teachers, administrators, specialists, students, etc., have been spelled out. | X | X | | X | X | X | | |
| 4. An Implementation Coordination Team has been designated; they have a clear charge and procedures for operating. | X | | | | | X | | |
| 5. The evaluation process is being implemented as designed. | X | | | | | X | X | |
| 6. Communication between and among stakeholders is occurring. | X | X | X | X | X | X | X | |
| 7. Time has been allocated to work on the curriculum to align it with the NH frameworks. | X | X | | | X | X | | |
| 8. The Superintendent's Academy structure provides time for curriculum development related to block scheduling. | X | X | | | X | X | | |
| 9. Staff Development is focused on teaching strategies that are effective in the block scheduling format. | X | X | | | X | X | | |
| 10. Planning periods of at least the same length as before (90 minutes) are available for teachers to work together. | X | X | | | | X | | |
| 11. The high school schedule has been developed to support block scheduling. | X | X | | | | X | | |

| EVALUATIVE CRITERIA / DATA SOURCES | Factual Descriptions | Teacher Surveys | Parent Surveys | Student Surveys | Specialist Surveys | Admin. Surveys | School Board Interviews | *Socrates* |
|---|---|---|---|---|---|---|---|---|
| **EFFECTIVENESS CRITERIA**<br><br>**Teachers and Teaching** | | | | | | | | |
| 1. Teachers are using a variety of instructional methods, learning activities, grouping structures, etc., to deliver the curriculum. | | X | | | | X | | |
| 2. Teaching methods accommodate the different learning styles of students. | | X | | | X | X | | |
| 3. Teachers implement the classroom modifications in Individual Education Plans. | | | | | X | | | |
| 4. The student/teacher ratio in classes supports effective teaching and learning. | | X | | | | X | | |
| 5. The total number of students taught by each teacher has decreased. | X | X | | | | | | |
| 6. Interdisciplinary planning and coordination have increased. | | X | | | | | | |
| 7. Teachers perceive the school to be a more positive, stimulating learning environment. | | X | | | | | | |
| 8. Teachers perceive the school to be a more positive professional working environment. | | X | | | | | | |
| 9. Teachers believe that block scheduling enhances their teaching. | | X | | | | | | |
| 10. Teachers believe that block scheduling enhances student learning. | | X | | | | | | |
| 11. Teachers believe that block scheduling enhances the achievement of standards included in the NH Curriculum Frameworks and the 13 Graduation Standards. | | X | | | | | | |
| 12. Teachers' professional development goals focus on improving instructional strategies. | X | X | | | | X | | |
| 13. Teachers feel more relaxed and creative. | | X | | | | | | |

| **EVALUATIVE CRITERIA** / **DATA SOURCE** | Factual Descriptions | Teacher Surveys | Parent Surveys | Student Surveys | Specialist Surveys | Admin. Surveys | School Board Surveys | *Socrates* |
|---|---|---|---|---|---|---|---|---|
| 14. Planning and preparation may take more time, but teachers have more time to do it. | | X | | | | X | | |
| 15. Students who need more time to learn have the time. | | X | | X | X | X | | |
| 16. The teacher's role is shifting to that of facilitator of learning. | | X | | X | X | X | | |
| 17. The library is used more extensively than before. | | X | | X | X | | | |
| 18. Teacher attendance has approved. | X | | | | | | | |
| 19. Teachers want to continue to implement block scheduling and improve its effectiveness. | | X | | | | | | |
| 20. There are more opportunities for acceleration, remediation, and individualization. | X | X | X | X | X | X | | |
| **Central Office, SHS Leadership Team, Parents, School Board and Community** | | | | | | | | |
| 1. SHS Leadership Team members are enthusiastic and provide the necessary latitude to implement and refine the process. | | X | | | | X | | |
| 2. The principal reallocates the budget to block scheduling. | X | X | | | | X | | |
| 3. The principal and SHS Leadership Team support and ensure the on-going staff development. | X | X | | | | X | | |
| 4. The principal and SHS Leadership Team support shared decision making. | X | X | | | | X | | |
| 5. The principal and SHS Leadership Team communicate effectively with parents and the community. | | X | X | | | X | X | |
| 6. The principal and SHS Leadership Team participate in and support the Block Scheduling Implementation and Evaluation Team. | X | | | | | X | | |
| 7. Parents have positive attitudes about the impact of block scheduling on their children. | | | X | | | | | |
| 8. The School Board is enthusiastic and supportive of block scheduling. | | | | | | | X | |

| EVALUATIVE CRITERIA / DATA SOURCE | Factual Descriptions | Teacher Surveys | Parent Surveys | Student Surveys | Specialist Surveys | Admin. Surveys | School Board Interviews | *Socrates* |
|---|---|---|---|---|---|---|---|---|
| 9. The Central Office, parents, the school board, and community are allowing the school to implement block scheduling fully and refine it prior to deciding whether to continue or not. | X | X | | | | X | X | |
| 10. The Central Office supports block scheduling and provides the necessary latitude to implement and refine the process. | X | X | | | | X | X | |
| 11. The Central Office fulfills its obligation to provide leadership in quality assurance aspects regarding the implementation of the evaluation model for block scheduling. | X | X | | | | X | X | |
| **Students** | | | | | | | | |
| 1. More students are able to take first choice courses and electives. | | | | X | | X | | |
| 2. More students participate in extra-curricular activities due to an increase in optional courses taken. | | X | | X | | X | | |
| 3. Students are more actively involved in learning. | | X | | X | | | | |
| 4. The number of student-initiated activities has increased. | | X | | X | | | | |
| 5. Personal interaction with teachers has increased. | | X | | X | | | | |
| 6. Students are making meaningful connections between school work and their own lives. | | X | | X | | | | |
| 7. Students are beginning to do better on critical thinking problems. | | X | | X | | | | |
| 8. Students can apply knowledge rather than just spitting it back. | | X | | X | | | | |
| 9. Student writing is improving. | | X | | X | | | | X |
| 10. Students perceive the school to be a more positive, stimulating environment. | | | | X | | | | |
| 11. Students believe that block scheduling positively contributes to their academic and career goals. | | | | X | | | | |

| EVALUATIVE CRITERIA / DATA SOURCE | Factual Descriptions | Teacher Surveys | Parent Surveys | Student Surveys | Specialist Surveys | Admin. Surveys | School Board Interviews | *Socrates* |
|---|---|---|---|---|---|---|---|---|
| 12. The occasional lack of continuity (e.g., a course taken during first semester not followed up on until a year later) does not negatively impact student learning. | | X | X | X | | X | | X |
| **IMPACT CRITERIA** | | | | | | | | |
| **Non-Academic Student Outcomes** | | | | | | | | |
| 1. Attendance has improved. | | | | | | | | X |
| 2. The dropout rate has gone down. | | | | | | | | X |
| 3. The graduation rate has increased. | | | | | | | | X |
| 4. Disciplinary problems in classrooms have decreased. | | X | | | | | | |
| 5. Discipline referrals have gone down. | | X | | | | | | |
| 6. Tardiness has decreased. | | | | | | | | |
| 7. Class cuts have decreased. | | | | | | | | X |
| **Student Learning and Achievement** | | | | | | | | |
| 1. Grade Point Averages have increased, | | | | | | | | X |
| 2. Students are more focused on career clusters. | | X | | X | | X | | X |
| 3. More students are taking electives and participating in internships. | | X | | X | | X | | X |
| 4. Students are earning more credits over the four years of high school. | | | | | | | | X |
| 5. Course failures have decreased. | | | | | | | | X |
| 6. More students are taking AP courses. | | | | | | | | X |
| 7. AP test scores have improved. | | | | | | | | X |
| 8. More students are on the Honor Roll. | | | | | | | | X |
| 9. More students are being accepted into challenging colleges. | X | | | | | | | |
| 11. The quality of writing in writing samples is improving. | | X | | | | X | | X |

| **EVALUATIVE CRITERIA** / **DATA SOURCE** | Factual Descriptions | Teacher Surveys | Parent Surveys | Student Surveys | Specialist Surveys | Admin. Surveys | School Board Interviews | *Socrates* |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 12. More students pass the writing sample the first time. | | | | | | | | |
| 13. results on the $10^{th}$ grade assessment have improved. | | | | | | | | |
| 14. SAT percentile rank has remained the same or improved. | | | | | | | | X |
| 15. More special education students are achieving passing grades in their academic classes in the mainstream. | | | | | | | | X |
| **OTHER CRITERIA** | | | | | | | | |
| 1. Other school systems view Salem as a model of effective implementation of block scheduling. | X | | | | | | | |

# APPENDIX C

## Salem High School Block Scheduling Survey Summary 1999-2000

## Staff-Administrator Survey

## Open-Ended Questions

1. ***Do you perceive that you deal differently with a problem student (discipline) in your class under block scheduling? If so, how?***

   - While teachers indicated that their expectations have remained constant, the time in a 90-minute block enables them to handle more of the discipline within the classroom:
   - There is time to process with students and resolve issues instead of having the office handle it.
   - Many "problems" can be handled by giving a student more individual attention, and I am better able to do this in the block.

