The Influence of Teaching Methods on Student Achievement on Virginia's End of Course Standards of Learning Test for Algebra I

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Dissertation submitted to the Faculty of the

Virginia Polytechnic Institute and State University

In partial fulfillment of the requirements for the degree of

Doctor of Education

In

Educational Leadership and Policy Studies

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September 9, 2002

Virginia Beach, Virginia

Key Words: Algebra, Instructional Practices, Teaching Methods, Achievement

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Student Achievement on Virginia's End of Course Standards of Learning Test for Algebra I

by

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(Abstract)

Given Virginia's *Standards of Learning* (SOL)(1995) mandates, Virginia's Algebra I teachers and school leaders should utilize research for teaching methods; further, the relationship between teaching methods and student achievement on Virginia's End of Course SOL Test for Algebra I deserves investigation, since Virginia's students must pass this test to earn verified credit toward high school graduation.

Replicating Marcucci's (1980) methodology for meta-analysis, the present study focuses on research with methods for teaching secondary level algebra from 1980 to 2001. From a sample of 34 studies with 62 effect sizes, six categories for teaching methods and corresponding effect sizes were derived for "good" studies: direct instruction (.67), problem-based learning (.44), technology aided instruction (.41), cooperative learning (.26), manipulatives, models, and multiple representations (.23), and communication and study skills (.16).

Using results from the meta-analysis and review of literature and extensive content validation, a 51-item questionnaire with a reliability coefficient of .89 was developed. The questionnaire was posted as a web-site to survey selected Algebra I teachers in Region VII to ascertain how frequently they use research-based teaching methods and to determine the influence of teaching methods on their students' achievement on the spring, 2002, Algebra I SOL Test.

Ninety-eight percent of teachers surveyed responded. The 53 participating Algebra I teachers, representing 1,538 students, produced a passing mean scale score of 438.01 (SD = 32.67). Teachers indicated they used all teaching method categories more than half the time with mean usage frequencies ranging from 2.56 to 3.75 times out of five class sessions. Teaching method categories were then entered into a blockwise multiple regression analysis, ranked according to the strength of their correlations to teachers' mean scale SOL test scores. Teaching method usage shared 9.7% of variance with participating teachers' scores.

Meta- and regression analysis results suggest that Algebra I teachers should emphasize direct instruction, technology aided instruction, and problem-based learning. These three teaching method categories ranked highest in both analyses. The questionnaire developed here could be used with a larger sample for research into the influence of teaching methods on individual reporting categories on the Algebra I SOL test.

DEDICATION

Sheri and Mark, this work is for you. I love you right up to the moon – and back.

ACKNOWLEDGEMENTS

Dr. Travis Twiford, thank you for being a constant source of encouragement and friendship. You are an advisor in every best sense of the word and a blessing to me on this arduous journey. Dr. Mary Yakimowski, thank you for teaching me what I know about research and mentoring me. You inspired me to pursue this topic and gave me the confidence and tools I needed to do it. Dr. Steven Janosik, thank you for your well-timed and enlightening doses of reality. Your encouraging insights made me rethink my work for the better, and you always found a way to phrase them positively. Dr. Louis Tonelson, thank you for being my principal. I have always looked up to you, and you never fail to make me a better person. Dr. Stephen Parson, thank you for your timing, candor, and sense of humor. I have learned that a comment or question from you is always the right one at the right time; and, it is always an improvement.

I want to thank Dr. Robert Marcucci for allowing me to replicate his meta-analysis methodology for my review of literature. By spending a few minutes with me on the phone and giving his blessing for my study, Dr. Marcucci laid the foundation for my research. I must also thank the following people who made the study possible. Mr. Terry Hawthorne loaned me his talents in converting my questionnaire into an active server page. Dr. Skip Wilson and his spring, 2002, EDCI 4744 & 5744 students validated my questionnaire. Virginia Beach City Public Schools allowed me to work with fifteen math teachers to obtain reliability data for the scale; and, these fifteen teachers volunteered to participate. Mrs. Sheri Haas listened to countless renditions and aspects of this study and edited it.

I cannot thank the participating superintendents, principals, and teachers of Region VII of the Commonwealth enough for trusting me and working with me to complete this research. Your

willingness to participate speaks highly of your dedication to students and your interest in educational research.

Mr. Henry Blessing and Mrs. Susan Blessing gave me a place to stay and plenty of love during my orientation to residency and at every step of the way through this process.

My mother and father, James and Joan Haas, made me the type of person who can finish a job with ethics, with attention to detail, and with concern for other people, whether someone is watching or not. Knowing, as I always have, that my parents would love me through success or failure, made me willing to take this risk and to see it through.

My wife Sheri and my son Mark gave up their time with me and put up with me. They have been patient beyond reason and have supported me in every way and unconditionally. Of all the blessings I have, my wife and son are the greatest.

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CHAPTER I
THE PROBLEM AND ITS CONTEXT

"This intellectual Pearl Harbor, a real gutsy sock to the stomach."

Allen Hyneck, Professor of Astronomy and Director of Dearborn Observatory, Northwestern University, April 27, 1986.

An International Context

On October 4, 1957, the Soviet Union successfully launched the Earth's first artificial satellite. As Americans sat transfixed by their radios, listening to the repeated pattern of beeps emitted from Sputnik, they were caught off-guard. The public "feared that the Soviet's ability to launch satellites also translated into the capability to launch ballistic missiles that could carry nuclear weapons from Europe to the U.S" (NASA, 2000, p. 2). The United States responded with a satellite of its own on January 31, 1958, the Explorer. The first Explorer satellite aided scientists in discovering the Van Allen radiation belts and was followed by a series of other Explorer satellites used by the United States to investigate the solar system. In addition to the Explorer Satellite Series, NASA was created in October 1958 by an act of Congress (NASA, 2000).

According to Alexander and Salmon (1995), another act of Congress, established in 1958 in direct response to Sputnik, forever changed the relationship of the federal government to education. The National Defense Education Act, Public Law 85-864, approved large expenditures to provide for instructional programs at all levels ranging from elementary school through college in various areas including vocational training, foreign language instruction, and improved equipment, facilities, and training in mathematics and science (U.S. Congress, 1958). With this act the federal government infused money into the public schools with the intention of surpassing the Soviet Union and other nations in mathematics and scientific achievement. Since

1958, the United States has surpassed other nations by conducting the first manned orbit of the Earth and sending the first man to the moon.

Today, the Soviet Union no longer exists and “Space Race” is a term nostalgically associated with the Kennedy administration. The United States leads the world economy, but according to the National Center for Education Statistics (NCES), this leadership position is at risk. In its 2000 findings from the Third International Mathematics and Science Study – Repeat (TIMSS-R), NCES (2000) reported that U.S. eighth-graders continue to perform just below the international average in mathematics when compared to the 23 nations participating in both the 1995 Third International Mathematics and Science Study (TIMSS) and the 1999 TIMSS-R assessments, with no statistically significant changes in performance since 1995. According to this study U.S. eighth-graders exceeded the international average in mathematics among the 38 nations participating in 1999. This positive news is coupled with the disappointing news that the relative performance of the U.S. in mathematics was lower for eighth-graders in 1999 than it was for the same cohort of fourth graders four years earlier in the 1995 TIMSS.

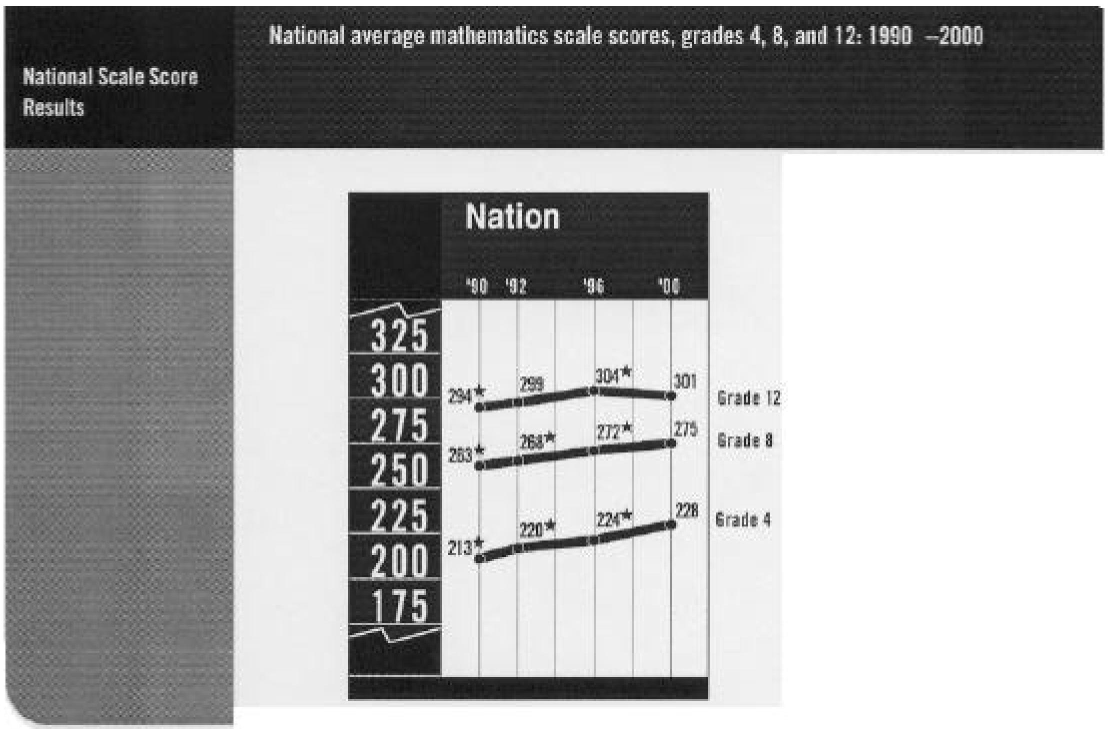
In the 1999 TIMSS-R, 14 nations had significantly higher scores in mathematics than the U.S. average, including the Russian Federation. Further, only nine percent of U.S. students reached the top 10% of all students assessed. This was a statistically insignificant increase from six percent in 1995. Eight nations had significantly higher percentages of students reaching the top 10%, including Japan. In the content area of algebra, 10 of the 38 nations assessed for the TIMSS-R in 1999 had scores significantly higher than those of U.S. eighth-graders (NCES, 2000).

A National Context

In the *No Child Left Behind Act of 2001*, President Bush (2001) outlined the blueprint for the U.S. educational system as the nation entered the twenty-first century. On January 8, 2002, this Act was signed into law. Two components of the law are increased accountability for student performance and a focus on scientifically based programs that show results. More specifically, one goal cited in the blueprint is strengthening mathematics and science education; “K-12 math and science education will be strengthened through math and science partnerships for states to work with institutions of higher education to improve instruction and curriculum” (Bush, 2001, p. 6).

The assessment used by the federal government is the National Assessment of Educational Progress (NAEP). Since 1969, the federal government has used the NAEP for the purposes of collecting, analyzing, and producing “valid and reliable information about the academic performance of students in the United States in various learning areas” (Reese, Miller, Mazzeo, & Dossey, (1997, p. 1). The 2000 NAEP assessment in mathematics constitutes the fourth time mathematics has been assessed with the new framework developed in the 1990s, enabling policy makers and educators to track mathematics achievement since the release of the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards for School Mathematics* in 1989.

Major findings from the 2000 NAEP mathematics assessment show progress in the mathematics performance by U.S. students when compared to the 1990 and 1992 assessments. See Figure 1. Fourth, eighth, and twelfth-grade students had higher average scores in 2000 than in 1990, the first year in which the current NCTM framework was used. Twelfth-graders’ scores increased from 1990 to 1996, but they declined in 2000. The percentage of students at or above the Proficient level increased for all three grades. Gains were made at the Advanced and Basic levels as well, but from 1996 to 2000, the percentage of twelfth graders reaching the basic level fell. Higher, middle and lower level students made gains since 1990 at each grade level, with the exception of the twelfth grade, where a decline in the average score was shown in the scores of students in the middle- and lower- performance ranges: the 50^{th}, 25^{th}, and 10^{th} percentiles.



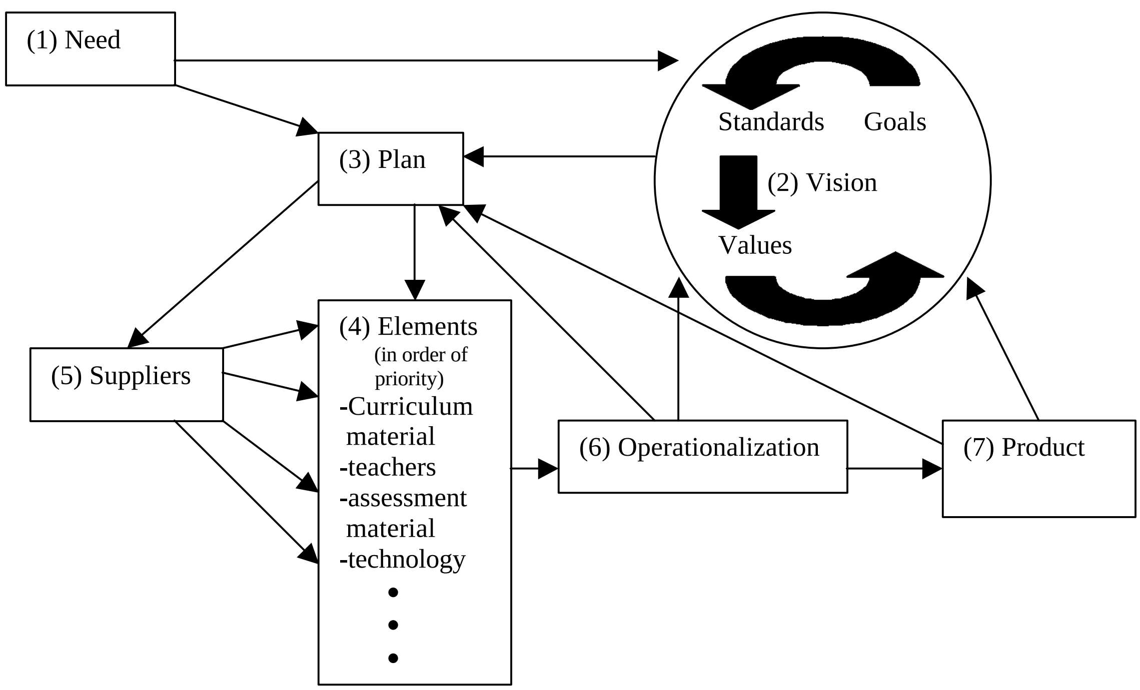
*Significantly different from 2000.
SOURCE: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 1990,1992,1996, and 2000 Mathematics Assessments

Note. From *The Nation's Report Card: Mathematics 2000,* (p. 24), by J. S. Braswell, A.D. Lutkus, W.S. Grigg, S.L. Santapau, B. Tay-Lim, and M. Johnson, 2001, Washington, DC: U.S. Department of Education.