Some teachers noted that disruptions in the lower level classes tend to increase as the block wears on – students are not learning from their mistakes! Also, if a student simply does not want to be in the class, there is no other class or study available and the student is unhappily in class for 90 minutes each day.

In summary, while teachers have not changed their discipline standards, the longer block enables them to work more extensively with students before sending them to the deans. They highlight the opportunity they have for getting to know students better than in a forty-five minute class.

2. ***Is your class preparation different under block scheduling? If so, how?***

Overwhelmingly, teachers indicated that more planning time was required to effectively teach a 90-minute class! In addition, much more time is required to grade projects, class work, and tests. Some teachers highlighted the fact that the classes are now more student-centered, resulting in more hands-on activities that build student skills in problem solving. While this is positive, some teachers did comment that the classes cover less content in order to provide the hands-on practice of those concepts, thus resulting in a more in-depth understanding of fewer concepts.

The following comments are typical:

- Takes much more time and resources.
- I need to be prepared on a deeper level. I prepare whole units to accommodate differing learning styles. I find I need to anticipate more, especially for supplies and transitional activities.

3. ***How does block scheduling affect the academic program of Salem High School?***

**Content:** As indicated by responses to the previous question, many of the staff feel that less content is being covered in the 90-minute class. Students can only absorb and retain just so much material. Thus, in sequential courses, i.e., Spanish 1, Spanish 2, etc. the students are not entering the upper level courses as well prepared as in the past. Some fear that material is being "watered down" to meet curriculum requirements.

**Course selection:** With eight periods each year and no study halls, students are able to take a wider variety of courses. There are more options for academic exploration and increased opportunity to study a particular subject in much greater detail over the four years.

**Time lapse:** There is growing concern over the lack of retention due to the potentially longer period of time between sequential courses. Thus, the teacher of a second level course is spending a greater period of time in review than previously.

**Academic atmosphere**: Several staff members alluded to the collegiate feel of the school. In addition, stress is limited because students are changing classes only three times during the day. Carrying only four classes at one time tends to reduce student stress.

**Absence**: Time missed from class is problematic because under block scheduling. When a student misses a class he/she is responsible for making up a more significant amount of material than under a yearlong format. In addition, both teachers and students find it difficult to schedule time before or after school with in order to get make-up work finished or to discuss material, particularly if the student is involved in sports, clubs or other organizations that meet only after school hours.

4. ***How has the role of the principal and other administrators changed under block scheduling?***

While the number of responses to this question were limited, teachers perceived no substantial change in the role of the administration under block scheduling, but those responding did indicate that they would like administrators to be more visible.

5. *What can Salem High School do to continue to support students, teachers, and parents under block scheduling?*

Class time is at a premium; therefore teachers would like fewer interruptions for visits to guidance, to move illegally parked cars, and for visits to the dean! Smaller classes would be advantageous. A block of time for make-up work would benefit both students and teachers. Several teachers commented that an attendance policy that states that, after a certain number of absences the student will automatically fail the class, needs to be developed.

Several teachers stated that the variety of activities which make the 90-minute classes interesting and appropriate necessitates more technical support, i.e., computers, televisions, overhead projectors, paper, etc.

Some typical comments:

- Do not schedule next year's classes so early. Carefully place students.
- Reduce class size. Everyone wins.
- Maximize diversity and continuity of schedule.

Additional comments:

The suggestion was made to modify the four-by-four block in order to accommodate certain types of curriculum. Perhaps some courses could run all year, instead of just one semester.

It was also suggested that guidance rethink how students are placed into classes. Because there is greater opportunity to take more classes, we need to hire additional staff in order to offer more elective options to our students. The contention is that by senior year students have exhausted the electives in which they have any interest and thus, spend their senior year in classes they don't want or need.

Several staff members suggested that a ten-minute passing time is too long. Additionally, the need for greater administrative visibility was repeated.

A logical consequence of providing more courses is that additional classroom space would be required. Given that the facility is currently utilized to its maximum capacity, additional courses would exacerbate the problem.

Overall, the block scheduling initiative, currently concluding its third year of implementation has been successful in meeting some of the original criteria for success.

A more comprehensive analysis of actual statistics related to GPS, attendance, drop-out, discipline, etc. will be developed for the Salem School Board and presented at a school board in the summer.

The Block Scheduling Survey will need to be revised during the next school year. Because block scheduling has been in effect for three years, it is no longer necessary to compare it to the traditional schedule. Consequently, the Block Scheduling Evaluation Team will need to devise a revised survey that asks questions about block scheduling specifically and not as it compares to other instructional configurations.

# APPENDIX D

## New Hampshire Educational Improvement and Assessment Program

## Mathematics Curriculum Framework

## How this Framework is Organized

The material in the K-12 Mathematics Curriculum Framework is organized around eight strands: Problem Solving and Reasoning; Communication and Connections; Numbers, Numeration, Operations, and Number Theory; Geometry, Measurement, and Trigonometry; Data Analysis, Statistics, and Probability; Functions, Relations, and Algebra; Mathematics of Change; and Discrete Mathematics. Within each of these areas, one or more K-12 Broad Goals identify general expectations of what ALL New Hampshire students are expected to know and be able to do. For example, the first Broad Goal in the Problem Solving and Reasoning strand states: Students will use problem-solving strategies to investigate and understand increasingly complex mathematical content.

Following each broad goal is a purpose statement which places the goal in context and elaborates on its role in the mathematics program. Further, in the case of discrete Mathematics, a definition is provided in order to clarify this emerging area of the K-12 curriculum Standards are presented in two parts: Curriculum Standards and Proficiency Standards. The Curriculum Standards identify the scope of the content recommended for grades K-3, 4-6, and 7-12. The Proficiency Standards identify specific expectations for the assessment of cumulative learning. They will serve as the basis for the development and ongoing revision of the mathematics assessment instruments to be administered statewide at the end of grades three, six, and ten. All of the Grade 3 Proficiency Standards found in the New Hampshire Mathematics Curriculum Framework: End of Grade Three (1993) are incorporated into this K-12 framework.

The Curriculum Standards, particularly at the 7-12 level, identify more than what is included in the standards to be tested. The developers of this framework were sensitive to what constitutes a full 4-year program of mathematics in high school and the fact that students will be tested statewide at the end-of-grade ten. Local educators and policy leaders should note that the recommended content for all high school students is richer than the content that has traditionally been included in some general mathematics courses.

**Rationale**

In the early part of this century, the needs of our society were dominated by an emerging industrial age driven by mass production. The needs of that society were served by mathematics education in which the acquisition of computational skills was the primary focus. Computational skills alone are no longer sufficient for the United States to remain competitive in the world marketplace. In the coming century the educational needs of our society will be very different. The economy is global, the economic environment is more competitive, and the workforce is more mobile. The acquisition of computational skills remains important, but more is needed today, due to rapidly changing technology.

The development of mathematical problem solving, reasoning, communication skills, and use of appropriate technology is essential so that people can skillfully address the more complex problems encountered in today's workplaces. We need individuals who can apply their understanding of mathematics to solve real-world problems for which there are no simple formulas and standard procedures. We need individuals who can use their knowledge of mathematics to make sense of complex situations and then communicate that understanding to others. We need individuals who are able to solve tomorrow's problems, as well as today's. Mathematics education for the twenty-first century must address these needs.

## Societal Goals

We believe the goals for New Hampshire schools are closely aligned with those espoused by various national commissions and groups in their efforts to reshape the mathematics curriculum. We commit to five primary goals. That:

- *all students* will develop a firm grounding in essential computational skills;
- *all students* will develop strong mathematical problem solving and reasoning abilities;
- *all students* will develop positive attitudes about mathematics;
- *all students* will develop the ability to use appropriate technology to solve mathematical problems; and
- *all students* will develop the ability to communicate their understanding of mathematics effectively.

## How Students Learn Mathematics

*"Students learn mathematics well only when they construct their own mathematical understanding."* (Everybody Counts, p. 58)

This view of learning, called constructivism, is the premise upon which the reform movement in mathematics education is based. When students learn mathematics by doing mathematics, by exploring and discussing concepts in the context of physical situations, what emerges from these experiences are skills which are anchored in understanding and clarity. The students not only know the basic procedures, but also know how to apply them to new situations. Research supports the fact that students learn best by experiencing mathematics and thereby constructing understanding for themselves. Research also indicates that mathematics education will best serve societal needs when the curriculum is so conceptually focused.

The attitudes students form influence their thinking and performance, and, later, influence their decisions about studying mathematics. Students are active individuals who construct, modify, and integrate ideas by interacting with materials, the world around them, and their peers. Thus, the learning of mathematics must be an active process: exploring, justifying, representing, solving, constructing, discussing, using, investigating, describing, developing, and predicting. These actions require both the physical and mental involvement of students both hands on and minds on.

## Functions, Relations and Algebra

**6a. K-12 Broad Goal: Students will recognize patterns and describe and represent relations and functions with tables, graphs, equations and rules, and analyze how a change in one element results in a change in another.**

**PURPOSE**: One of the central themes of mathematics is the study of patterns, relations, and functions. This study requires students to recognize, describe, and generalize patterns and build mathematical models to predict the behavior of real-world phenomenon that exhibit the observed pattern. This study of patterns leads to an exploration of functions, a concept which is an important unifying idea in all aspects of mathematics.

**6b. K-12 Broad Goal: Students will use algebraic concepts and processes to represent situations that involve variable quantities with expressions, equations, inequalities, matrices and graphs.**

**PURPOSE**: Algebra is the language through which much of mathematics is communicated. It provides a means of representing concepts at an abstract level and then applying those concepts. Students in grades K-6 should explore algebraic concepts in an informal way, emphasizing physical models, data, graphs and other mathematical representations. Formal algebraic manipulation may be deferred to later grades. The understanding of algebraic representation is a prerequisite to formal work in virtually all of mathematics. Algebraic processes are important tools in the study of natural sciences and social sciences.

## Mathematics of Change

**7a. K-12 Broad Goal: Students will be able to use concepts about mathematical change in analyzing patterns, graphs, and applied situations.**

**PURPOSE**: All natural phenomena are characterized by change. Mathematics is a tool for representing and describing this change, and a preliminary understanding of change is an important precursor to the more formal ideas of calculus. Through explorations of patterns, tables, graphs, functions, and situations which focus on the nature of change, representation, understanding, and recognition of types of change can be promoted. Real-world examples of change can be examined. Proportional reasoning and experience with rates should be part of this process.

## Discrete Mathematics

Discrete mathematics is defined as the study of topics which involve items that can be counted, rather than continuous amounts which can only be measured. Discrete mathematics is actually an umbrella term which includes such topics as: counting techniques, sets, relations, functions, logic and reasoning, patterning (iteration and recursion), algorithms, and induction. Probability, networks, graph theory, social decision making, and matrices should also be included in a discrete mathematics curriculum. Embedded in these areas are the three main themes of discrete mathematics: existence (Is there a solution?), counting (How many solutions are there?), and efficiency (What is the best solution?).

**8a. K-12 Broad Goal: Students will use a variety of tools from discrete mathematics to explore and model real-world situations.**

**PURPOSE:** Information and communication continue to impact the modern world and require the understanding of discrete mathematics. Decision making involving sets and systems having a countable number of elements needs to be integrated throughout the curriculum. Students should have experiences with finite graphs, matrices, sequences, recursion and the development and testing of algorithms.

# APPENDIX E

## Salem High School Mathematics Course Descriptions

**COURSE DESCRIPTION: Algebra 1** stresses both the structure and the development of problem-solving concepts and the skills of a first-year algebra course.

**TEXTBOOK:** Merrill Algebra One by Foster, et al Glencoe 1998

**COURSE OBJECTIVES:**

The student will be able to:

**Chapter 1**

1. Translate verbal expressions into mathematical expressions and vice-versa.
2. Solve problems by looking for a pattern.
3. Use mathematical properties to evaluate expressions.
4. Solve open sentences.
5. Use and interpret stem-and-leaf plots, tables, graphs, and functions.

**Chapter 2**

6. Display and interpret statistical data on line plots.
7. Add, subtract, multiply, and divide rational numbers.
8. Find square roots.
9. Write equations and formulas.

**Chapter 3**

10. Solve equations using one or more operations.
11. Solve problems that can be represented by equations.
12. Work backward to solve problems.
13. Define and study angles and triangles.
14. Find measures of central tendency.

**Chapter 4**

15. Solve proportions.
16. Find the unknown measures of the sides of two similar triangles.
17. Use trigonometric ratios to solve right triangles.
18. Solve percent problems.
19. Find the probability and odds of a simple event.
20. Solve problems involving direct and inverse variation.

**Chapter 5**

21. Graph ordered pairs, relations, and equations.
22. Solve problems by making a table.
23. Identify the domain, range, and inverse of a relation.
24. Determine if a relation is a function.
25. Write an equation to represent a relation.
26. Calculate and interpret the range, quartiles, and interquartile range of a set of data.

**Chapter 6**

27. Find the slope of a line, given the coordinates of two of its points..
28. Write linear equations in point-slope, standard, and slope-intercept forms.
29. Draw a scatter plot and find the equation of a best-fit line for the data.
30. Solve problems by using models.
31. Graph linear equations.
32. Use slope to determine if two lines are parallel or perpendicular.

**Chapter 9**

33. Solve problems by looking for a pattern.
34. Multiply and divide monomials.
35. Express numbers in scientific notation.
36. Add, subtract, and multiply polynomials.

**Chapter 10**

37. Find the prime factorizations of integers.
38. Find the greatest common factors (GCF) for sets of monomials.
39. Factor polynomials.
40. Solve problems by using guess and check.
41. Use the zero product property to solve equations.

**COURSE DESCRIPTION: Algebra 2** stresses both the structure and the development of problem-solving concepts and skills of a second-year algebra course. Certain Algebra 1 topics will be covered in greater depth, in addition to quadratic equations and functions, conic sections, logarithmic and exponential functions.

**TEXTBOOK:** Merrill Algebra Two by Foster, et al Glencoe 1998

**COURSE OBJECTIVES:**

The student will be able to:

1. Use the order of operations to evaluate expressions;
2. Use formulas;
3. Determine the sets of numbers to which a number belongs;
4. Represent and interpret data using line plots and stem-and-leaf plots;
5. Find and use the median, mode, and mean to interpret data;
6. Translate verbal expressions and sentences into algebraic expressions and equations; Solve equations by using the properties of equalities;
7. Solve equations for a specific variable;
8. Solve equations containing absolute value;
9. Solve problems by making lists;
10. Solve inequalities and graph the solution sets;
11. Solve compound inequalities using "and" and "or";
12. Solve inequalities involving absolute value and graph the solutions;
13. Graph a relation, state its domain and range, and determine if it is a function; 14.
14. Find values of functions for given elements of the domain;
15. Identify equations that are linear and graph them;
16. Write linear equations in standard form;
17. Determine the intercepts of a line and use them to graph an equation;
18. Use a graphing calculator to approximate solutions to equations with one variable;
19. Determine the slope of a line;
20. Use slope and a point to graph an equation;
21. Determine if two lines are parallel, perpendicular, or neither;
22. Solve problems by identifying and using a pattern;
23. Write an equation of a line in slope-intercept form given the slope and one or two points;
24. Write an equation of a line that is parallel or perpendicular to the graph of a given equation;
25. Draw scatter plots;
26. Find and use prediction equations;
27. raw graphs of inequalities in two variables;
28. Solve systems of equations by graphing;
29. Use the substitution and elimination methods to solve systems of equations;