Figure 1. NAEP progress from 1990 to 2000.

A State Context

In the summer of 1995, the Commonwealth of Virginia took a major step in initiating educational reform as outlined by Romberg (1998) NCTM Chair from 1986 to 1995: the incorporation of a vision for preparing students for the twenty-first century into goals and standards. See Figure 2 below. The product of this step toward goals and standards, entitled *Standards of Learning* (SOLs), was intended to "chart the course" for implementing such a vision in the four core areas of instruction: English, mathematics, science, and history.



Note. From "Comments: NCTM's curriculum and evaluation standards," by T. A. Romberg, 1998, *Teachers College Record*, 100, p. 16.

Figure 2. The next steps: Romberg's model for mathematics education reform.

The NCTM's *Curriculum and Evaluation Standards for School Mathematics* (1989) was the source of the SOL goals for mathematics: "The content of the mathematics standards [SOLs] is intended to support the following four goals for students: becoming mathematical problem solvers, communicating mathematically, reasoning mathematically, and making mathematical connections" (Commonwealth of Virginia, 1995, p. 9).

Virginia lawmakers and educators further aligned the state's standards with the NCTM standards (1989) by proposing that all students are to learn algebra; "All students are expected to achieve the Algebra I standards" (Commonwealth of Virginia, 1995, p. 10). The NCTM had previously outlined new societal goals, including "Opportunity for All."

> The social injustices of past schooling practices can no longer be tolerated. Current statistics indicate that those who study advanced mathematics are most often white males. Women and most minorities study less mathematics and are seriously underrepresented in careers using science and technology. Creating a just society in which women and various ethnic groups enjoy equal opportunities and equitable treatment is no longer an issue. Mathematics has become a critical filter for employment and full participation in our society. We cannot afford to have the majority of our population mathematically illiterate. Equity has become an economic necessity. (1989, p. 4)

According to the NCTM (1989), "Algebra is the language through which most of mathematics is communicated" (p. 150). For students to apply the mathematics they have learned to participation in the work force, they must have a more sophisticated understanding of algebraic representation. This is so because "increasing use of quantitative methods, both in the natural sciences and in such disciplines as economics, psychology, and sociology, have made algebraic processing an important tool for applying mathematics" (NCTM, 1989, p. 150). For students to apply the mathematics they have learned to do the work they will some day find themselves doing, they must be able to reason algebraically. Thus, it is essential for students to master algebra. To this end, Virginia requires students to earn three credits in mathematics at or above the level of algebra in order to receive a standard diploma (SOLs, 1995, p. 3).

According to Romberg's (1998) model for implementing changes in a mathematics curriculum, Virginia educators should be engaged in the ongoing process of planning and developing the elements of curriculum change so that suppliers may provide for these elements and so that operationalization of the plans can take place. As mathematics educators make decisions regarding algebra curricula and teaching methods, they should examine indicators of student achievement on standardized assessments aligned with the curriculum, such as the End of Course Standards of Learning (SOL) Test for Algebra I. The percentage of Virginia's students passing the Algebra I SOL Assessment has risen since 1998 when 40.4% passed. In 2001, 74% of all students taking the assessment passed, representing a 34% increase since 1998 (Virginia Department of Education, 2001c).

Table 1

Percentage of Students Passing Virginia's End of Course Standards of Learning (SOL) Test for Algebra I

Pass Rates				Change		
1998	1999	2000	2001	Second Year	Third Year	Fourth Year
40	56	65	74	+16	+25	+34

The NAEP 1996 Mathematics State Report Card for Virginia also showed an increase in the average scale score for Virginia's eighth grade algebra students. This positive trend is blemished, however, by other data presented. Virginia's algebra students lost ground when compared with other students in the U.S. and in the Southeast region of the U.S. (Reese, Jerry, & Ballator, 1997). This trend is demonstrated in Table 2. While Virginia's average algebra scale score on the NAEP assessment rose from 265 in 1990 to 271 in 1996, the Southeast region's score increased from 256 to 266 during the same time period. Further, the national average scale score rose from 260 to 272. Finally, while Virginia's students increased their scores on the algebra NAEP from 1990 to 1996, they still scored at the basic level.

Table 2

NAEP 1990-1996 Algebra Scale Scores for Virginia, Southeast Region, and U.S.

Region	Average Scale Score		Change
	1990	1996	
Virginia	265	271	+6 Points
Southeast Region	256	266	+10 Points
United States	260	272	+12 Points

More recent data from the 2000 Mathematics NAEP (U.S. Department of Education, 2000b) shows gains for Virginia's eighth graders in the general area of mathematics. Since one of the strands for the NAEP is algebra, there may be a promising trend for Virginia's mathematics program of studies because the 2000 NAEP allows for five years of implementation of the Standards of Learning for Virginia's students.

Table 3

NAEP Mathematics Scale Scores for Virginia, Southeast Region, and U.S., 1990-2000

Region	Average Scale Score			Change
	1990	1996	2000	
Virginia	264	270	277	+13
Southeast Region	254	264	265	+11
United States	262	271	274	+12

Statement of the Problem

Since the NCTM's (1989) first publication of the *Curriculum and Evaluation Standards for School Mathematics*, the Council has published two other documents: *Professional Standards for Teaching Mathematics* (1991) and *Assessment Standards for School Mathematics* (1995). Recently, the NCTM released its first revision of the original 1989 document, *Principles and Standards for School Mathematics* (2000). Although this document and the others are intended to be resource guides for educational decision makers as they plan for curriculum changes in mathematics (NCTM, 2000), the question looms as to what extent the operationalization stage of Romberg's model for mathematics education reform is being carried out in the classroom by Virginia's high school Algebra I teachers. Further, while 74% of students taking the end of course SOL assessment for Algebra I passed it in 2000,more than one-fourth did not. It is this remaining quarter of students that may be the most challenging to reach.

Research Purpose

The major purpose of the current study is to investigate the influence of teaching methodology on student achievement on the SOL assessment for Algebra I. The operationalization stage for mathematics education reform leads into an output stage. Currently, the "output" measure for Virginia's Algebra I teachers is the End of Course SOL Test for Algebra I. Thus, it is important to determine the effectiveness of research-based teaching methods using this output measurement. The NCTM and the Commonwealth of Virginia have set standards for algebra instruction. To paraphrase Wagner and Kieran (1989), it is timely to examine teaching methods within the context of these standards in order to make applicable recommendations to classroom teachers to improve children's learning of algebra.

Research Questions

For the review of literature, Marcucci's (1980) meta-analysis of experimental research on teaching methods for mathematics problem solving has been replicated with the goal of updating his research to synthesize research findings from 1980 to 2001 on methods for teaching algebra knowledge and skills at the secondary school level. Pertinent research studies have been categorized according to the teaching method investigated, and the mean effect size for studies in each category is used to compare teaching method types. Thus, the central question addressed will be similar to that found in Marcucci's dissertation: Based upon available research evidence, which type of teaching methodologies appear to be the most effective in teaching algebra knowledge and skills to students at the secondary school level? Related to this question is an examination of the influence of study characteristics on the results of the studies included in the meta-analysis.

The categories derived for teaching method types will be used to focus further exploration of teaching methods. The culminating research question for this study is addressed with the use of these teaching method categories as independent variables in a multiple regression analysis: To determine the extent and manner in which the teaching method categories explain variance in student achievement on Virginia's End of Course SOL Test for Algebra I. Table 4 provides the constitutive and operational definitions for the research questions.

Table 4

Constitutive and Operational Definitions

Term	Constitutive Definition	Operational Definition
Algebra student achievement	The student's demonstration of skill and knowledge acquisition in algebra	The student's scale score on the Algebra I Standards of Learning (SOL) Assessment
Teaching method types	Clusters of specific teaching methods	Cooperative learning; communication and study skills; technology aided instruction; problem-based learning; manipulatives, models, and multiple representations; direct instruction
Teaching methods	Narrow behavioral activities used in teaching algebra	Narrow behavioral activities used in teaching algebra

Limitations and Delimitations of the Study

This study involves intact classrooms in natural settings; thus, it cannot approach true experimental conditions and contains limitations within the research design that reduce the generalizability of results to a population other than the one studied. The choice of research design was based on an attempt to explain variance in student achievement through teaching methods. Within the classroom setting, the methodology of the teacher plays a crucial role in student achievement; however, as Walberg (1984) explains, there are many other factors that affect student achievement that are beyond the control of the teacher and the researcher.

Factors such as students' grade level and prior ability level in mathematics may be intervening variables that affect the external validity of this study. Marcucci (1980) classified effect sizes for teaching methods for mathematics problem solving (one component of learning algebra) by student grade level and ability level. Each teaching method produced varied effects, depending on the grade level and prior ability level of the students. For example, the heuristic method, a "method stressing the teaching of general problem solving skills, such as drawing a diagram or simplifying a problem using smaller numbers, so that the subject develops a repertoire of problem solving strategies," (p. 24) produced a mean effect size of 0.35 (n = 21) for elementary students and –0.02 (n = 16) for secondary students. The same teaching method produced a mean effect size of 0.18 (n = 7) for low ability students, a mean effect size of 0.06 (n = 3) for middle ability students, and 0.05 (n = 5) for high ability students.

Teacher effects on students go beyond and can interact with teaching methods to influence student learning. These effects may include the teachers' knowledge of and experience with teaching Algebra I in Virginia, coverage of curriculum as it is assessed on the end of course test, rapport between the teacher and student, and classroom management practices. Any of these teacher effects can interact with teaching methods to enhance or detract from student achievement, and in addition, the results of this study. The NCTM (2000) states

> Teachers need several different kinds of mathematical knowledge – knowledge about the whole domain; deep, flexible knowledge about curriculum goals and about the important ideas that are central to their grade level; knowledge about the challenges students are likely to encounter in learning these ideas; knowledge about how ideas can be

represented to teach them effectively; and knowledge about how students' understanding can be assessed. (p. 17)

This type of knowledge may be largely dependent on the teacher's experience with a particular curriculum and subject area. Marzano, Pickering, and Pollack (2001) warn that focusing only on instructional strategies leaves out other components of teaching that affect student achievement, suggesting that "effective pedagogy involves three related areas: (1) the instructional strategies used by the teacher, (2) the management techniques used by the teacher, and (3) the curriculum designed by the teacher" (p. 10).

Another limitation for this study is the use of multiple school districts and schools for its setting. Virginia developed the Standards of Learning (1995) to prompt curricular changes throughout the state. Teachers have access to a standard scope and sequence for Algebra I instruction provided by the Virginia Department of Education (2001b). The Department of Education (2002) has also recently provided a curriculum framework for algebra and other mathematics instruction. While these documents are provided to standardize instruction and provide guidance to mathematics teachers, school districts may approach the challenge of implementing the state curriculum with differing curricula and textbooks. These aspects of instruction may play a large role in student achievement in conjunction with teaching methods, as suggested above by Marzano, Pickering, and Pollock (2001); yet, they are unaccounted for in this study.

Certain restrictions, such as choice of instrumentation, are intentionally entered into the research design. These parameters are referred to as delimitations and also serve as threats to external validity in the case of this study. The choice of Algebra I as the subject area falls into this category. The decision to use Algebra I as a delimitation within this design was based on the fact that Algebra I is the one secondary level mathematics course that all Virginia students must pass to graduate (Commonwealth of Virginia, 1995). The Virginia Algebra I SOL assessment was chosen because it is the sole measurement used to determine whether a student receives a verified credit toward graduation for Algebra I, if the student earns a passing grade in the course.

The choice to use a researcher-developed questionnaire is another delimitation for this study. The questionnaire was developed based on categories from a quantitative review of literature followed by content validation by experts. The quantitative review of literature has many limitations and delimitations as discussed in Chapter II. Choices regarding the definition for each category and the placement of teaching methods under each category were this researcher's responsibility. The questionnaire is a self-report instrument with items based on the results of the meta-analysis in Chapter II, thus it may be considered subjective in nature, although every effort was made to make each item a forced choice. Further, the response window for the questionnaire was immediately prior to the spring administration of the SOL tests for 2002. This time period was chosen because teachers may emphasize different teaching methods before and after the testing window.

Finally, only one region of Virginia was selected as the population for this study, and seven of its nineteen school districts were selected within the region. The systematic sampling procedure is described in Chapter III. This was done in order to add credibility to the process by having it known to participants that this researcher lives and works in the region. Teachers may have found it imposing and perhaps intimidating to participate in this study; this researcher tried to alleviate these feelings by working with a small sample to build positive relations with superintendents and principals before moving forward. This choice of one region does impact the study’s generalizability to other populations in the Commonwealth, as each region is unique in terms of geography and demographics.

A Theory of Educational Productivity

Walberg (1984), following the tenets of research in agriculture, engineering, and medicine, proposed abandoning early research practices where the relation of a single cause and effect are studied. His premise is that we should begin to view the educational process in terms of its power to produce outcomes. Many American industries have increased the value of their output through experimentation and statistical studies; educational leadership should use the same approach. While cost is inevitably a factor, it is not a factor until after the effectiveness of an approach is tested exhaustively to see if it has an effect on the productivity of schools. Thus, those who argue that costs should be considered first in light of dwindling financing for education are arguing counterproductively. This type of thinking, according to Walberg, leads to attempts at quick fixes based on fads that lead to greater costs and loss of productivity in the long run.

After synthesizing an expansive body of research, Walberg determined nine factors that “require optimization to increase affective, behavioral, and cognitive learning” (1984, p. 20). See Figure 3. Walberg states that these “potent, consistent, and widely generalizable” factors fall into three groups: student aptitude, instruction, and environment. Student aptitude includes:

1) Ability or prior achievement, as measured by the usual standardized tests,
2) Development, as indexed by chronological age or stage of maturation, and
3) Motivation, or self-concept, as indicated by personality tests or the student’s willingness to persevere intensively on learning tasks.

Instruction includes:

4) The amount of time students engage in learning and

5) The quality of the instructional experience, including psychological and curricular aspects.

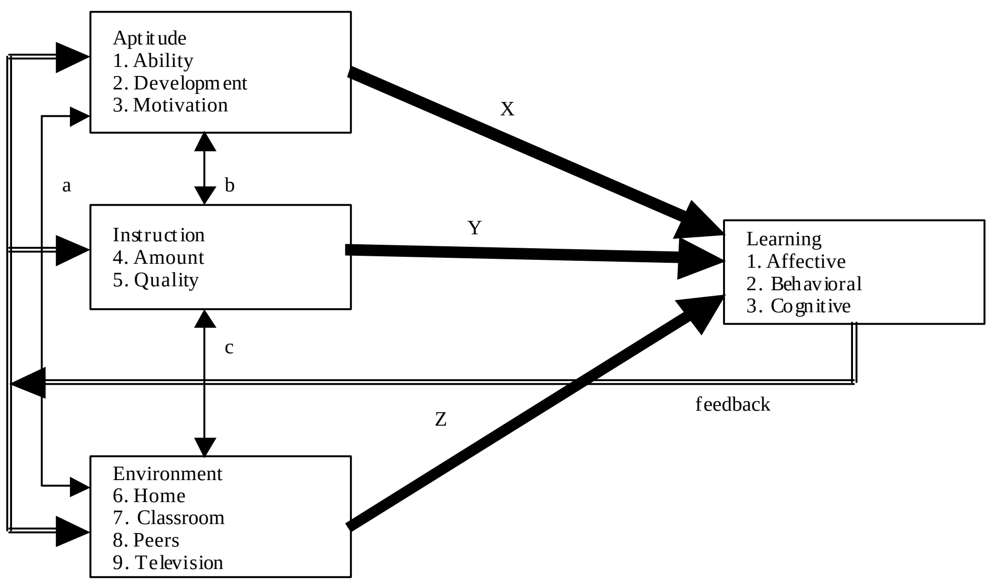
Four environmental factors also consistently affect learning: the educationally stimulating, psychological climates of

6) The home,

7) The classroom and social group,

8) The peer group outside the school, and

9) Use of out-of-school time (specifically leisure-time television viewing).



Aptitude, instruction, and the psychological environment are major direct causes of learning (shown as thick arrows X, Y, and Z). They also influence one another (shown as arrows a, b, and c), and are influenced by feedback on the amount of learning that takes place (shown as outlined arrows).

Note. From "Improving the productivity of America's schools," by H. J. Walberg, 1984, *Educational Leadership*, 41, p. 21.

Figure 3. Walberg's model for causal influences on student learning.

Walberg states that the first five factors are well known in several educational models. Each of these factors appears necessary for learning in school. None can be readily ignored. For example, large amounts of unsuitable instruction will cause students to learn very little. While these five factors are important, they are only moderately alterable by educational leadership, since curricula and time allotments spent on various subjects and activities are partly determined by many and diverse economic, political, and social forces.

Educational leaders must acknowledge the fact that they cannot raise student achievement by their efforts alone. Environmental factors have a strong influence on student achievement. Further, we must not assume that all influences on student learning outside school are working counter to school goals. Walberg states that even television viewing time, when kept to 10 hours, as opposed to the typical 30 hours per week, can enhance student learning in school. It is necessary to place school factors and environmental factors in their proper perspectives. One way to do so, as proposed by Walberg, is according to time. One hundred and eighty days of school for thirteen years of a person's life accounts for roughly 13% of his time between birth and age 18. Thus, factors outside the control of school may dominate the individual's development.

One hundred and thirty-five hours of algebra instruction constitutes less than six percent of a student's waking hours during a single school year. Rather than looking at this fact and deciding that there is little the school or teacher can do to affect student achievement in light of the remaining 94% of the time spent away from algebra, the educational leader must concentrate on improving the quality of instruction the student is receiving. This is the only factor within the realm of the principal's and teacher's direct control. Even researchers who propose that students "construct" their own knowledge in algebra, label education as the single process that shapes the student’s understanding and skills in algebraic concepts. This concept is demonstrated in Figure 4 from Blais (1988).

Note. From “Constructivism: A theoretical revolution for algebra,” by D. M. Blais, 1988, *Mathematics Teacher*, 81, p. 624.

Figure 4: Blais’ constructivist model for algebra learning.

Learning theories differ according to how they explain the student’s transformation from novice to expert in algebra, but the key element is education as it is named in many terms and defined in many ways. Walberg proposes no specific learning theory within his model; rather, the premise is that the teaching method should be researched empirically for its effectiveness beyond the theory from which it derives. For the purposes of this study, quality of instruction is the focus.

Within Romberg’s model in Figure 2, the “planning” and “standards” development stages would be better informed from research focusing not only on the curriculum as outlined in the “elements” stage of mathematics education reform, but also from research examining the influence of methods used by algebra teachers in implementing the curriculum. Figure 5 displays an algebra instruction focus from Walberg’s model within the context of the operationalization stage of Romberg’s model.

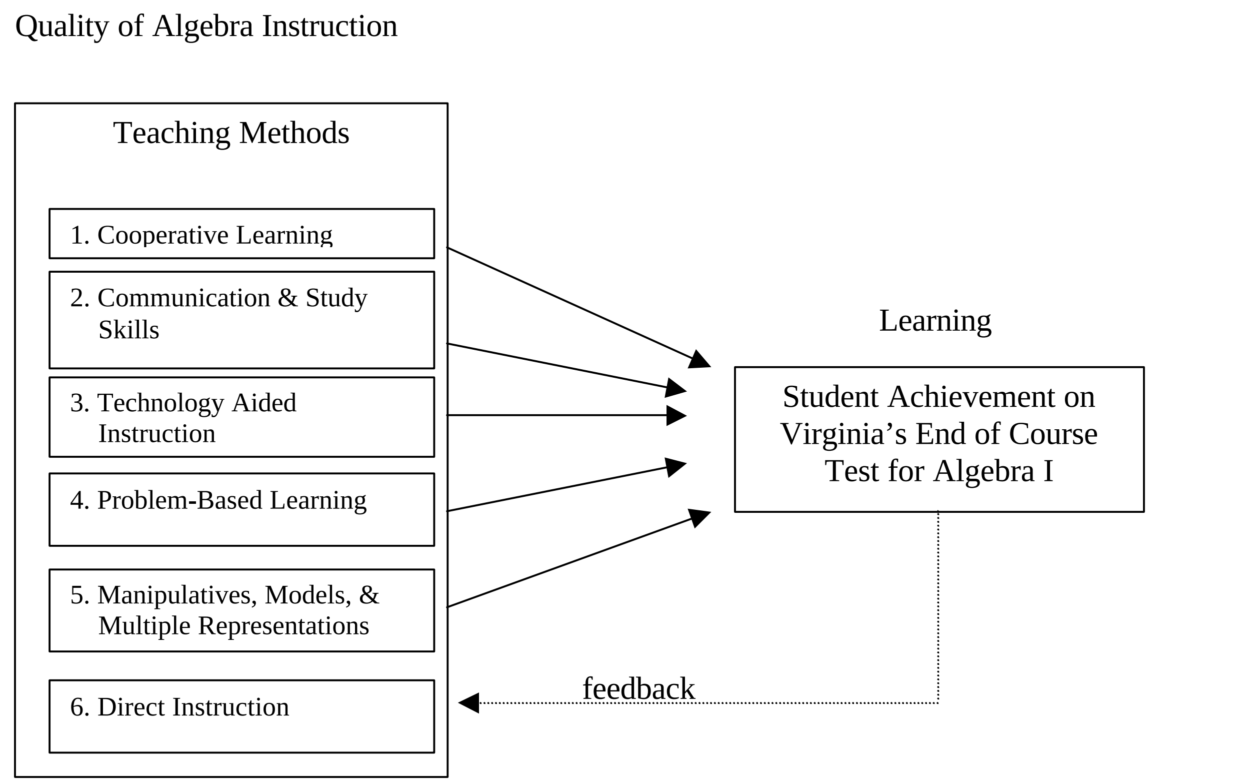


Figure 5. Theoretical model explaining algebra student achievement by teaching methods.

Overview of Succeeding Chapters

Chapter II is divided into five sections. The first section discusses the mathematics education reform movement and its proposals. The second section states the nature and scope of the review of literature. This section discusses the meta-analysis approach to reviewing experimental research regarding teaching methods for algebra. The third section explains the application of meta-analysis to experimental research studies as a method for research integration. The fourth section presents the analysis of data and results. This includes an overview of the teaching method types and their effect sizes based on the review of literature.

Section five outlines the use of multiple regression analysis to apply results from the quantitative review of literature to Virginia's current assessment for Algebra I achievement.

Chapter III includes a detailed account of the methodology used in the culminating investigation, including the setting and population, the research design, data collection, instrumentation, and analysis techniques. Chapter IV presents the analysis of data and results in four sections. First, there is a description of the sample of participants. Next, a correlation matrix is provided to display relationships between variables. A table and equation describing the results of the regression analysis present the relationship between teacher usage of each teaching method category and the mean scale score on the End of Course SOL Test for Algebra I. This is followed by a summary of findings for each teaching method category.

Chapter V contains a summary of the findings and a discussion. In the context of this discussion, both the limitations and implications of the research results are communicated. This information is followed by recommendations for practitioners, suggestions for future studies, final reflections, and a conclusion.

CHAPTER II
REVIEW OF LITERATURE

"Perhaps I could best describe my experience of doing mathematics in terms of entering a dark mansion. You go into the first room and it's dark, completely dark. You stumble around, bumping into furniture. Gradually, you learn where each piece of furniture is. And finally, after six months or so, you find the light switch and turn it on. Suddenly, it's all illuminated and you can see exactly where you were. Then you enter the next dark room…"

Professor Andrew Wiles
(Aczel, 1996, p. xi)

According to Romberg (1992), reform efforts in the U.S. education system, including the National Council of Teachers of Math (NCTM) *Curriculum and Evaluation Standards for School Mathematics* (1989), are a response to criticisms of contemporary education practices. The most potent of these criticisms is found in the National Commission on Excellence in Education's (NCEE) 1983 report entitled *A Nation at Risk*. The report presented the status of the United States as a nation in competition with the world's other leading nations, stating that our educational system was failing to prepare young people to take leadership in this competition. Further, as a nation, we would never allow a foreign invader to force an educational system like ours on our children. "We have even squandered the gains in student achievement made in the wake of the Sputnik challenge" (1983, p. 5).

In *A Nation at Risk*, the NCEE made several recommendations for improving our nation's educational system, among them was a recommendation to strengthen state and local high school graduation requirements. To implement this recommendation, the following illustration was provided:

> The teaching of mathematics in high school should equip graduates to: (a) understand geometric and algebraic concepts; (b) understand elementary probability and statistics; (c) apply mathematics in everyday situations; and (d) estimate, approximate, measure, and test the accuracy of their calculations. In addition to the traditional sequence of

studies available for college-bound students, new, equally demanding mathematics curricula need to be developed for those who do not plan to continue their formal education immediately. (p. 25)

Responding to *A Nation at Risk* and reports like it, Berliner and Biddle (1995) discussed the “interpretive spin” that is placed on NAEP scores by critics to reinforce their claims that U.S. schools are failing. In *A Manufactured Crisis* the authors stated that the NAEP program is an excellent source of data regarding student performance in mathematics. NAEP scores for the 1970s and 1980s, however, do not support the “mythic decline of American student achievement;” rather, the scores show very little variation over this time period. Berliner and Biddle suggest that American students are learning as much mathematics, science, and reading as did their parents. “[E]vidence from the NAEP also does *not* confirm the myth of a recent decline in American student achievement. Instead, it indicates a general pattern of stable achievement combined with modest growth in achievement among students from minority groups and from ‘less advantaged’ backgrounds” (1995, p. 27).

Berliner and Biddle furthered their argument by describing the NAEP test as one that measures two extremes of student achievement: basic and advanced. A continuum of questions ranging from easy to difficult distinguishes those students who are advanced from those who are not. If the majority of students scores in the middle and is found to be average, it is because the test is designed so that average students will have an average score. Finally, the authors argued against reformers who claim that while stable achievement over 20 years on the NAEP shows that students are achieving as well as ever in mathematics, it is not good enough to prepare them for the twenty-first century. While reformers have claimed that the jobs of tomorrow will require high-level skills, economists predict that the employment sectors most likely to grow in the near future are those in the service industry, hospitality, and retail sales. “So if schools do not prepare everyone to perform high-level mathematics, perhaps it is because students and their teachers are responding sensibly to the looming job market” (p. 28).

Romberg (1992) maintained that recommendations made by the NCEE are appropriate, because they are the result of future needs expressed by business and industry, not merely criticisms of what has happened in the past. Our society has transformed from an industrial to an information based society; yet, until recent reform movements, including the first publication of the NCTM’s *Curriculum and Evaluation Standards for School Mathematics* (1989), state and local school systems’ mathematical curricula reflected the needs of an industrial society. According to Romberg, we must attempt to visualize the important features of our society as it will be in the future, “if we are to adequately prepare today’s children for meeting its challenge” (p. 428). Moreover, U.S. educational leaders can no longer subscribe to the notion that higher-level mathematics is to be reserved for a small number of intellectual elite, as the majority of society learns enough mathematics to sustain itself while functioning as production workers.