30. Find the values of second-order determinants;
31. Solve systems of equations by using Cramer's rule;
32. Solve systems of inequalities by graphing;
33. Find the maximum and minimum values of a function over a region using linear programming techniques;
34. Solve problems by solving a simpler problem;
35. Solve a system of three equations in three variables;
38. Multiply and divide expressions written in scientific notation;
39. Add, subtract, and multiply polynomials;
40. Divide polynomials using long division;
41. Divide polynomials by binomials using synthetic division;
42. Factor polynomials. Use factoring to simplify polynomial quotients;
43. Simplify radicals having various indices;
44. Use a calculator to estimate roots of numbers;
45. Simplify radical expressions;
46. Rationalize the denominator of a fraction containing a radical expression;
47. Add, subtract, multiply, and divide radical expressions;
48. Solve problems by identifying and achieving subgoals;
49. Write expressions with radical al exponents in simplest radical form and vice versa; Evaluate expressions in either exponential or radical form;
50. Solve equations containing radicals;
51. Simplify square roots containing negative radicands;
52. Solve quadratic equations that have pure imaginary solutions;
53. Add, subtract, and multiply complex numbers;
54. Simplify rational expressions containing complex numbers in the denominator;
55. Write functions in quadratic form;
56. Graph quadratic functions;
57. Solve quadratic equations by graphing;
58. Solve problems by using the guess-and-check strategy;
59. Solve quadratic equations by factoring;
60. Solve quadratic equations by completing the square;
61. Solve quadratic equations by using the quadratic formula;
62. Use discriminates to determine the nature of the roots of quadratic equations;
63. Find the sum and product of the roots of quadratic equations;
64. Find a quadratic equation to fit a given condition;
65. Graph quadratic equations of the form $y = a(x - h)^2 + k$;
66. Determine the equation of a parabola by using points on its graph;
67. Graph quadratic inequalities;
68. Solve quadratic inequalities in one variable.

**COURSE DESCRIPTION: Honors Algebra 1** stresses both the structure and the development of problem-solving concepts and the skills of a first-year algebra course. It is an accelerated course that covers additional topics in algebra and explores them in greater depth than Algebra 1.

**TEXTBOOK:** Merrill Algebra One by Foster, et al Glencoe 1998

**COURSE OBJECTIVES:**

The student will be able to:

Chapter 1

1. Translate verbal expressions into mathematical expressions and vice-versa.
2. Solve problems by looking for a pattern.
3. Use mathematical properties to evaluate expressions.
4. Solve open sentences.
5. Use and interpret stem-and-leaf plots, tables, graphs, and functions.

Chapter 2

6. Display and interpret statistical data on line plots.
7. Add, subtract, multiply, and divide rational numbers.
8. Find square roots.
9. Write equations and formulas.

Chapter 3

10. Solve equations using one or more operations.
11. Solve problems that can be represented by equations.
12. Work backward to solve problems.
13. Define and study angles and triangles.
14. Find measures of central tendency.

Chapter 4

15. Solve proportions.
16. Find the unknown measures of the sides of two similar triangles.
17. Use trigonometric ratios to solve right triangles.
18. Solve percent problems.
19. Find the probability and odds of a simple event.
20. Solve problems involving direct and inverse variation.

Chapter 5

21. Graph ordered pairs, relations, and equations..
22. Solve problems by making a table.
23. Identify the domain, range, and inverse of a relation.
24. Determine if a relation is a function.
25. Write an equation to represent a relation.
26. Calculate and interpret the range, quartiles, and interquartile range of a set of data.

Chapter 6

27. Find the slope of a line, given the coordinates of two of its points..
28. Write linear equations in point-slope, standard, and slope-intercept forms.
29. Draw a scatter plot and find the equation of a best-fit line for the data.
30. Solve problems by using models.
31. Graph linear equations.
32. Use slope to determine if two lines are parallel or perpendicular.

Chapter 7

33. Solve inequalities, and graph solutions of inequalities.
34. Graph solutions of inequalities.
35. Graph solutions of open sentences that involve absolute value.

Chapter 8

36. Graph systems of equations.
37. Solve systems of equations using various methods.
38. Organize data to solve problems.
39. Solve systems of inequalities by graphing.

Chapter 9

42. Solve problems by looking for a pattern.
43. Multiply and divide monomials.
44. Express numbers in scientific notation.
45. Add, subtract, and multiply polynomials.

Chapter 10

46. Find the prime factorizations of integers.
47. Find the greatest common factors (GCF) for sets of monomials.
48. Factor polynomials.
49. Solve problems by using guess and check.
50. Use the zero product property to solve equations.

Chapter 12

57. Simplify rational expressions.
58. Add, subtract, multiply, and divide rational expressions.
59. Divide polynomials.
60. Make organized lists to solve problems.

**COURSE DESCRIPTION: Honors Algebra 2** stresses both the structure and the development of problem-solving concepts and skills of a second-year algebra course. Certain Algebra 1 topics will be covered in greater depth, in addition to quadratic equations and functions, conic sections, logarithmic and exponential functions.
It is an accelerated course that covers additional topics in algebra and explores them in greater depth than Algebra 2.

**TEXTBOOK:** Merrill Algebra Two by Foster, et al Glencoe 1998

**COURSE OBJECTIVES:**

The student will be able to:

1. Use the order of operations to evaluate expressions;
2. Use formulas;
3. Determine the sets of numbers to which a number belongs;
4. Represent and interpret data using line plots and stem-and-leaf plots;
5. Find and use the median, mode, and mean to interpret data;
6. Translate verbal expressions and sentences into algebraic expressions and equations;
7. Solve equations by using the properties of equalities;
8. Solve equations for a specific variable;
9. Solve equations containing absolute value;
10. Solve problems by making lists;
11. Solve inequalities and graph the solution sets;
12. Solve compound inequalities using "and" and "or";
13. Solve inequalities involving absolute value and graph the solutions;
14. Graph a relation, state its domain and range, and determine if it is a function;
15. Find values of functions for given elements of the domain;

16. Use a graphing calculator to graph an equation;
17. Identify equations that are linear and graph them;
18. Use a graphing calculator to approximate solutions to equations in one variable;
19. Write linear equations in standard form;
20. Determine the intercepts of a line and use them to graph an equation;
21. Use a graphing calculator to approximate solutions to equations with one variable;
22. Determine the slope of a line;
23. Use slope and a point to graph an equation;
24. Determine if two lines are parallel, perpendicular, or neither;
25. Solve problems by identifying and using a pattern;
26. Write an equation of a line in slope-intercept form given the slope and one or two points;
27. Write an equation of a line that is parallel or perpendicular to the graph of a given equation;
28. Draw scatter plots;
29. Find and use prediction equations;
30. Draw graphs of inequalities in two variables;
31. Use a graphing calculator to graph and solve systems of linear equations;
32. Solve systems of equations by graphing;
33. Use the substitution and elimination methods to solve systems of equations;
34. Find the values of second-order determinants;
35. Solve systems of equations by using Cramer's rule;
36. Solve systems of inequalities by graphing;
37. Find the maximum and minimum values of a function over a region using linear programming techniques;
38. Solve problems by solving a simpler problem;
39. Evaluate the determinant of a 3X3 matrix;
40. Solve a system of three equations in three variables;
41. Multiply and divide monomials;
42. Represent numbers in scientific notation;
43. Multiply and divide expressions written in scientific notation;
44. Add, subtract, and multiply polynomials;
45. Divide polynomials using long division;
46. Divide polynomials by binomials using synthetic division;
47. Factor polynomials.
48. Use factoring to simplify polynomial quotients;
49. Simplify radicals having various indices;
50. Simplify radical expressions;
51. Rationalize the denominator of a fraction containing a radical expression;
52. Add, subtract, multiply, and divide radical expressions;
53. Solve problems by identifying and achieving subgoals;
54. Write expressions with radical al exponents in simplest radical form and vice versa;
55. Evaluate expressions in either exponential or radical form;