To change schools so that students graduate prepared for the twenty-first century, Romberg argues that educators must change the epistemology of mathematics in schools, or “ the sense on the part of the teachers and students of what the mathematical enterprise is all about” (1992, p. 431). Romberg stated that the NCTM’s 1989 *Curriculum and Evaluation Standards* were developed under the premise that “all students need to learn more, and different, mathematics, and instruction in mathematics must be significantly revised” (NCTM, 1989, p. 1.). He elaborates on this statement with five key notions:

1. Teaching mathematics to "all students" emphasizes the fact that all students need to be mathematically literate if they are to be productive citizens in the twenty-first century. In particular, this includes underrepresented groups, not just "talented, white males."
2. "More mathematics" implies that all students need to learn more than how to manipulate arithmetic routines. At present, nearly half of U.S. students never study mathematics beyond arithmetic.
3. "Often different mathematics" refers to the fact that the mathematics all students need to learn includes concepts from algebra, geometry, trigonometry, statistics, probability, discrete mathematics, and even calculus.
4. "To learn" means more than to be shown or to memorize and repeat. Learning involves investigating, formulating, representing, reasoning, and using strategies to solve problems, and then reflecting on how mathematics is being used.
5. "Revised" instruction implies that classrooms must become discourse communities where conjectures are made, arguments presented, strategies discussed, and so forth. (Romberg, 1998, p. 9)

Romberg (1998) explained that in most of today's mathematics classrooms, instruction follows a five step pattern involving homework review, explanation and examples of a new problem type by the teacher, seat work where students work independently to practice the new problem type, summarization of work and a question and answer period conducted by the teacher, and teacher-assigned homework consisting of similar problems. Invariably, the next class period begins with a review of these homework problems. This cycle, according to Romberg, needs to be broken because to learn something involves more than repeating what one is shown.

Scheffler (1975) posited that mathematics instruction has been oversimplified because mathematics has become a subject rather than a process. As a subject, mathematics must be presented in a mechanistic, exact, numerical, and precise manner. For every question there is an answer. Further, the answer will be the one and only correct answer to the question, and it will be stated in precise, numerical terms. Rather than presenting mathematics in this manner, Polya (1957) stated that the mathematics teacher should take advantage of the great opportunity to first arouse and then challenge the curiosity of students by offering them problems that meet them at their ability level and challenge them to employ previous concepts in ways that are new and different to them. The ultimate goal of this kind of instruction, that goal for which all mathematics teachers should aim, is the development of students' independent thought.

When the NCTM developed its standards in 1989, the organization set out to contradict the Mathematic Sciences Education Board's (MSEB) statement, "We have inherited a mathematics curriculum conforming to the past, blind to the future, and bound by a tradition of minimum expectations" (1990, p. 4). Romberg (1998) claimed, "When we [NCTM] developed the standards, we thought instruction should take an approach involving investigating, formulating, representing, reasoning, reading, using strategies to solve problems, providing assertions, and reflecting on how mathematics is being used" (p. 12).

The intent of the NCTM in publishing the 1989 *Curriculum and Evaluation Standards* was to begin a process of changing the way mathematics is taught. It was hoped that the 1989 Standards would be used as a document with ideas for starting points for a reform movement involving "creative development and trials of new materials and methods of instruction" (Romberg, 1998, p. 14). After the publication of the NCTM's standards (1989), the Mathematics and Sciences Education Board (MSEB) advocated a year of national dialogue. Because we live in a supply-and-demand economy, a strategy for change assumed that changes in the way mathematics is taught would produce changes in the materials and support provided to schools and school systems based on this change.

As indicated earlier, before any plan can proceed, a need for change must be established, such as the need for students to be prepared for participation in the knowledge-based economy of the twenty-first century. The NCTM standards were designed to provide a vision for the new U.S. mathematics program. The next stage in the process of change is planning, which involves including all stakeholders so that a consensus may be reached regarding plans and timelines for change. It is here where demands are placed on suppliers to provide the elements required to operationalize the vision for change into a product. The product is the curriculum and the assessment designed to determine how effective the curriculum is in enabling students to fulfill their educational needs and the needs of their state and nation. Once curriculum is in place, the onus for executing it falls squarely on classroom teachers. As Virginia’s mathematics teachers seek methods for use in their classrooms, it is important for educational leaders to provide them with choices guided by research.

Meta-Analysis of Research on Algebra Teaching Methods

The purpose of this meta-analysis is to quantitatively synthesize the research findings from 1980 to 2001 on methods for teaching algebra at the secondary school level. The first requirement in reviewing literature is to locate and obtain relevant research studies. Six databases described in Table 5 were used as starting points to find research studies pertaining to secondary level algebra teaching methods.

Table 5

Databases Searched for Algebra Teaching Methods Studies

Data-base and Vendor	Description	Subject
Education Abstracts from First Search	Leading publications in the field of education.	Social Sciences
ERIC from Ovid	Journal articles and reports on all aspects of education, including counseling, tests, and measurement from 1966 to present with full-text of ERIC Document (items with ED numbers) from 1966 to present.	Social Sciences Human Resources
ERIC from First Search	Journal articles and reports on all aspects of education, including counseling, tests, and measurement from 1966 to present with full-text of ERIC Document (items with ED numbers) from 1966 to present.	Social Sciences Human Resources
Dissertation Abstracts on Line from First Search	Dissertations and theses from institutions in the North America and Europe.	General Interest
Virginia Tech Electronic Theses and Dissertations from NDLTD	Full texts of theses and dissertations written by graduates of Virginia Tech.	General Interest
Psych Info from Ovid	Online version of *Psychological Abstracts*, 1887 to present. Covers journal articles, book chapters, books, technical reports, and dissertations, in psychology and psychological aspects of related disciplines.	Social Sciences Agriculture and Biological Sciences

Selection Method and Criteria

Databases were searched with the combined key words, algebra and teaching methods. Each of these key words maps through the First Search and Ovid thesauruses to several other terms. Search terms were exploded to include these other terms so that articles regarding algebra teaching methods that may not have either term as key words could still be reviewed. The search was focused by combination of search terms. For example, the search term “algebra” generated 669 hits in the Psych Info database for publications from 1980 to 2001, and “teaching methods” generated 19,597 hits. When combined, the search was narrowed to 214 hits.

The abstract for each study was reviewed. Key words within the description of the study were investigated to generate new hits, and studies that appeared to meet the selection criteria outlined in Table 6 were obtained from the Virginia Tech Library or through the interlibrary loan service. Marcucci (1980) established selection criteria for his meta-analysis. Marcucci's criteria have been replicated with revisions to the types of treatment and the inclusion of studies exploring computer technology (computers or calculators) and cooperative or small group instruction. Marcucci did not include these areas of research because at the time of his study, the use of these teaching methods was not prevalent. Since then, these methods have grown in popularity and usage. While they have not been extensively researched for algebra instruction in particular, they deserve attention as teaching methods as they are advocated within the context of mathematics teaching reform (R. G. Marcucci, personal communication, September 10, 2001).

After a report was obtained, it was further reviewed to determine whether it met the criteria for meta-analysis, and if not, whether it warranted inclusion as advocating a teaching method to include under a category in the questionnaire development. The reference lists for all studies, whether they were acceptable or not, were searched for more potential studies. Studies found in the reference lists of reports were reviewed for applicability.

Table 6

Selection Criteria for Studies to be Integrated with Meta-Analysis

1	The study was conducted between 1980 and 2001 at the secondary school level (grades 7-12) where algebra instruction was the focus.
2	The study was an experimental investigation, comparing a treatment group to a control group, whose outcome variable was a measure of the subject's algebra knowledge and skills achievement.
3	The method of instruction in the study dealt with algebra knowledge and skills achievement per se and not with factors related to it.

In general, the literature pertaining to algebra teaching methods abounds with opinion regarding what (curriculum) should be taught so that mathematics students are prepared for the twenty-first century. It primarily concerns proposals for methods as advocated by mathematics reform organizations such as the NCTM. A relative few experimental investigations of teaching methods for algebra exist from 1980 to 2001. Marcucci encountered a similar problem when calculating effect sizes for the subject area of algebra at the secondary level. Of the 200 studies Marcucci initially found pertaining to elementary or secondary mathematics problem solving teaching methods from 1950 to 1980, thirty-three met his criteria for inclusion. Of those 33, eleven examined mathematics problem solving in secondary algebra classes. At least 1,418 articles were initially reviewed for the present study. This figure was narrowed to 72 for closer examination, and 34 were chosen for inclusion.

Referring to selection criterion one, for the purposes of this study, this researcher did not limit the review to only reports dealing with problem solving. The constitutive definition for algebra achievement for this study is the student's demonstration of knowledge and skill acquisition in algebra. This expands the number of reports that may be included and aligns the research with the operational definition for algebra achievement for this study: the student's scale score on the End of Course SOL Test for Algebra I, an assessment of the student's algebra knowledge and skills.

For the purpose of this study, selection criterion two applies only to those studies included in the meta-analysis. Reports that discuss teaching methods for algebra that are rooted in research or reform are included within the review of literature in order to augment the results from the meta-analysis and for the development of the questionnaire described in Chapter III. Teaching methods found in these reports are categorized according to which teaching methodology they typify. This is done so that each teaching method type may be fleshed out for investigation in the regression analysis described in Chapter III.

Table 7

Experimental Studies with Secondary Algebra Teaching Methods, 1980 – 2001: Search Results by Database

Data-base	Number of Initial Hits Reviewed	Number of Studies Selected for Further Review	Number of Studies Selected for Inclusion in Meta-Analysis
Education Abstracts from First Search	137	5	2
ERIC from Ovid	463	14	7
ERIC from First Search	543	8	4
Dissertation Abstracts on Line from First Search	96	17	11
Virginia Tech Electronic Theses and Dissertations from NDLTD	1	1	1
Psych Info from Ovid	181	24	8
Reference Lists of Reports	all	3	1
Total	At least 1,418	72	34

The End of Course SOL Test for Algebra I is not singularly a problem solving test, and the mathematics standards in the Virginia curriculum are not solely based on problem solving. Selection criterion number three expands Marcucci's to include reports that addressed algebra knowledge and skills. Table 7 displays the number of studies selected for review and final inclusion in the meta-analysis according to the database searched. There was some redundancy in the number of hits among databases, but there is no redundancy among studies selected for further review. The final decision to include a study in the meta-analysis was based on the criteria for selection.

Study Characteristics

According to Gay (1996), one characteristic of meta-analysis that distinguishes it from more traditional approaches to research integration is that there is an emphasis for the researcher to be as inclusive as possible. “Reviewers are encouraged to include results typically excluded, such as those presented in dissertation reports and unpublished work” (p. 266). Critics have claimed that this emphasis leads to the inclusion of “poor” studies. Glass, McGaw, and Smith (1981) argued that there is no proof that this is the case. They further argued that articles published in journals tend to have larger effect sizes, thus causing an over estimation of the value of an intervention. The inclusion of unpublished reports and dissertations tempers this factor, because dissertations demonstrate higher design quality than published journal articles and tend to have smaller effect sizes.

Rather than excluding a study, it is important to contextualize its inclusion by coding and analyzing it according to characteristics. Marcucci (1980) stated that there are many characteristics that influence the measure of a treatment’s effectiveness. An important part of his study replicated here is the identification and coding of study characteristics so that “their relationship to the effectiveness of the methods employed to teach [algebra knowledge and skills] could be determined” (p. 22). Thus, rather than excluding a study off hand, the researcher may include it in light of its characteristics. Marcucci identified four groups of study characteristics: subject variables, treatment variables, design variables, and study variables. These groupings are replicated here; however, alterations have been made to the content of the groups to facilitate the current study. Study features within each characteristic are described below, and a copy of the coding sheet for these variables is found in Appendix B.

Subject Variables

1. Grade Level: The grade level of the subjects, 7 – 12.

2. Ability Level: The ability level of the subjects as defined by the author of the study was recorded as unspecified, low, middle, or high.

Treatment Variables

3. Length of Treatment: This variable was measured by the number of weeks from the beginning to the end of instruction and by the total number of hours of instruction. If length of treatment was not specified in these terms, it was calculated based on information given. If time amounts were not given for class sessions, the total number of hours of instruction was determined by multiplying the number of weeks by 3.5 hours, replicating Marcucci.

4. Algebra Course: The algebra course level for the study: pre-algebra, algebra, or advanced algebra, as defined by the researcher.

5. Type of Treatment: Based on the reviews of the literature on algebra teaching methods and a careful reading of the studies included in this review of literature. Studies were grouped according to the treatments under investigation and category names were derived from these groupings. Categories were developed in an attempt to clearly differentiate one type of teaching methodology from those within other categories. This was important to the development of the meta-analysis and in the inclusion of studies not incorporated within it. The categories developed here set the stage for the multiple regression analysis in Chapter III.

a. Cooperative Learning: A method of instruction characterized by students working together to reach a common goal.

b. Communication and Study Skills: A method of instruction characterized by teaching students to read and study mathematical information effectively and providing opportunities for students to communicate mathematical ideas verbally or in writing (thinking aloud).

c. Technology Aided Instruction: A method of instruction characterized by using computer software applications and/or hand-held calculators to enhance instruction.

d. Problem-Based Learning: Teaching through problem solving where students apply a general rule (deduction) or draw new conclusions or rules (induction) based on information presented in the problem.

e. Manipulatives, Models, and Multiple Representations: A method of instruction characterized by teaching students techniques for generating or manipulating representations of algebraic content or processes, whether concrete, symbolic, or abstract.

f. Direct Instruction: A method of instruction characterized by teaching through establishing a direction and rationale for learning by relating new concepts to previous learning, leading students through a specified sequence of instructions based on predetermined steps that introduce and reinforce a concept, and providing students with practice and feedback relative to how well they are doing.

Marcucci (1980) used four teaching methodology types. For this study, this area is expanded to six to include current trends in mathematics education and the introduction of technologies that were not widely available in or prior to 1980. The six types of teaching methods outlined here should not be considered mutually exclusive because one method may contain another. For example, a problem-based learning approach to teaching may include the use of technology, such as calculators for graphing, to enhance student understanding. This researcher’s goal is to provide general classifications so that mean effect sizes may be inclusive of teaching methods related to one another.

When a study seemed to use a combination of teaching methods, the decision for classification into a category was based on the definition of the teaching method and the purpose of the study as described by the researcher. As is the case in Marcucci’s study, in all cases the researcher is responsible for classifying each teaching method described in a report or study into its category. For the present study, teaching method classifications were revised and verified through the content validation process described in chapter III.

Design Variables

1. Sample Size: “The total number of participants in the study” (Marcucci, p. 24).

2. Outcome Measure: The instrument used to measure algebra knowledge and skills acquisition was coded as experimenter designed or standardized test.

3. Assignment to Treatment: A three-point scale was used to assess this aspect of design quality. “One point was given to a study where subjects were randomly assigned to treatments. Two points were given where treatments were randomly assigned to groups, and the researcher presented convincing evidence accounting for initial differences between treatment and control groups” (Marcucci, p. 25). Three points were given to a study when no such evidence was given.

4. Homogeneity of Variance: This variable was measured as the ratio of the treatment group’s variance to the control group’s variance or the inverse (Marcucci, p. 25)

5. Novelty Effect: Hartley (1978) defines a novel classroom situation as a period of instruction less than nine weeks in length (as cited in Marcucci, 1980).

6. Adjusted Means: This variable indicated whether means on the outcome measure where adjusted for initial differences between the treatment and control groups (Marcucci, p. 25).

Calculating Effect Sizes

According to Glass, "We need methods for the orderly summarization of studies so that knowledge can be extracted from the myriad individual researchers" (1976, p. 4). To do this, as Marcucci stated, accurate measurement of treatment effects is necessary. Further, the measurement of treatment effects is the most important study attribute to be quantified in a meta-analysis. For the purposes of this study, Marcucci's methodology for calculating effect sizes has been replicated. Effect sizes provide a standardized unit of measurement for determining and indicating the effectiveness of an instructional practice. As a result, treatments investigated in research reports and studies using diverse outcome measures can be compared on the basis of their effect sizes.

Effect size is defined as the difference between treatment and control group means on a measurement of algebra knowledge and/or skill divided by the standard deviation of the control group:

$$\text{Effect Size} = \frac{\overline{X}_T - \overline{X}_C}{S_C}$$

Where X_T = the treatment group mean, X_C = the control group mean, and S_C = the standard deviation for the control group (Marcucci, p. 26). Marcucci assumed that the treatment and control group have the same variance. Glass, McGaw, and Smith support this:

> Standardization of mean differences by the control group standard deviation at least has the advantage of assigning equal effect sizes to equal means. This seems reason enough to resolve the choice in favor of the control group standard deviation, at least when there are more than two treatment conditions and only one control condition. (1981, p. 107)

The Meaning of Effect Size

Marzano, Pickering, and Pollock defined effect size as an expression of "the increase or decrease in achievement of the experimental group (the group of students who are exposed to a specific instructional technique) in standard deviation units" (2001, p. 4). For example, suppose the effect size for an instructional technique examined in a particular study is determined to be 1.0. This indicates that students exposed to the instructional technique scored one standard deviation unit higher than students in the control group on the outcome measure.

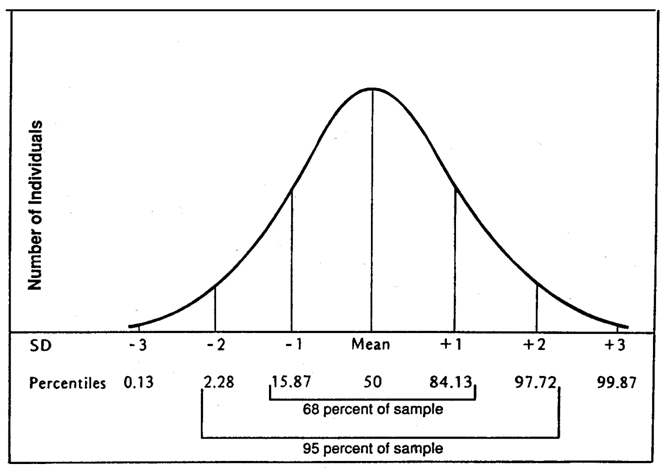


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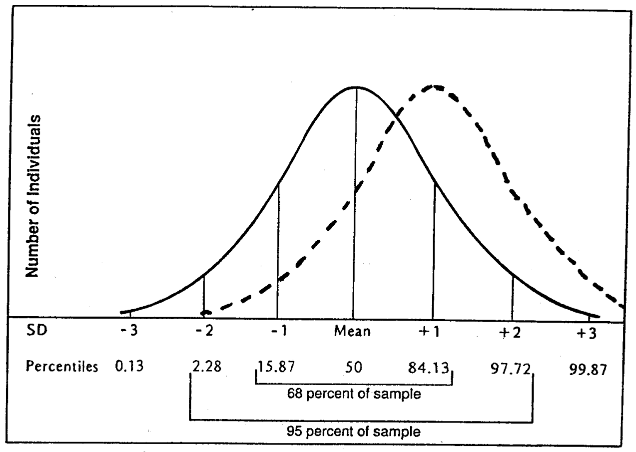
Figure 6. The normal distribution.

Another way Marzano, Pickering, and Pollock (2001) define the relationship between an effect size for a treatment and an outcome measurement for a control group is in terms of percentiles. Given the example stated previously with an effect size of 1.0, a student in the treatment group at the 50th percentile on an outcome measurement would be one standard deviation above a student at the 50th percentile in the control group. An effect size can also be translated into a percentile gain (Marzano, Pickering, and Pollock, 2001). Note that in Figure 6, there are three standard deviations above the mean and three standard deviations below the mean. Since an effect size of 1.0 would represent one standard deviation above the mean, it would also represent a percentile gain of 34%.



Note. From *Educational research: An introduction* (6th ed.), (p. 179), by M. Gall, W. Borg, and J. Gall, 1996, White Plains: Longman. All Rights Reserved. Copyright 1996 by Longman Publishers, USA. Adapted with permission.

Figure 7. The normal distribution with an effect size of 1.0.

See Figure 7, where the dotted line represents an effect size of 1.0. Similarly an effect size of negative1.0 would represent a percentile loss of 34% caused by the experimental teaching practice. A final way to interpret an effect size is to give it a value. Cohen (1988) stated that an effect size of .20 can be considered small, while an effect size of .50 and .80 can be considered medium and large, respectively (as cited in Marzano, Pickering, and Pollock, 2001).

Variations on Effect Size Calculations

As stated by Marcucci, while the explanation of effect size seems uncomplicated, the actual calculation of an effect size for a treatment can be difficult for several reasons. First and most encountered was the situation where the researcher simply reported no descriptive statistics for the control and experimental groups. While there may have been legitimate reasons for this decision, it provides the reader with little basis for evaluating results reported in an analysis of variance source table. For many of the studies, the effect size could be calculated straight from the definition, using the posttest means of the experimental and control group and the standard deviation for the control group. When a study lacked crucial information for determining an effect size in a straightforward manner, this researcher referred to Marcucci (1980) and Glass and Smith (1978) for alternative ways to convert statistical information reported in a study into an effect size. These procedures were adapted to this synthesis of research as appropriate.

Sample Sizes and t-statistic Reported

In studies where only sample sizes and t-test statistics were reported, the effect size for the experimental treatment was determined with this formula:

$$(1) \qquad \text{Effect Size} = t\sqrt{\frac{1}{n_T} + \frac{1}{n_C}} \qquad \text{where } t = \frac{X_T - X_C}{S\sqrt{\frac{1}{n_T} + \frac{1}{n_C}}}$$

n_T = the number of subjects in the treatment group, n_C = the number of subjects in the control group, and S = the pooled standard deviation of the treatment and control groups. Whether the effect size was positive or negative was determined from the study (Marcucci, p. 27).

F-test Statistic Reported

When an F-test statistic was reported with only two groups, the square root of F was substituted for the value of the t-test statistic in formula (1).

Analysis of Variance Design

When a study used analysis of variance (ANOVA) design and the standard deviation of the control group was not reported, an estimate for it was found using the following procedure.

1. Adding the sum of squares for all factors except treatment.

2. Dividing the above result by the sum of the degrees of freedom for all factors except treatment.
3. Taking the square root of the result in step (2).

Analysis of Covariance Design

When studies used an analysis of covariance design (ANCOVA), the numerator of the formula for effect size was calculated from the adjusted means of the control groups. Whenever possible, the denominator was estimated in a similar manner to the ANOVA estimate.

Multiple Effect Sizes

Some studies yield more than one effect size. In a one factor ANOVA study, for example, comparisons of more than one instructional practice to a control group would produce an effect size for each practice. In the case of a multi-factor ANOVA, more than one effect size could also be obtained. For example, when grade level or ability level is a factor, effect sizes could be calculated for each grade or ability level. When a study has both grade level and ability level as factors, effect sizes can be calculated for each factor independently, and ability level effect sizes can be coded as redundant data.

Limitations of Meta-Analysis

Abrami, Cohen, and d'Apollonia (1988) stated, "The great promise of meta-analysis is that it attempts to make the process of reviewing as scientific as the conduct of the primary research. To this end, meta-analysis should be precise, objective, and repeatable" (p. 174). Marcucci (1980) identified limitations of meta-analysis for synthesizing research. Precision, objectivity, and repeatability concerns affect both the validity and reliability of meta-analysis results. Issues related to study selection, comparability of studies, and the interpretation of meta-analysis results are treated within the context of this review of literature in an effort to address these concerns. Some are addressed by using the meta-analysis as the descriptive part of this research study while using a different methodology for making inferences regarding the effectiveness of particular teaching methods where student achievement in algebra is concerned.

Sample of Studies

This researcher has attempted to demonstrate that the studies included in the present meta-analysis were found from a variety of sources ranging from published journals to university archives and reference lists of studies. Although every attempt was made to be thorough in this review, it could not be exhaustive. Limited resources and time affected Marcucci's review. While this search was greatly aided by computer technology, resources and time still had an effect. Database selection may also have had an effect. Databases searched were chosen by their description. For example, those that included "social sciences" in their description were assumed to include a broad spectrum of research including studies in educational issues. Some redundancy occurred across databases. Confidence in studies selected was increased if they were found in more than one database.

However, some studies were found in one database and not the others; even the two databases for ERIC did not produce a great deal of redundancy using the same search terms. This reduced confidence in the probability of exhausting all possibilities. One further phenomenon that affected this confidence was the finding of a study in another's reference list that probably should have been "hit" while searching the databases. This could have been a result of the descriptors or search terms used, although new avenues were continuously investigated by adding to key word lists.

Although restricted by these conditions and the subjectivity involved in judging whether a study met the selection criteria (Abrami, Cohen, & d'Apollonia, 1988, p. 156,), the sample appears to contain a substantial number of the available studies meeting the three criteria for inclusion. When compared against Marcucci's number of studies obtained over a thirty year period with broader selection criteria, the number obtained here is wide-ranging and supports a methodical and thorough search.

A related problem discussed by Marcucci is whether the sample of studies is in some way "representative" of a conceptualized population of studies. Does this sample of studies represent the population of all studies satisfying the criteria for inclusion? This question raises the issue of sampling error in the calculation of statistical results designed to apply primary research methodologies to a synthesis of research studies, allowing the researcher to make inferences about the population of studies. Whether the results of a meta-analysis should be interpreted inferentially is a question that has been debated since Glass developed this form of research synthesis (Abrami, Cohen, & d'Apollonia, 1988). In the case of this research study, meta-analysis is intended as an improvement in description and explanation over the traditional narrative review of literature. Inferential statistics were applied to assist the reader in making judgments regarding the body of research analyzed, but this is to further enhance the descriptive nature of the synthesis of research. See Appendices C through R.

Comparability of Studies

Marcucci (1980) addressed the issue of interpreting results and the problems of sampling and sampling error by using procedures to be described in this section. Abrami, Cohen, and d'Apollonia (1988) later advocated these procedures in their discussion of implementation problems in meta-analysis. Each of the studies selected to contribute to the "results" of this review of literature was intended to reveal the effectiveness of a particular teaching practice for secondary level algebra. This common goal and the classification of teaching methods into general categories established a basis for comparison. The studies selected, however, vary greatly with respect to sample size, sample characteristics, outcome measures, experimental design, and suitability of statistical analysis. Other than in a narrative format, how can the findings of such different studies be combined and synthesized (Marcucci, 1980)?

The question posed above by Marcucci and this researcher is the key to the logic of research integration as developed by Glass (1976). In Marcucci's investigation, the response to the "different studies question" included two strategies later advocated by Abrami, Cohen, and d'Apollonia (1988). These strategies were used in the present study.

Correlation of Study Characteristics to Effect Size

Important study characteristics (e.g., sample size, type of outcome measure, weeks of treatment) were quantified and correlated with effect size. See Appendices C through R. A low correlation provides some evidence that the study characteristic under investigation is not systematically related to the effect size. Consequently, assuming low correlation, it would seem practical to compare the results of studies that differ on the given characteristic.

Comparing Teaching Methods by Subset

Different subsets of the sample, which share a common design feature, were used to compare teaching methods. For example, the effectiveness of the six types of methods was compared across grade levels (7 through 12) and across course (pre-algebra, algebra, advanced algebra). Further, the design quality of each study was rated as "good" or "poor" based on the extent of randomization in assigning subjects to treatments. The design quality ratings provide a dimension from which to combine study findings and provide a way of assessing one of the major criticisms of meta-analysis results. Specifically, the findings of "good" studies and "poor" studies should not be pooled to determine treatment effectiveness (Marcucci, 1980). Slavin

(1984) stated that overly broad inclusion criteria result in either the introduction of systematic bias from poorly designed studies or the senseless combination of notably different studies. Mansfield and Busse (1977, p. 3) noted, “Poorly designed studies are likely to yield spurious findings precisely because these studies are poorly designed” (as cited in Marcucci, 1980).

Interpretation of Results

This review of literature on teaching methods for algebra differs from the typical narrative review found in dissertations in that it produced “results” to guide the researcher in designing the instrumentation utilized in conducting the culminating analysis described in Chapter III. The overall results of this meta-analysis will be expressed as comparisons of mean effect sizes for the six general types of methods for algebra instruction and as correlations between effect size and study characteristics. To further refine this process, mean effect sizes and correlations are viewed in light of design quality.