56. Solve equations containing radicals;
57. Simplify square roots containing negative radicands;
58. Solve quadratic equations that have pure imaginary solutions;
59. Add, subtract, and multiply complex numbers;
60. Simplify rational expressions containing complex numbers in the denominator;
61. Write functions in quadratic form;
62. Graph quadratic functions;
63. Use a graphing calculator to graph and solve quadratic equations;
64. Solve quadratic equations by graphing;
65. Solve problems by using the guess-and-check strategy;
66. Solve quadratic equations by factoring;
67. Solve quadratic equations by completing the square;
68. Solve quadratic equations by using the quadratic formula;
69. Use discriminants to determine the nature of the roots of quadratic equations;
70. Find the sum and product of the roots of quadratic equations;
71. Find a quadratic equation to fit a given condition;
72. Graph quadratic equations of the form $y = a(x - h)^2 + k$;
73. Use a graphing calculator to graph and explore similarities between parabolas;
74. Determine the equation of a parabola by using points on its graph;
75. Graph quadratic inequalities;
76. Solve quadratic inequalities in one variable;
77. Find the distance between two points in the coordinate plane;
78. Find the midpoint of a line segment in the coordinate plane;
79. Write equations of parabolas.
80. Graph parabolas having certain properties;
81. Write equations of circles.
82. Graph circles having certain properties;
83. Write equations of ellipses;
84. Graph ellipses having certain properties;
85. Write equations of hyperbolas;
86. Graph hyperbolas having certain properties;
87. Write equations of conic sections in standard form;
88. Identify conic sections from their equations;
89. Use simulation to solve problems;

**COURSE DESCRIPTION:** **Geometry** is a course that is centered about the study of planar figures such as triangles, quadrilaterals and circles. Methods of inductive and deductive logic are emphasized through the development of geometric proofs using basic assumptions and definitions.

**TEXTBOOK:** Glencoe Geometry by Boyd, et al Glencoe 1998

**SAT CONTENT:**

Area and perimeter of a polygon; area and circumference of a circle; volume of a box, cube and cylinder; Pythagorean Theorem and special properties of isosceles, equilateral and right triangles; 30-60-90 and 45-45-90 triangles; properties of parallel and perpendicular lines; simple coordinate geometry; slope; similarity; geometric visualization

**COURSE OBJECTIVES:**

The student will be able to:

1. Graph ordered pairs on a coordinate plane;
2. Identify collinear points;
3. Identify and model points, lines, and planes;
4. Identify coplanar points and intersecting lines and planes;
5. Solve problems by listing the possibilities;
6. Solve problems by using formulas;
7. Find maximum area of a rectangle for a given perimeter;
8. Find the distance between two points on a number line and between two points in a coordinate plane;
9. Use the Pythagorean Theorem to find the length of the hypotenuse;
10. Find the midpoint of a segment;
11. Complete proofs involving segment theorems;
12. Identify and use adjacent, vertical, complementary, supplementary, and linear pairs of angles, and perpendicular lines;
13. Determine what information can and cannot be assumed from a diagram;
14. Make conjectures based on inductive reasoning;
15. Write a statement in *if-then* form;
16. Write the converse, inverse, and contrapositive of an *if-then* statement;
17. Identify and use basic postulates about points, lines, and planes;
18. Use properties of equality in algebraic and geometric proofs;
19. Complete proofs involving segment theorems;
20. Complete proofs involving angle theorems;
21. Solve problems by drawing a diagram;
22. Identify the relationships between two lines or two planes;
23. Name angles formed by a pair of lines and a transversal;
24. Use the properties of parallel lines to determine angle measures;
25. Find the slopes of lines;
26. Use slope to identify parallel and perpendicular lines;
27. Recognize angle conditions that produce parallel lines;
28. Prove two lines are parallel based on given angle relationships;
29. Recognize and use distance relationships among points, lines and planes;

30. Solve problems by drawing a diagram;
31. Identify the relationships between two lines or two planes;
32. Name angles formed by a pair of lines and a transversal;
33. Use the properties of parallel lines to determine angle measures;
34. Find the slopes of lines;
35. Use slope to identify parallel and perpendicular lines;
36. Recognize and use distance relationships among points, lines, and planes.
37. Find the distance between a point and a line;
38. Identify points, lines, and planes in spherical geometry;
39. Compare and contrast basic properties of plane and spherical geometry;
40. Identify and use medians, altitudes, angle bisectors, and perpendicular bisectors in a triangle;
41. Recognize and use tests for congruence of right triangles;
42. Recognize and apply relationships between sides and angles in a triangle;
43. Apply the Triangle Inequality Theorem;
44. Apply the SAS Inequality and the SSS Inequality;
45. Find the geometric mean between two numbers;
46. Solve problems involving relationships between parts of a triangle and the altitude to its hypotenuse;
47. Use the Pythagorean Theorem and its converse;
48. Use the properties of 45°-45°-90° and 30°-60°-90° triangles;
49. Find trigonometric ratios using right triangles;
50. Solve problems using trigonometric ratios;
51. Use trigonometry to solve problems involving angles elevation or depression;
52. Recognize and apply the properties of a parallelogram;
53. Find the probability of an event;
54. Recognize and apply the conditions that ensure a quadrilateral is a parallelogram;
55. Identify and use subgoals in writing proofs;
56. Recognize and apply the properties of rectangles;
57. Recognize and apply the properties of squares and rhombi;
58. Recognize and apply the properties of trapezoids;
59. Recognize and use ratios and proportions;
60. Apply the properties of proportions;
61. Identify similar figures;
62. Solve problems involving similar figures;
63. Identify similar triangles;
64. Use similar triangles to solve problems;
65. Use proportional parts of triangles to solve problems;
66. Divide a segment into congruent parts;
67. Recognize and use the proportional relationships of corresponding perimeters, altitudes, angle bisectors, and medians of similar triangles;
68. Recognize and describe characteristics of fractals;
69. Solve problems by solving a simpler problem;

70. Identify and use parts of circles;
71. Solve problems involving the circumference of a circle;
72. Recognize major arcs, minor arcs, semicircles, and central angles;
73. Find areas of parallelograms;
74. Find areas of triangles, rhombi, and trapezoids;
75. Find areas of regular polygons;
76. Find areas of circles.

If time permits, cover Objectives 73-76.

**COURSE DESCRIPTION: Honors Geometry** deals with the properties and relationships of triangles, rectangles, squares, parallelograms, rhombuses and circles. Rules and definitions are used to prove these facts using formal proofs. It is an accelerated course that covers additional topics in geometry and explores them in greater depth than Geometry.

**TEXTBOOK:** Glencoe Geometry by Boyd, et al Glencoe 1998

**COURSE OBJECTIVES:**

The student will be able to:

77. Graph ordered pairs on a coordinate plane;
78. Identify collinear points;
79. Identify and model points, lines, and planes;
80. Identify coplanar points and intersecting lines and planes;
81. Solve problems by listing the possibilities;
82. Solve problems by using formulas;
83. Find maximum area of a rectangle for a given perimeter;
84. Find the distance between two points on a number line and between two points in a coordinate plane;
85. Use the Pythagorean Theorem to find the length of the hypotenuse;
86. Find the midpoint of a segment;
87. Complete proofs involving segment theorems;
88. Identify and use adjacent, vertical, complementary, supplementary, and linear pairs of angles, and perpendicular lines;
89. Determine what information can and cannot be assumed from a diagram;
90. Make conjectures based on inductive reasoning;
91. Write a statement in *if-then* form;
92. Write the converse, inverse, and contrapositive of an *if-then* statement;
93. Identify and use basic postulates about points, lines, and planes;
94. Use properties of equality in algebraic and geometric proofs;
95. Complete proofs involving segment theorems;
96. Complete proofs involving angle theorems;