Sources of Bias

Marcucci noted that there were several potential sources of bias in the results of his study. Slavin (1984) and Abrami, Cohen, and d’Apollonia (1988) also discuss these sources of bias as they affect the interpretation of results from meta-analysis.

1. Although the criteria for determining the types of teaching methods and design quality ratings are stated clearly and precisely, the investigator is solely responsible for both decisions. The influence of this type of bias may be reduced as content validity is explored in the instrument development as described in Chapter III.
2. There is also the possibility of experimenter bias. Mansfield and Busse (1977, p. 3) state, “If, as is often the case in educational studies, an experimental program is

confounded with the expertise and commitment of those implementing it, spurious findings are likely to be obtained" (as cited in Marcucci, 1980).

3. Publication bias is a third possibility.

> Large, well-designed studies are likely to be published whatever the statistical significance of their findings. But small, poorly designed studies are likely to be published only if significant treatment effects are obtained. Thus, summaries of published studies can be expected to yield over-optimistic estimates of the effectiveness of treatments. (Mansfield and Busse, 1977, p. 3)

Marcucci found that the influence of this type of publication bias was reduced for his study because he used more than twice as many studies from unpublished sources than from journals. In the case of the present study, the number of unpublished studies used is more than four times the number of published studies.

The fundamental question pertaining to the interpretation of the results for this review of literature is the same as for Marcucci's. Should meta-analysis findings be used mainly for descriptive purposes or to answer questions of statistical inference? Abrami, Cohen, and d'Apollonia also posed this question. Marcucci's response took into account the concept of "independence" as stated by Glass (1978),

> The inferential statistical problems of the meta-analysis of research are uniquely complex. The data set to be analyzed will invariably contain complicated patterns of statistical dependence. 'Studies' cannot be considered the unit of data analysis without aggregating findings above the level at which many interesting relationships can be studied. There is no simple answer to the question of how many independent units of information exist in the larger data set. (p. 375)

Glass proceeded to discuss the risks of interpreting inferential calculations under the assumption that each effect size is independent of the others. In light of the problems associated with inferential procedures, the results of Marcucci's meta-analysis and this meta-analysis are aimed at description and summarization of the findings of the studies in the sample. It is meant to be an enhancement and improvement over the traditional narrative approach to reviewing literature within the context of a dissertation.

Analysis of Data and Results

The major undertaking of this review of literature was to quantitatively synthesize the research findings from 1980 to 2001 on methods for teaching algebra at the secondary school level. Specifically, six types of teaching methods, cooperative learning; communication and study skills; technology aided instruction; problem-based learning; manipulatives, models, and multiple representations; and direct instruction, were identified, and the results of experimental studies that examined the effectiveness of each of these methods were integrated using the concept of effect size and the techniques of meta analysis.

The analysis of data and results reported here are presented in seven sections. First, there is an overall comparison of the effectiveness of the six types of teaching methods along with a brief profile of the studies within the sample. Within this discussion, information pertaining to study characteristics that had an apparent correlation to the findings is presented. This will be followed by a summary of findings for each teaching method category. In some cases, the results should be viewed with caution because of the relatively small number of studies contributing effect sizes to the computation of means.

To augment his results, Marcucci took into account one significant aspect of design quality of the studies and assigned each study a "good" or "poor" design quality rating based on the experimenter's control over the assignment of subjects to treatments. This method is replicated here and should be noted when referring to Table 8. A study was classified as "good" when the experimenter (a) assigned subjects to treatments randomly or (b) assigned treatments randomly to intact groups of subjects and presented credible evidence of accounting for or controlling some of the initial difference between groups (e.g., a reasonable application of analysis of covariance). A study was classified as "poor" when it did not satisfy the "good" criteria mentioned above.

Overall Effects of Teaching Methods

As stated previously, the purpose of this meta-analysis is to quantitatively synthesize the research findings from 1980 to 2001 on methods for teaching algebra at the secondary school level. Detailed tables replicated from Marcucci's (1980) meta-analysis containing descriptive results are found in Appendices C through R. The following tables and narrative are intended to summarize the meta-analysis in a manner leading to the development of the research question to be investigated using the methodology discussed in Chapter III. Table 8 displays the meta-analysis results for all categories for comparison.

The sample represented in Table 8 consisted of 34 studies meeting the three criteria for inclusion. From these 34 studies, 62 effect sizes were calculated. The majority of the studies (22) were "good" in design quality according to Marcucci's definition. Further, more than half of the sample (18) consisted of doctoral dissertations, while six were obtained from journal articles. The remaining ten studies were primarily ERIC documents, many of which were master's theses. Some studies initially found in the ERIC database were hit upon in a later year as published journal articles. When this occurred, the study was recoded as a journal document and eliminated from the unpublished document count. Most of the studies in the sample were conducted during the decade from 1991 through 2001. One interesting note is that all seven of the studies investigating problem-based learning were conducted during this decade, following the publication of the first NCTM *Standards* Document (1989).

Table 8

Categories of Teaching Methods Investigated in Research Studies from 1980 – 2001

Category	Mean Effect Size (ES)		Standard Deviation (SD)		Percentile Gain*		Number of ESs		Number of Studies	
	All	"Good"	All	"Good"	All	"Good"	All	"Good"	All	"Good"
Cooperative Learning (CL)	0.34	0.26	0.16	0.12	13	11	3	2	3	2
Communication and Study Skills (CS)	0.07	0.16	0.26	--	3	6	5	2	3	1
Technology Aided Instruction (TAI)	0.07	0.41	0.69	0.74	3	16	12	6	7	4
Problem-Based Learning (PBL)	0.52	0.44	0.70	0.51	20	17	14	9	7	4
Manipulatives, Models, and Multiple Representations (MMR)	0.23	0.23	0.26	0.26	9	9	9	9	4	4
Direct Instruction (DI)	0.55	0.67	0.59	0.54	21	25	19	16	10	7

Percentile Gain is determined from a table found in Marzano, Pickering, and Pollock (2001, p. 160)

The mean study sample size, weeks of treatment, and hours of treatment are reported for each teaching method in Appendix D. For the sample as a whole, mean sample sizes ranged from 83.70 for DI to 188 for PBL. The teaching method with the greatest variance in sample sizes was TAI with a standard deviation of 161.17. TAI studies also varied the most in terms of length of study with a mean weeks of treatment of 25.57 and standard deviation of 17.36. The whole sample ranged in mean weeks of treatment from 5.67 for CL to 25.57 for TAI studies. Hours of treatment followed this trend, because many studies failed to report the hours of instruction. When this occurred, Marcucci's (1980) estimation of the hours of treatment by multiplying the weeks of treatment by 3.5 was replicated.

Interpretation of Overall Effects

The sample of studies presented in this quantitative review produced a collection of effect sizes represented in Table 8. For each teaching method category, the mean effect sizes for all studies and “good” studies are presented for comparison. Each effect size is interpreted as a percentile gain determined from a conversion table found in Marzano, Pickering, and Pollock (2001). Considering the limitations affecting interpretation of results mentioned previously, the ample descriptive and quantitative information derived from the aggregation of the research studies in the sample establishes a reasonable basis for deciding which teaching method type was most effective for teaching algebra knowledge and skills (Marcucci, 1980).

Overall, the categories for teaching methods produced effect sizes ranging from small (0.07) to medium (0.55). This trend is mirrored when only “good” studies are considered, although the range increases from a small 0.16 to a medium 0.67. This trend goes against the findings of Marcucci. In his study, he found that “good” studies produced smaller effect sizes. One explanation for this study’s larger effect sizes for “good” studies may be found by examining other characteristics of the studies that appear to be related to effect size. Appendix Q displays significant, moderate, negative correlations between length of treatment and effect size (-.40 for weeks and -.43 for hours); sample size and effect size (-.34); and homogeneity of variance and effect size (-.49). Also, a significant, positive correlation is displayed for novelty effect and effect size (.30).

In other words, for all studies, as length of treatment, sample size, and homogeneity of variance increased, effect size decreased. These attributes are also indicators of study quality, so it makes sense that improvements in each of them would reduce effect size. Within the same table however, it should be noted, that a significant, small, positive correlation (.28) exists between design quality and effect size. Thus, as a researcher introduced randomization, he increased the effect of his treatment, if, as in the case of this sample of studies, he also conducted a lengthy study, with a large sample of two homogeneous groups. This phenomenon is more noticeable in Appendix R, where only studies using randomization of treatment are considered. The only significant correlation remaining is the moderate, negative relationship between homogeneity of variance and effect size.

Other study characteristics also seem to have an impact on effect size. See Appendices K through P. Whether all or only "good" studies are considered, published studies yielded larger effects than unpublished studies. Studies with a novelty effect also produced larger effects than those without it, whether all or only "good" studies are examined. Where outcome measure is the focus, studies using a standardized assessment yielded smaller effect sizes than those using an experimenter-designed instrument in the case of all studies. Where only "good" studies are considered, this trend is reversed.

Apparently, the Direct Instruction (DI) category represents the most effective teaching methods for all studies with a mean effect size of 0.55 or a movement of a typical student on a normal distribution curve from the 50th percentile to the 71st. When only "good" studies were examined, DI produced an effect size of 0.67. This is still in the medium range; however, it represents the movement of a typical student from the 50th percentile to the 75th.

Summary of Results for Each Category

At this point in the review of literature, the results from the meta-analysis are discussed. Detailed tables replicated from Marcucci's (1980) meta-analysis containing descriptive results are found in Appendices C through R. Each teaching method type is defined and quantified in terms of its effect size. Individual teaching methods will then be presented, including those found in theory and reform based documents that were not part of the meta-analysis. Individual teaching methods were included under each category only after the content validation by experts described in Chapter III. The summary will culminate in reference to Walberg's (1984) model.

Cooperative Learning

For the purposes of this study, cooperative learning (CL) is defined as a method of instruction characterized by students working together to reach a common goal. Experimental research results for CL are displayed in Table 9. One of the three studies included was published in a journal. The mean sample size for CL studies was 145.33 with a (SD = 108.3). The studies had a mean length of 5.67 weeks with a standard deviation of 1.16 weeks.

Table 9

Experimental Research Results for Cooperative Learning

Author(s) & Year	Focus	Number of ESs	Mean ES	Percentile Gain
Allsop, 1997	Peer Tutoring	1	0.178	7
Hawkins, 1982	Small Group Instruction with Peer Tutoring	1	0.493	19
Parham, 1994	Peer Tutoring	1	0.34	14
Category		3	0.34	14

Cooperative learning is strongly endorsed by the NCTM (2000) and has been widely researched across subject areas. Marzano, Pickering, and Pollock (2001) reported an effect size of 0.73 for CL in a synthesis of research on instructional strategies across grade levels and subject areas. Marcucci did not include this category in his meta-analysis due to the paucity of research in this area from 1950 to 1980 (R. G. Marcucci, personal communication, September 10, 2001). Experimental research from 1980 through 2001, focused on CL for algebra instruction, is also apparently minimal. An assumption regarding its effectiveness due to its large effects in other areas of instruction may be responsible for its widespread popularity without experimental research in algebra instruction. Within this sample of studies, CL produced the third largest effect size for all studies and the fourth largest for “good” studies. CL produced a mean effect size of 0.34 for Pre-Algebra courses and 0.18 for Algebra courses where only “good” studies were considered.

Table 10

Non-Experimental Research Results for Cooperative Learning

Teaching Method(s) Discussed	Author(s) & Year
Collaboration in problem solving and equation work.	Davis, 1998
Allow students to engage in cooperative problem solving.	McCoy, Baker, & Little, 1996
Reward group performance in the cooperative setting.	Yueh, 1988
Reward individual performance in the cooperative setting.	Yueh, 1988
Assign students to work in homogeneous groups.	Yueh, 1988
Assign students to working heterogeneous groups.	Yueh, 1988
Collaborate with the whole class in finding the solution to a problem.	Davis, 1998
Allow students to discuss solutions to algebra problems with peers.	Wilson & Blank, 1999
Allow students time to begin homework in class with peer assistance	Wilson & Blank, 1999
Approach new problem-solving scenarios in a collaborative setting with other learners.	Davis, 1998; Hawkins, 1982
Pair students to work as peer tutors.	Allsop, 1999; Parham, 1994

The literature presented in Table 10 combined with the experimental studies presented in Table 9 conveys the five elements of cooperative learning as defined by Johnson and Johnson (1999) to varying degrees: positive interdependence (sense of sink or swim together); face-to-face promotive interaction (helping each other learn, applauding successes and efforts); individual and group accountability (each of us has to contribute to the group achieving its goals); interpersonal and small group skills (communication, trust, leadership, decision-making, and conflict resolution); and group processing (reflecting on how well the team is functioning and how to function even better). CL is inclusive of other types of teaching methods, but it is unique in its function and application in algebra instruction as indicated by the results of the review of literature.

Communication and Study Skills

Communication and study skills (CS) is defined as a method of instruction characterized by teaching students to read and study mathematical information effectively and providing opportunities for students to communicate mathematical ideas verbally or in writing (thinking aloud). Experimental research results for CS are displayed in Table 11. None of the three studies presented was published in a journal. The mean sample size for CS studies was 102 (SD = 58.59). The mean and standard deviation for weeks of instruction were 18 and 15.87, respectively.

Communication stands alone as a standard in the NCTM's *Principles and Standards for School Mathematics* (2000),

> In high school, there should be a substantial growth in the students' ability to structure logical chains of thought, express themselves coherently and clearly, listen to the ideas of others, and think about their audience when they write or speak. (p. 348)

The algebra teacher's role in developing communication skills is largely that of providing students with opportunities to read, write, and talk about mathematics in a non-threatening environment. Non-experimental research presented in Table 12 presents many methods for accomplishing this objective. Further, "teachers must help students to clarify their statements, focus carefully on problem conditions and mathematical explanations, and refine their ideas" (NCTM, 2000, p. 351). Part of this process, as proposed by Pippen and Carr (1989), should be the provision of guidance through directed reading instruction and supplemental reading guides for students as they study word problems and other difficult mathematics literature.

Table 11

Experimental Research Results for Communication and Study Skills

Author(s) & Year	Focus	Number of ESs	Mean ES	Percentile Gain or Loss
Dick, 1980	Students select homework problems for review	2	-.155	-6
Hodo, 1989	Study skills instruction	2	.16	6
Pippen & Carr, 1989	Reading skills instruction	1	0.34	14
Category		5	0.07	14

Study skills instruction became linked with communication skills during the content validation by experts process described in Chapter III. Hodo (1989) defined study skills as special abilities used when studying mathematics. For example, one study skill proposed by Hodo is the practice of "studying graphs, charts, and examples to understand material better" (p.103). Marcucci did not include this category in his meta-analysis, as communication skills were not widely proposed as part of the mathematics content area prior to the publication of the first NCTM *Standards* document (1989). Experimental research from 1980 through 2001, focused on communication and study skills as a part of algebra instruction, is also apparently minimal. Within this sample of studies, CS was tied in fourth place with technology aided instruction and produced the smallest effect size when only "good" studies were included. For "good" studies in Advanced Algebra courses, CS produced a mean ES of 0.16. CS enhances other teaching types, but it is unique in its function and application in algebra instruction as indicated by the results of the review of literature.

Table 12

Non-Experimental Research Results for Communication and Study Skills

Teaching Method(s) Discussed	Author(s) & Year
Students write original word problems.	Davis, 1998
Students explain their thought processes in solving equations verbally or in writing to discover any fallacies or confusions.	Davis, 1998
Encourage students to use mathematics vocabulary terms in class discussions.	Davis, 1998; Feigenbaum, 2000; & Gordon, 1988
Provide mathematics vocabulary terms and definitions.	Davis, 1998
Give students opportunities to make oral and written presentations in class.	Davis, 1998
Give students opportunities to communicate verbally and in writing using mathematical terms.	Davis, 1998
Model and encourage "thinking aloud" about mathematical concepts and processes.	Davis, 1998
Have students describe thought processes orally or in writing during problem solving.	Davis, 1998; Gordon, 1988; & Wilson & Blank, 1999
Require students to share their thinking by conjecturing, arguing, and justifying ideas.	McCoy, Baker, & Little, 1996; & Wilson & Blank, 1999
Have students write about problem solving strategies.	McIntosh, 1997
Provide reading guides for students to improve their word problem comprehension.	McIntosh, 1997
Encourage students to verbalize steps of an algebraic process to themselves or other students.	Feigenbaum, 2000
Practice proper reading of word phrases so that students can achieve an accurate translation of both the symbols and meaning of language in algebra.	Feigenbaum, 2000
Emphasize proper reading and writing of algebra terms.	Feigenbaum, 2000
Treat algebra as a foreign language with its own alphabet and grammar.	Feigenbaum, 2000
Have students write observations of what they see happening in pre-worked examples of problems.	Carroll, 1995
Assign students to write about algebra.	Wilson & Blank, 1999
Encourage students to ask questions when difficulties arise.	Tenenbaum, 1986
Teach students reading comprehension skills in the context of algebra class.	Pippen & Carr, 1989
Provide strategies for reading comprehension.	Pippen & Carr, 1989
Have students write observations of what they see happening in worked examples of problems.	Carroll, 1995
Use reading instructional strategies to help students with comprehension.	Pippen & Carr, 1989
Provide students with study skills instruction .	Hodo, 1989

Technology Aided Instruction

The NCTM (2000) discusses technology as a matter of principle in mathematics instruction, "electronic technologies – calculators and computers – are essential tools for teaching, learning, and doing mathematics. They furnish visual images of mathematical ideas, they facilitate organizing and analyzing data, and they compute efficiently and accurately" (p. 24). Technology Aided Instruction (TAI) is defined as a method of instruction characterized by using computer software applications and/or hand-held calculators to enhance instruction. Experimental research results for TAI are presented in Table 13.

Table 13

Experimental Research Results for Technology Aided Instruction

Author(s) & Year	Focus	Number of ESs	Mean ES	Percentile Gain or Loss
Gesshel-Green, 1986	Use of an interactive microcomputer software program	1	1.42	42
Heath, 1987	Student access to Commodore Computers and TI 1001 calculators	2	0.44	17
Rich, 1990	Calculator use to graph functions: Casio fx-7000G calculator	2	0.27	11
Schumacker, Young, & Bembry, 1995	Integrated Learning Environment. Learning Logic: a complete first year algebra course developed by the National Science Center Foundation	2	-0.72	26
Smith, 2001	Computer Assisted Instruction: Carnegie Algebra Tutor	1	-0.07	2
Thomas & Rickhuss, 1992	Computer Assisted Instruction: MuMath	2	0.13	5
Wohlgehagen, 1992	Computer Assisted Instruction: Learning Logic Computer Courseware- Mastery Type	2	-0.38	14
Category		12	0.07	3

Two of the seven studies in the sample were published in a journal. The mean sample size for TAI was168.7 (SD = 161.17). The mean length of the sample of studies was 25.7 weeks and the standard deviation was 17.36.

Non-experimental research results for TAI are displayed in Table 14.

Table 14

Non-Experimental Research Results for Technology Aided Instruction

Teaching Method(s) Discussed	Author(s) & Year
Give simple instructions for the calculator and allow students time with guided practice to examine the technology and discover some of its capabilities.	Davis, 1998
Allow students to use calculators during testing situations.	Hembree & Dessart, 1986
Have students use calculators for problem solving instruction and activities.	Hembree & Dessart, 1986; Heath, 1987
Have students use hand-held electronic calculators as a pedagogical device to help develop mathematical concepts.	Hembree & Dessart, 1986
Have students use hand-held electronic calculators as a pedagogical device to help develop problem-solving strategies.	Hembree & Dessart, 1986
Have students use calculators for computations.	Hembree & Dessart, 1986
Have students use graphing calculators to explore linear relationships.	Patterson, 1999
Use computer spreadsheets, such as Microsoft Excel, for problem solving instruction.	Sutherland & Rojano, 1993
Assign students to use calculators as a course requirement.	Wilson & Blank, 1999
Use computer software to provide practice opportunities.	Allsop, 1999; Heath, 1987; Geshel-Green, 1986; Wohlgehagen, 1992; Smith, 2001; Thomas & Rickhuss, 1992; Schumacker, Young, & Bembry, 1995
Provide graphing calculators for student use.	Arcavi, 1995; Rich, 1990

Prior to the development of the first personal computers in the early 1980s, computers were not widely used to enhance instruction. Hand-held calculators were primarily used to assist computation and for answer checking. Thus, Marcucci (1980) did not include TAI as a category for his meta-analysis (R. G. Marcucci, personal communication, September 10, 2001). Considering the widespread availability of computer and calculator technology and its advocacy for mathematics instruction by the NCTM, experimental research in the algebra classroom from 1980 to 2001 is not as abundant as expected. Within the sample of studies for this meta-analysis, TAI ranked fifth along with CS with a mean ES of 0.07 for all studies, but when only “good” studies were considered, TAI moved to third place with a small to medium ES of 0.41. TAI showed its strongest ES for Advanced Algebra course students (1.42), while its second strongest ES (0.63) was found for Algebra course students, and its lowest ES was produced for Pre-

Algebra course students (0.44) for “good” studies. These results are mirrored when applied to ability level. High ability students showed an ES of 0.40, while low ability students produced an effect of 0.20 for “good” studies.

TAI enhances other teaching methods for algebra by providing opportunities for students to practice algebra skills and visualize algebra concepts, whether through “drill” exercises, “intelligent tutoring,” or software applications. TAI is unique in its function and application in the algebra classroom as indicated by the results of the review of literature.

Problem-Based Learning

For the purposes of this study, problem-based learning (PBL) is characterized by teaching through problem solving where students apply a general rule (deduction) or draw new conclusions or rules (induction) based on information presented in the problem. PBL is similar to Marzano, Pickering, and Pollock’s (2001) category labeled “Generating and testing hypothesis,” where students apply knowledge to new situations by induction or deduction. The authors found an effect size of 0.61 across grade levels and subject areas.

It is difficult to tease out a teaching method from Marcucci’s (1980) study for comparison to PBL, since his whole meta-analysis is devoted to mathematics problem solving instruction. PBL is most similar to Marcucci’s category labeled “Guided Discovery,” where appropriate questioning strategies are employed to guide a subject to discover the solution of the problem. In Marcucci’s study, Guided Discovery teaching methods produced a negative effect size (-0.08) for “good” studies for elementary and secondary students and all courses. When narrowed to algebra courses for “good” studies, the effect was small and positive (.013). For the present study, PBL produced the second largest effect for all (0.52) and “good” (0.44) studies. The trend of increasing effect size due to course matriculation is not replicated from Marcucci. “Good”

Pre-Algebra course studies showed an effect of (0.62) for PBL, while Algebra course studies resulted in a small, negative ES (-0.21), and Advanced Algebra course studies resulted in a medium ES (0.64).

Experimental research results for PBL are presented in Table 15. All of the PBL studies were unpublished and were completed after the publication of the NCTM's first *Standards* document (1989). The mean sample size for PBL studies was 188 with a standard deviation of 158.3. The mean length for the studies was eleven weeks (SD = 12.21).

Table 15

Experimental Research Results for Problem-Based Learning

Author(s) & Year	Focus	Number of ESs	Mean ES	Percentile Gain or Loss
Brenner, Brar, Duran, Mayer, Mosley, Smith, and Webb, 1997	Anchoring problem solving instruction in meaningful thematic contexts	5	0.50	19
Cyrus, 1995	Concept-based problem solving instruction	3	0.57	21
Elshafei, 1998	Problem-Based learning through constructivist approach	2	0.64	24
Hodgkins, 1994	Constructivist approach	1	1.79	46
Makanong	Constructivist teaching based model	1	-0.22	-8
Watson, 1996	Constructivist teaching based model	1	-0.20	-8
Wilkins	Problem-solving approach to instruction	1	-0.24	-10
Category		14	0.52	20

Problem solving is a standard proposed by the NCTM (2000).

> Successful problem solving requires knowledge of mathematical content, knowledge of problem-solving strategies, effective self-monitoring, and a productive disposition to pose and solve problems. Teaching problem solving requires even more of teachers, since they must be able to foster such knowledge and attitudes in their students. (p. 341)

An abundance of non-experimental research exists regarding problem-based learning. Reports from 1980 to 2001 are presented in Table 16.

Table 16

Non-Experimental Research Results for Problem-Based Learning

Teaching Method(s) Discussed	Author(s) & Year
Engage students in solving problems based on relevant situations.	Davis, 1998
Engage students in finding differences and similarities between types of equations and problems.	Davis, 1998
Have students create their own rules in new problem solving situations.	Davis, 1998
Teach general methods for students to solve mathematically formulated problems.	Price & Martin, 1997
Draw mathematical concepts from "real-life" problems.	Price & Martin, 1997; Makanong, 2000
Students investigate and create problems from given situations.	McIntosh, 1997
Students pursue open-ended and extended problem-solving projects.	McIntosh, 1997
Derive a formula from a given problem situation from theory before assigning and manipulating algebraic symbols.	Phillipp & Schappelle, 1999
Emphasizing understanding of algebraic concepts over reliance on rules for problem solving.	Feigenbaum, 2000; Watson, 1996; Cyrus, 1995
Use linear equations derived from real-life for instruction on graphing.	Patterson, 1999
Encourage students to experiment with alternative methods for problem solving.	Carroll, 1995; Wilkins, 1993
Work on problems that have no immediate solution.	Wilson & Blank, 1999
Analyze already worked out examples of problems with students.	Zhu & Simon, 1987
Create problems from the individual interests of students.	Choike, 2000; Lwo, 1992; Farrell, 1980
Assign goal-free problems to students.	Sweller & Cooper, 1985
Recognize many alternative problem solving practices.	Brenner et al., 1997; Hodgkins, 1994
Emphasize the problem solving process, rather than the solution.	Brenner et al., 1997
Anchor problem solving skills instruction within a meaningful situation.	Brenner et al., 1997; Elshafei, 1998

Problem-based learning is a teaching method type that may encompass all of the others. It is a framework for instruction not only used in algebra and other areas of mathematics, but across the curriculum. Within this sample of studies, it is differentiated from the other teaching methods in that PBL requires a teaching process where the problem and problem solving are the preeminent concern and the focus for learning.

Manipulatives, Models, and Multiple Representations

In the context of the present study, manipulatives, models and multiple representations (MMR) is a category of instruction where students are taught techniques for generating or manipulating representations of algebraic content or processes, whether concrete, symbolic, or abstract. It is similar to Marcucci's (1980) "modeling" category, defined as a method characterized by the use of visual aids, manipulative materials, or physical models to illustrate the conditions or relationships in the problems. Marcucci found a small, negative ES for "good" studies (-0.23), and for "good" studies in Algebra Courses (-0.10).

MMR is also similar to Marzano, Pickering, and Pollock's (2001) category labeled "Nonlinguistic Representations," where studies across grade levels and content areas produced a large, positive ES (0.75). The authors include a variety of activities in this category, such as creating graphic representations, making physical models, generating mental pictures, drawing pictures and pictographs, and engaging in kinesthetic activities.

For the present study, MMR produced the fourth largest ES (0.23) for all studies and the fifth largest (0.23) for "good" studies. Experimental research results for MMR are presented in Table 17. Three of the four studies quantified in this sample were published in journals. The mean and standard deviation for sample size were 111 and 71.91, while the mean and standard deviation for length of treatment were 5.75 and 4.99 weeks. MMR had its largest effects in "good" Algebra Course studies (0.28).

Table 17

Experimental Research Results for Manipulatives, Models, and Multiple Representation

Author(s) & Year	Focus	Number of ESs	Mean ES	Percentile Gain or Loss
Keller, 1984	Table building vs. direct translation for word problems	2	.17	7
Matthews, 1997	Techniques for solving two equations with two unknowns	4	.45	17
McClung, 1998	Algeblocks for problem / equation representation	2	-0.70	-25
St. John, 1992	Table building methods for word problems	1	0.09	3
Category		9	0.23	9

The NCTM (2000) includes MMR within its Representation standard, stating that instructional programs should enable students to

> create and use representations to organize, record, and communicate mathematical ideas; select, apply and translate among mathematical representations to solve problems; and use representations to model and interpret physical, social, and mathematical phenomena. (P. 360)

MMR enhances other teaching methods for algebra by providing opportunities for students to see and feel algebra on their terms and to communicate algebra to others in a variety of formats. MMR is unique in its function and application in the algebra classroom as indicated by the results of the review of literature. MMR teaching methods gleaned from non-experimental research are presented in Table 18.