97. Solve problems by drawing a diagram;
98. Identify the relationships between two lines or two planes;
99. Name angles formed by a pair of lines and a transversal;
100. Use the properties of parallel lines to determine angle measures;
101. Find the slopes of lines;
102. Use slope to identify parallel and perpendicular lines;
103. Recognize angle conditions that produce parallel lines;
104. Prove two lines are parallel based on given angle relationships;
105. Recognize and use distance relationships among points, lines and planes;
106. Solve problems by drawing a diagram;
107. Identify the relationships between two lines or two planes;
108. Name angles formed by a pair of lines and a transversal;
109. Use the properties of parallel lines to determine angle measures;
110. Find the slopes of lines;
111. Use slope to identify parallel and perpendicular lines;
112. Recognize and use distance relationships among points, lines, and planes.
113. Find the distance between a point and a line;
114. Identify points, lines, and planes in spherical geometry;
115. Compare and contrast basic properties of plane and spherical geometry;
116. Identify and use medians, altitudes, angle bisectors, and perpendicular bisectors in a triangle;
117. Recognize and use tests for congruence of right triangles;
118. Recognize and apply relationships between sides and angles in a triangle;
119. Apply the Triangle Inequality Theorem;
120. Apply the SAS Inequality and the SSS Inequality;
121. Find the geometric mean between two numbers;
122. Solve problems involving relationships between parts of a triangle and the altitude to its hypotenuse;
123. Use the Pythagorean Theorem and its converse;
124. Use the properties of 45°-45°-90° and 30°-60°-90° triangles;
125. Find trigonometric ratios using right triangles;
126. Solve problems using trigonometric ratios;
127. Use trigonometry to solve problems involving angles elevation or depression;
128. Recognize and apply the properties of a parallelogram;
129. Find the probability of an event;
130. Recognize and apply the conditions that ensure a quadrilateral is a parallelogram;
131. Identify and use subgoals in writing proofs;
132. Recognize and apply the properties of rectangles;
133. Recognize and apply the properties of squares and rhombi;
134. Recognize and apply the properties of trapezoids;
135. Recognize and use ratios and proportions;
136. Apply the properties of proportions;
137. Identify similar figures;

138. Solve problems involving similar figures;
139. Identify similar triangles;
140. Use similar triangles to solve problems;
141. Use proportional parts of triangles to solve problems;
142. Divide a segment into congruent parts;
143. Recognize and use the proportional relationships of corresponding perimeters, altitudes, angle bisectors, and medians of similar triangles;
144. Recognize and describe characteristics of fractals;
145. Solve problems by solving a simpler problem;
146. Identify and use parts of circles;
147. Solve problems involving the circumference of a circle;
148. Recognize major arcs, minor arcs, semicircles, and central angles;
149. Find measures of arcs and central angles;
150. Solve problems by making circle graphs;
151. Recognize and use relationships among arcs, chords, and diameters;
152. Recognize and find measures of inscribed angles;
153. Apply properties of inscribed figures;
154. Recognize tangents and use properties of tangents;
155. Find the measures of angles formed by intersecting secants and tangents in relation to intercepted arcs;
156. Identify and name polygons;
157. Find the sum of the measures of interior and exterior angles of convex polygons and measures of interior and exterior angles of regular polygons;
158. Solve problems involving angle measures of polygons;
159. Identify regular and uniform (semi-regular) tessellations.
160. Create tessellations with specific attributes;
161. Solve problems by using guess and check;
162. Find areas of parallelograms;
163. Find areas of triangles, rhombi, and trapezoids;
164. Find areas of regular polygons;
165. Find areas of circles;
166. Use area to solve problems involving geometric probability.

**COURSE DESCRIPTION: Precalculus** provides a strong foundation of precalculus concepts, techniques and applications to prepare students for Honors Calculus. The content of Precalculus deals with the algebra of linear, quadratic, polynomial and trigonometric functions. Technology is used as a tool to facilitate learning and doing mathematics. The intent of the course is to develop quantitative reasoning and problem solving skills as well as the ability to understand and communicate mathematical ideas effectively.

**TEXTBOOK:** Glencoe Advanced Mathematical Concepts by Gordon-Holliday, et al, Glencoe 1999.

**COURSE OBJECTIVES:**

The student will be able to:

1. Determine whether a given relation is a function;
2. Identify the domain and range of any relation or function;
3. Perform operations with functions;
4. Find composite functions;
5. Find and recognize inverse functions;
6. Find zeros of linear functions;
7. Graph linear equations and inequalities;
8. Find the distance between two points;
9. Find the slope of a line through two points;
10. Prove geometric theorems involving slope, distance and midpoints analytically;
11. Write linear equations using slope-intercept form;
12. Write linear equations using point-slope form;
13. Write equations of parallel and perpendicular lines;
14. Prove geometric theorems involving parallel and perpendicular lines analytically;
15. Solve systems of equations graphically;
16. Solve systems of equations algebraically;
17. Identify symmetrical graphs;
18. Use symmetry to complete a graph
19. Identify an odd function and an even function;
20. Identify the graphs of simple polynomial functions, absolute value functions, and step functions;
21. Sketch the graphs of these functions;
22. Determine the inverse of a relation or function;
23. Graph a function and its inverse;
24. Determine horizontal, vertical, and slant asymptotes;
25. Graph rational functions;
26. Graph polynomial, absolute value, and radical inequalities;
27. Find the derivative of a function;
28. Find the slope and the equation of a line tangent to the graph of a function at a given point;
29. Find the critical points of the graph of a polynomial function and determine if each is a minimum, maximum, or point of inflection;
30. Determine continuity or discontinuity of functions;
31. Identify the end behavior of graphs;
32. Determine roots of polynomial equations;
33. Apply the fundamental theorem of algebra;
34. Solve quadratic equations;
35. Use the discriminant to describe the roots of quadratic equations;
36. Graph quadratic equations and inequalities;

37. Find the factors of polynomials using the remainder and factor theorems;
38. Identify all possible rational roots of a polynomial equation by using the rational root theorem;
39. Determine the number of positive and negative real zeros a polynomial function has;
40. Approximate the real zeros of a polynomial function;
41. Graph polynomial functions;
42. Find the least common denominator of rational expressions;
43. Solve rational equations and inequalities;
44. Decompose a fraction into partial fractions;
45. Solve radical equations and inequalities;
46. Change from radian to degree measure and vice versa;
47. Find angles that are coterminal with a given angle;
48. Find the reference angle for a given angle;
49. Find the length of an arc given the measure of the central angle;
50. Find linear and angular velocities;
51. Find the area of a sector;
52. Find the values of the six trigonometric functions of an angle in standard position given a point on its terminal side;
53. Find exact values for the six trigonometric functions of special angles;
54. Find decimal approximations for the values of the six trigonometric functions of any angle;
55. Solve right triangles;
56. Determine whether a triangle has zero, one, or two solutions;
57. Solve triangle by using the law of sines;
58. Solve triangles by using the law of cosines;
59. Find the area of triangles;
60. Use the graphs of trigonometric functions;
61. Find the amplitude, period, and phase shift;
62. Graph various functions;
63. Evaluate inverse trigonometric functions;
64. Find principal values of inverse trigonometric functions;
65. Write equations for inverses of trigonometric functions;
66. Graph inverses of trigonometric functions;
67. Solve problems involving simple harmonic motion;
68. Identify and use reciprocal identities, quotient identities, Pythagorean identities, and symmetry identities;
69. Use the basic trigonometric identities to verify other identities;
70. Find numerical values of trigonometric functions;
71. Use the sum and difference identities for sine, cosine, and tangent functions;
72. Use the double- and half-angle identities for the sine, cosine, and tangent functions;
73. Solve trigonometric equations;

74. Write a linear equation in normal form;
75. Find the distance from a point to a line;
76. Find the distance between parallel lines;
77. Write the equations of lines that bisect angles formed by intersecting lines;
78. Use the properties of exponents;
79. Evaluate and simplify expressions containing rational exponents;
80. Evaluate expressions with irrational exponents;
81. Graph exponential functions;
82. Graph exponential inequalities;
83. Use the exponential function $y = e^x$;
84. Evaluate expressions involving logarithms;
85. Solve equations involving logarithms;
86. Graph logarithmic functions and inequalities;
87. Find common logarithms and antilogarithms of numbers;
88. Use common logarithms to compute powers and roots;
89. Solve exponential and logarithmic equations;
90. Solve exponential and logarithmic inequalities;
91. Find natural logarithms of numbers;
92. Solve equations using natural logarithms.

**COURSE DESCRIPTION:** **Honors Calculus** deals with functions, differentiation, limits, continuity, and techniques of integration. These techniques will be applied to such problems as curve sketching, maximum-minimum, finding area between curves and determining volumes of revolution. Students are required to select and research a mathematical topic and do a report on it.

**TEXTBOOK:** Calculus of a Single Variable by Larsen, et al, D.C. Heath 1994

**COURSE OBJECTIVES:**

The student will be able to:

1. Use and interpret interval notation.
2. Interpret graphs.
3. Find intercepts, domain, range for all functions.
4. Recognize and use symmetry in sketching functions and identify a function as odd, even or neither.
5. Evaluate composite functions.
6. Sketch the graph of the following functions: line, absolute value, rational, square root, quadratic and cubic.
7. Name and describe a limit.
8. Use the properties to determine limits.
9. Use appropriate techniques to evaluating limits.

10. Apply the concept of continuity and determine one-sided limits.
11. Determine infinite limits.
12. Apply the derivative to the tangent line problem.
13. Apply basic differentiation rules and rates of change.
14. Apply the product and quotient rules and determine higher order derivatives.
15. Apply the chain rule.
16. Apply the implicit differentiation method.
17. Solve problems involving related rates.
18. Identify extrema on an interval.
19. Apply Rolle's Theorem and the Mean Value Theorem.
20. Apply the first derivative test to determine the intervals over which a function is increasing or decreasing.
21. Apply the second derivative test to determine the concavity of a function.
22. Determine limits at infinity.
23. Solve optimization problems.
24. Apply indefinite integration to determine antiderivatives.
25. Determine the area under a curve.
26. Evaluate Riemann Sums and definite integrals.
27. Apply The Fundamental Theorem of Calculus.
28. Apply the method of integration by substitution.
29. Define the natural logarithmic function and determine the derivative of functions that involve the natural logarithm.
30. Integrate functions that involve the natural logarithm.
31. Determine the inverse of a function if it exists.
32. Apply the appropriate methods of differentiation and integration to exponential functions.
33. Determine the area of a region between two curves.
34. Apply the disk method to determine volume.

**COURSE DESCRIPTION: Math 1** is the first of an integrated three-course mathematics program. It is designed to help students learn algebra and apply it to the real world. Students will be given the opportunities to make connections from concrete models to abstract concepts. The real-world photographs and realistic data will help students see algebra in their world. Students will have many opportunities to review and use arithmetic and geometry concepts as they study algebra.

**TEXTBOOK:** Algebra Concepts & Applications, Cummins, et al, Glencoe, 2001

**SAT CONTENT:**

Simple computations; mean, median, and mode; odd and even numbers; data interpretation related to charts and graphs; signed number properties; simplifying algebraic expressions; solving equations; algebraic representation; slope of a line.

**COURSE OBJECTIVES:**

The student will be able to:

Chapter 1

1. Translate words into algebraic expressions and equations.
2. Use the order of operations to evaluate expressions.
3. Use the commutative and associative properties to simplify expressions.
4. Use the Distributive Property to evaluate expressions.
5. Use a four-step plan to solve problems.
6. Explore inductive and deductive reasoning.
7. Collect and organize data using sampling and frequency tables.
8. Construct and interpret line graphs, histograms, and stem-and –leaf plots.

Chapter 2

9. Graph integers on a number line and compare and order integers.
10. Graph points on a coordinate plane.
11. Add integers.
12. Subtract integers.
13. Multiply integers.
14. Explore matrices.
15. Divide integers.

Chapter 3

16. Compare and order rational numbers.
17. Add and subtract rational numbers.
18. Find the mean, median, mode, and range of a set of data.
19. Explore arithmetic sequences.
20. Determine whether a given number is a solution of an equation.
21. Solve addition and subtraction equations by using models.
22. Solve addition and subtraction equations by using properties of equality.
23. Solve equations involving absolute value.

Chapter 4

1. Multiply rational numbers.
2. Use tree diagrams or the Fundamental Counting Principle to count outcomes.
3. Explore permutations and combinations.
4. Divide rational numbers.
5. Solve multiplication and division equations by using the properties of equality.

6. Solve equations involving more than one operation.
7. Solve equations with variables on both sides.
8. Solve equations with grouping symbols.

Chapter 5

9. Solve proportions.
10. Solve problems involving scale drawings and models.
11. Solve problems by using the percent proportion.
12. Solve problems by using the percent equation.
13. Explore box-and-whisker plots.
14. Solve problems involving percent of increase or decrease.
15. Find the probability and odds of a simple event.
16. Find the probability of mutually exclusive and inclusive events.

Chapter 6

17. Show relations as sets of ordered pairs, in tables, and as graphs.
18. Solve linear equations for a given domain.
19. Graph linear relations.
20. Determine whether a given relation is a function.
21. Explore functions.
22. Solve problems involving direct variations.
23. Solve problems involving inverse variations.

Chapter 7

24. Find the slope of a line given the coordinates of two points on the line.
25. Write a linear equation in point-slope form given the coordinates of a point on the line and the slope of the line.
26. Write a linear equation in slope-intercept form given the slope and y-intercept.
27. Graph and interpret points on scatter plots.
28. Use best-fit lines to make predictions.
29. Graphing linear equations by using the x- and y-intercepts or the slope and y-intercept.
30. Explore the effects of changing the slopes and y-intercepts of linear functions.
31. Write an equation of a line that is parallel or perpendicular to the graph of a given equation and that passes through a given point.

**COURSE DESCRIPTION**: **Math 2** is the second of an integrated three-course mathematics program. It is designed to help students discover, learn and apply geometry. Students will be challenged to make connections from concrete examples to abstract concepts. The real-world photographs and realistic art will help students to see geometry in their world. They will have many opportunities to review and use algebra concepts as they study geometry.

**TEXTBOOK:** Geometry Concepts & Applications, Cummins, et al, Glencoe, 2001

**SAT CONTENT:** Area and perimeter of geometric figures; special properties of isosceles, equilateral, and right triangles; properties of parallel and perpendicular lines; simple coordinate geometry; slope of a line.

**COURSE OBJECTIVES:**

The student will be able to:

Chapter 1

1. Identify patterns and use inductive reasoning.
2. Explore number patterns in Pascal's triangle.
3. Identify and draw models of points, lines, and planes, and determine their characteristics.
4. Identify and use basic postulates about points, lines, and planes.
5. Write statements in if-then form and write the converses of the statements.
6. Use geometry tools
7. Use a four-step plan to solve problems that involve the perimeters and areas of rectangles and parallelograms.

Chapter 2

8. Find the distance between two points on a number line.
9. Apply the properties of real numbers to the measure of segments.
10. Identify congruent segments and find the midpoints of segments.
11. Name and graph ordered pairs on a coordinate plane.
12. Explore vectors.
13. Find the coordinates of the midpoint of a segment.

Chapter 3

14. Name and identify parts of an angle.
15. Measure, draw, and classify angles.

16. Explore triangles, quadrilaterals, and midpoints.
17. Find the measure of an angle and the bisector of an angle.
18. Identify and use adjacent angles and linear pairs of angles.
19. Identify and use complementary and supplementary angles.
20. Identify and use congruent and vertical angles.
21. Identify, use properties of, and construct perpendicular lines and segments.

Chapter 4

22. Describe relationships among lines, parts of lines, and planes.
23. Identify the relationships among pairs of interior and exterior angles formed by two parallel lines and a transversal.
24. Explore spherical geometry.
25. Identify the relationships among pairs of corresponding angles formed by two parallel lines and a transversal.
26. Identify conditions that produce parallel lines and construct parallel lines.
27. Find the slopes of lines and use slope to identify parallel and perpendicular lines.
28. Write and graph equations of lines.

Chapter 5

29. Identify the parts of triangles and classify triangles by their parts.
30. Use the Angle Sum Theorem.
31. Identify translations, reflections, and rotations and their corresponding parts.
32. Name and label corresponding parts of congruent triangles.
33. Explore congruence postulates.
34. Use the SSS and SAS tests for congruence.
35. Use the ASA and AAS tests for congruence.

Chapter 6

36. Identify and construct medians in triangles.
37. Identify and construct altitudes and perpendicular bisectors in triangles.
38. Identify and use angle bisectors in triangles.
39. Explore circumcenter, centroid, orthocenter, and incenter.
40. Identify and use properties of isosceles triangles.
41. Use tests for congruence or right triangles.
42. Use the Pythagorean Theorem and its converse.
43. Find the distance between two points on the coordinate plane.

Chapter 7

44. Apply inequalities to segment and angle measures.
45. Identify exterior angles and remote interior angles of a triangle and use the Exterior Angle Theorem.
46. Explore measure of angles and sides in triangles.
47. Identify the relationships between the sides and angles of a triangle.
48. Identify and use the Triangle Inequality Theorem.

Chapter 8

49. Identify parts of quadrilaterals and find the sum of the measures of the interior angles of a quadrilateral.
50. Identify and use the properties of parallelograms.
51. Identify and use tests to show that a quadrilateral is a parallelogram.
52. Identify and use the properties of rectangles, rhombi, and squares.
53. Identify and use the properties of trapezoids and isosceles trapezoids.
54. Explore kites.

Chapter 9

55. Use ratios and proportions to solve problems.
56. Identify similar polygons.
57. Use AA, SSS, and SAS similarity tests for triangles.
58. Identify and use the relationships between proportional parts of triangles.
59. Use proportions to determine whether lines are parallel to sides of triangles.
60. Explore ratios of golden triangles.
61. Identify and use the relationships between parallel lines and proportional parts.
62. Identify and use proportional relationships of similar triangles.

**COURSE DESCRIPTION:** **Math 2** is the second of an integrated three-course mathematics program. It is designed to help students discover, learn and apply geometry. Students will be challenged to make connections from concrete examples to abstract concepts. The real-world photographs and realistic art will help students to see geometry in their world. They will have many opportunities to review and use algebra concepts as they study geometry.

**TEXTBOOK:** Geometry Concepts & Applications, Cummins, et al, Glencoe, 2001

**SAT CONTENT:** Area and perimeter of geometric figures; special properties of isosceles, equilateral, and right triangles; properties of parallel and perpendicular lines; simple coordinate geometry; slope of a line.

**COURSE OBJECTIVES:**

The student will be able to:

Chapter 1

1. Identify patterns and use inductive reasoning.
2. Explore number patterns in Pascal's triangle.
3. Identify and draw models of points, lines, and planes, and determine their characteristics.
4. Identify and use basic postulates about points, lines, and planes.
5. Write statements in if-then form and write the converses of the statements.
6. Use geometry tools
7. Use a four-step plan to solve problems that involve the perimeters and areas of rectangles and parallelograms.

Chapter 2

8. Find the distance between two points on a number line.
9. Apply the properties of real numbers to the measure of segments.
10. Identify congruent segments and find the midpoints of segments.

11. Name and graph ordered pairs on a coordinate plane.
12. Explore vectors.
13. Find the coordinates of the midpoint of a segment.

Chapter 3

14. Name and identify parts of an angle.
15. Measure, draw, and classify angles.
16. Explore triangles, quadrilaterals, and midpoints.
17. Find the measure of an angle and the bisector of an angle.
18. Identify and use adjacent angles and linear pairs of angles.
19. Identify and use complementary and supplementary angles.
20. Identify and use congruent and vertical angles.
21. Identify, use properties of, and construct perpendicular lines and segments.

Chapter 4

22. Describe relationships among lines, parts of lines, and planes.
23. Identify the relationships among pairs of interior and exterior angles formed by two parallel lines and a transversal.
24. Explore spherical geometry.

25. Identify the relationships among pairs of corresponding angles formed by two parallel lines and a transversal.
26. Identify conditions that produce parallel lines and construct parallel lines.
27. Find the slopes of lines and use slope to identify parallel and perpendicular lines.
28. Write and graph equations of lines.

Chapter 5

29. Identify the parts of triangles and classify triangles by their parts.
30. Use the Angle Sum Theorem.
31. Identify translations, reflections, and rotations and their corresponding parts.
32. Name and label corresponding parts of congruent triangles.
33. Explore congruence postulates.
34. Use the SSS and SAS tests for congruence.
35. Use the ASA and AAS tests for congruence.

Chapter 6

36. Identify and construct medians in triangles.
37. Identify and construct altitudes and perpendicular bisectors in triangles.
38. Identify and use angle bisectors in triangles.
39. Explore circumcenter, centroid, orthocenter, and incenter.
40. Identify and use properties of isosceles triangles.
41. Use tests for congruence or right triangles.
42. Use the Pythagorean Theorem and its converse.
43. Find the distance between two points on the coordinate plane.

Chapter 7

44. Apply inequalities to segment and angle measures.
45. Identify exterior angles and remote interior angles of a triangle and use the Exterior Angle Theorem.
46. Explore measure of angles and sides in triangles.
47. Identify the relationships between the sides and angles of a triangle.
48. Identify and use the Triangle Inequality Theorem.

Chapter 8

49. Identify parts of quadrilaterals and find the sum of the measures of the interior angles of a quadrilateral.
50. Identify and use the properties of parallelograms.
51. Identify and use tests to show that a quadrilateral is a parallelogram.

52. Identify and use the properties of rectangles, rhombi, and squares.
53. Identify and use the properties of trapezoids and isosceles trapezoids.
54. Explore kites.

Chapter 9

55. Use ratios and proportions to solve problems.
56. Identify similar polygons.
57. Use AA, SSS, and SAS similarity tests for triangles.
58. Identify and use the relationships between proportional parts of triangles.
59. Use proportions to determine whether lines are parallel to sides of triangles.
60. Explore ratios of golden triangles.
61. Identify and use the relationships between parallel lines and proportional parts.
62. Identify and use proportional relationships of similar triangles.

APPENDIX F

Pairwise Comparison of Mathematics Course Sequences Using CATMT as a Covariate

| Course Sequence Pairwise Comparison | Mean Difference | Standard Error | Significance (exact *p* level) |
|---|---|---|---|
| MNNM-ANGA | -11.777 | 4.642 | .012 |
| MNNM-MAGA | -14.995 | 4.525 | .001 |
| MNNM-NANG | -8.437 | 4.000 | .036 |
| MNNM-AGNA | -12.879 | 6.430 | .046 |
| MNNM-MNMN | 9.682 | 4.513 | .033 |
| MNNM-NMMN | 11.788 | 5.241 | .025 |
| ANGA-ANMN | 10.300 | 4.927 | .038 |
| ANGA-MNMN | 21.459 | 4.222 | .000 |
| ANGA-NMMN | 23.565 | 4.998 | .000 |
| ANGA-NMNM | 17.880 | 5.188 | .001 |
| ANNG-NAGA | -7.104 | 3.455 | .041 |
| ANNG-MNMN | 17.573 | 3.699 | .000 |
| ANNG-NMMN | 19.680 | 4.562 | .000 |
| ANNG-NMNM | 13.995 | 4.752 | .004 |
| NAGA-AMNG | 7.104 | 3.455 | .041 |
| NAGA-NAGN | 8.309 | 3.577 | .021 |
| NAGA-NANG | 6.558 | 3.289 | .047 |
| NAGA-ANGN | 9.206 | 3.683 | .013 |
| NAGA-ANMN | 13.518 | 4.850 | .006 |
| NAGA-MNMN | 24.677 | 4.112 | .000 |
| NAGA-NMNM | 21.098 | 5.091 | .000 |
| NAGN-MNMN | 16.367 | 3.763 | .000 |
| NAGN-NMMN | 18.474 | 4.614 | .000 |
| NAGN-NMNM | 12.789 | 4.797 | .008 |
| NANG-MNMN | 18.119 | 3.553 | .000 |
| NANG-NMMM | 20.226 | 4.445 | .000 |
| NAGN-NMNM | 14.541 | 4.641 | .002 |
| AGNA-MNMN | 22.561 | 6.165 | .000 |
| AGNA-NMMN | 24.667 | 6.719 | .000 |
| AGNA-NMNM | 18.983 | 6.849 | .006 |
| ANAG-MNMN | 19.135 | 4.751 | .000 |
| ANAG-NMMN | 21.242 | 5.451 | .000 |
| ANAG-NMNM | 15.557 | 5.613 | .006 |
| ANGN-MNMN | 15.470 | 3.914 | .000 |
| ANGN-NMMN | 17.577 | 4.739 | .000 |
| ANGN-NMNM | 11.892 | 4.923 | .016 |
| ANMN-ANGA | 10.300 | 4.927 | .038 |
| ANMN-MNMN | 11.159 | 4.958 | .025 |
| ANMN-NMMN | 13.265 | 5.630 | .019 |
| NMNM-MNNM | 11.788 | 5.241 | .025 |
| NMMN-NAGA | 26.783 | 4.905 | .000 |
| NMMN-NAGN | 18.474 | 4.614 | .000 |