Table 18

Non-Experimental Research Results for Manipulatives, Models, and Multiple Representations

Teaching Method(s) Discussed	Author(s) & Year
Students use cubes or blocks to represent algebraic equations.	Raymond & Leinenbach, 2000; McClung, 1998
Provide a classroom environment with colorful posters representing mathematical concepts and processes.	Davis, 1998
To aid students in visualizing an equation and its parts, compare it to everyday, familiar things.	Price & Martin, 1997
Illustrate mathematical concepts for students with pictures.	Price & Martin, 1997
Teach students to represent algebraic expressions with graphs.	McCoy, Baker, and Little, 1996
Teach students to represent problems with tables.	McCoy, Baker, and Little, 1996; Keller, 1984; St. John, 1992
Teach students to represent problems with written expressions.	McCoy, Baker, and Little, 1996
Make connections between mathematics and other subjects.	McIntosh, 1997
Describe a model by thinking aloud and including the students in the thinking aloud process.	Maccini & Hughes, 2000
Teach students to create templates or patterns for representing and evaluating algebraic expressions.	Feigenbaum, 2000
Use colored pencils to highlight relevant information or to draw specific signs and symbols in algebraic expressions.	Feigenbaum, 2000
Emphasize the use of multiple representations: words, tables, graphs, and symbols.	Choike, 2000
Represent problems using tables, graphs, and symbols.	Brenner, et al., 1997
Use symbols to help students learn to solve equations.	Austin & Vollrath 1989
Use diagrams to help students learn to solve equations.	Austin & Vollrath 1989
Use physical objects to help students learn to solve equations.	Austin & Vollrath 1989
Provide math games for students to practice algebraic skills.	Tenenbaum, 1986
Teach students to represent problems with charts to break information into smaller pieces.	Matthews, 1997
Teach students to use two variables when there are two unknowns in solving algebraic word problems.	Matthews, 1997

Direct Instruction

In the context of this study, direct instruction (DI) is defined as teaching through establishing a direction and rationale for learning by relating new concepts to previous learning, leading students through a specified sequence of instructions based on predetermined steps that introduce and reinforce a concept, and providing students with practice and feedback relative to how well they are doing. This category of teaching method is similar to Marzano, Pickering, and Pollock’s (2001) “Setting objectives and providing feedback” category. The authors found an average effect size of 0.61 across subject areas and grade levels for this category of instruction. None of Marcucci’s (1980) teaching method types is comparable to DI.

Table 19

Experimental Research Results for Direct Instruction

Author(s) & Year	Focus	Number of ESs	Mean ES	Percentile Gain or Loss
Carroll, 1992	Teaching through worked examples	1	0.65	24
Carroll, 1994	Providing practice for students enhanced with worked examples	6	0.58	22
Clay, 1998	The “Saxon Method” or continuous review approach	1	0.20	8
Collazo, 1987	Programmed / Individualized instruction	1	-0.30	-12
Denson, 1989	The “Saxon Method” or distributed practice and continuous review through drill	1	-0.24	-11
Farrell, 1980	Individualized instruction	1	-0.34	-13
Hutchinson & Hemingway, 1987	Using scripts and feedback for problem solving steps	3	1.27	40
Lwo, 1992	Individualized instruction	2	0.41	16
Pierce, 1984	Continuous review	1	0.01	1
Tenenbaum, 1986	Enhanced cues, reinforcement, and feedback corrective procedure	2	1.35	41
Category		18	0.55	21

Results from experimental research studies from 1980 to 2001 are presented in Table 19. For this sample, two of the ten experimental studies were published in journals. The mean sample size for DI was 83.70 (SD = 63.30). The mean length of treatment was 11.68 weeks, and the standard deviation was 14.19 weeks. DI produced the largest effect size for all studies, a medium 0.55. Direct instruction produced the largest ES for “good” studies (0.67). Direct instruction produced its largest effect size in “good” Algebra course studies (0.74) and with students classified as low ability level (0.84).

Table 20

Non-Experimental Research Results for Direct Instruction

Teaching Method(s) Discussed	Author(s) & Year
Relate new algebra concepts to previously learned concepts.	Davis, 1998
Begin instruction with a target skill or concept for students to master.	London, 1983
Close instruction by reviewing concepts with students, emphasizing comparisons to previously covered concepts.	London, 1983
When providing feedback, target incorrect responses and error patterns.	Maccini & Hughes, 2000
Identify a new skill or concept at the beginning of instruction and provide a rationale for learning it.	Maccini & Ruhl, 2000
Provide a graduated sequence of instruction, moving students from the concrete to the abstract in defined steps.	Maccini & Ruhl, 2000; Hutchinson & Hemingway, 1987
When giving feedback, recognize correct thinking in students although it may be incomplete or lacking closure.	Choike, 2000
When a student responds incorrectly, give the student a chance to try again after providing a cue.	Tenenbaum, 1986
Return to familiar problem settings when introducing a new problem type.	Choike, 2000
Analyze already worked out examples of problems with students.	Carroll, 1995
Administer quizzes to indicate student mastery of unit content and for feedback purposes.	Tenenbaum, 1986
Provide cues to indicate to students what is to be learned and what actions are required of students.	Tenenbaum, 1986
Following each learning task, provide time for error correction.	Tenenbaum, 1986
Follow feedback to students with methods for correcting errors.	Tenenbaum, 1986
Tell students what skill they will learn, linking the current lesson to past lessons, and providing a rationale for the importance of learning the skill.	Allsop, 1999
Grade homework to provide feedback.	Dick, 1980
Allow students time to work on homework in class, while providing assistance.	Dick, 1980
Allow students to use index cards as flash cards with basic algebraic processes, necessary formulas, or needed reminders.	Feigenbaum, 2000
Provide students with worked examples along with their practice work.	Sweller, 1985
Give pre-worked examples to accompany homework assignments.	Carroll, 1994
Give pre-worked examples to accompany class work assignments.	Carroll, 1995
Provide pre-worked examples with homework.	Carroll, 1995
Have students find errors in pre-worked examples.	Carroll, 1995
Use pre-worked examples to introduce or reinforce topics.	Carroll, 1995
Provide practice and feedback in computational skills.	Wilson & Blank, 1999
When assigning practice work, ensure that the majority of problems assigned review previously covered material.	Clay, 1998; Pierce, 1984; & Denson, 1989

Direct instruction is a teaching method type that may encompass all of the others. It is a framework for instruction not only used in algebra and other areas of mathematics, but across the curriculum. Within this sample of studies, it is differentiated from the other teaching methods in that DI requires a focused skill or concept mastery as the preeminent concern and the focus for learning.

Summary and Application of Meta-Analysis Results

According to Walberg (1984), the educational leader must concentrate on improving the quality of instruction the student is receiving. This is the only factor within the realm of the principal's and teacher's direct control. The opening sections of Chapter II presented a proposal for mathematics instruction reform that has long been advanced by the NCTM and other educational organizations. This meta-analysis of experimental research studies on teaching methods for algebra from 1980 to 2001 covers the span of time from three years before the publication of *A Nation at Risk* (1983) through the publication of all of the NCTM *Standards* documents.

From this quantitative review of literature, six categories of instruction were derived: cooperative learning; communication and study skills; technology aided instruction; problem-based learning; manipulatives, models, and multiple representations; and direct instruction. Each has yielded a positive effect size for algebra instruction, with direct instruction presenting the largest effect. To augment the quantitative review of literature, teaching methods from non-experimental research reports are presented. Experts placed teaching methods in each category, as outlined in Chapter III. These method descriptions serve to provide flesh to the skeleton laid out as teaching method categories. In culminating this study, the results of the meta-analysis are applied to determine the influence of teaching methodology on student achievement on the SOL assessment for Algebra I, the most current standardized assessment offered to students in the Commonwealth of Virginia.

Multiple Regression Analysis

According to Gay (1996) and Gall, Borg, and Gall (1996), meta-analysis has three important attributes that make it a powerful tool for integrating research: focus on the magnitude of the effect observed in each study, provision of an effect size, and determination of study features that affect the results of the review.

There are also three drawbacks to relying on a meta-analysis of previous research to provide results for current practitioners. First, studies integrated, in this case in particular, use various assessments (experimenter and standardized) not necessarily related to the assessment used currently for high stakes testing. In this case, Virginia's Algebra I teachers may be primarily interested in the relationship between teaching methods and student achievement on the SOL assessment, rather than various other assessments. The second disadvantage to meta-analysis as discussed by Marcucci (1980) is that it does not explore the relationship between experimental treatments. In this case, teaching method types can be compared based on their effect sizes; however, the relationship between each teaching method type and student achievement is not explored in light of the other teaching method types. A third and final disadvantage to relying solely on results from the meta-analysis is that background or demographic characteristics of the students, schools, and teachers are not correlated to effect sizes.

Hierarchical multiple regression with teaching method categories derived from the meta-analysis will provide a clearer explanation of each category's influence on a single dependent variable, while controlling for other categories of teaching methods. Hafner (1993) examined the influence of mathematics specific teaching practices on class-level mathematics achievement, using data from the 1995 Second International Mathematics Study (SIMS). Hafner's study used a sample of 227 classes and their teachers who participated in the SIMS, analyzing teacher responses to four teaching scale questionnaires that accompanied the achievement tests given to the students.

Hafner performed stepwise multiple regression analysis to examine the influence of mathematics-specific teaching practices on class-level mathematics achievement. More specifically, Hafner sought to determine the extent and manner in which seven achievement dependent variables could be predicted or explained by student performance on pretests, socio-economic status (SES), class type, opportunity to learn (OTL) the subject, and five teaching practice types: show and tell, comparison, inductive, eclectic, and abstract/memorization. Results for the algebra achievement dependent variable are displayed in Table 21. All of the variables together contributed roughly 86% of the variance in the student's scores on the algebra achievement variable. Individual unstandardized regression weights are provided for the variables.

Noteworthy is the *b* value for abstract teaching practice types, .90. This was significant at $p<.05$. The abstract/memorization scale measured an approach to teaching that focuses on "memorization of rules and formulae, justifying steps, and teaching abstract meanings" (p. 79). An example of an item from this scale is "It is important to justify steps in solving problems" (p.91). Hafner's results would indicate that teachers who use practices in the abstract/memorization category contribute positively to their student's scores in algebra achievement.

Table 21

Hafner's Results (beta weights) for Teaching Method and Demographic Influence on Class wide Achievement on the SIMS

Dependent Variable	Beta Weight	t
Pre-algebra achievement	1.36	21.60**
SES	.97	1.94**
Class Type	.54	.85
OTL algebra	.08	3.67**
Show & Tell	-.02	-.16
Comparison	-.23	-1.12
Inductive	.03	.16
Eclectic	-.12	-.64
Abstract	.90	3.07**

*p<.10, **p<.05

Leclerc, Bertrand, and Dufour (1986) examined the relationship between certain teaching practices and the educational achievement of students learning algebra for the first time. In this case, the teaching practices used as independent variables for multiple regression analysis were recorded in a series of observations. The researchers allowed their observations to guide the naming of categories for teaching practices. The dependent variable was the teachers' class mean scores on a researcher-designed algebra posttest adjusted for pretest scores. Of the several teacher behaviors observed, two, teacher academic instructional discourse and lecturing using materials, showed the largest positive coefficient of determination (R^2=.37).

In a similar study, Seifert and Beck (1984) examined the relationship between student achievement and several teaching approaches by observing and coding behaviors of the teachers and students. One major focus for this study was to determine the effect of the amount of engaged learning time on student achievement on a mathematics posttest. Teacher behaviors were assessed in light of how well they promoted time-on task. “The lecture/discussion method of instruction yielded the highest correlation (r=0.46) when compared with achievement gain” (p. 9). The researchers also found that seatwork appears to be negatively correlated with achievement gain.

Teaching Methods and Educational Productivity

Each of these three studies examined quality of instruction in terms of how the teacher presents concepts and skills. Leclerc, Bertrand, and Dufour (1986) and Seifert and Beck (1984) largely examined how the teacher teaches and the amount of time the teacher spends in each category of teaching methods. Hafner used factor analysis to group teacher statements regarding philosophical approaches to what they taught into broader categories. Walberg (1984) linked amount and quality of instruction as inputs in his productivity model.

For the purposes of this study, teaching practices are grouped according to broader categories and validated with domain association by experts. The individual method defines itself in terms of the extent to which it is a “how to” or “what to” teach. The broader definition for the category in which each method falls encompasses and ties together methods that may differ somewhat in these aspects. The “amount” of time the teacher spends within each category of teaching method is quantified by the teacher’s self-report of how often class time is devoted to the category over a typical five class periods. To provide descriptive information pertaining to this time element, teachers were asked to tell what type of schedule their schools use as a part of background information as well as how many credits the Algebra I course is worth. A two-credit course for Algebra I is twice the duration of a one-credit course.

CHAPTER III
METHODOLOGY

"To study a construct or variable scientifically we must be able to identify the sources of its variation."
(Pedhazer, 1997, p. 2)

This chapter discusses the methodological tools to be used in the culminating analysis for this study. The methodology to be utilized here is quantitative as it leads to the development of a regression equation for predictive and explanatory purposes. Teaching methods reviewed in Chapter II are considered variables known to be correlates of the criterion for this study: student achievement on the End of Course SOL Test for Algebra I. The remainder of this chapter includes a discussion of the research question, research design, setting and sample, data collection, instrumentation, and the data analysis techniques to be employed.

Research Question

In Chapter II, experimental research studies from 1980 to 2001 were quantitatively integrated so that teaching method types could be examined in terms of their effects on student achievement. These teaching method types include specific methods explored in the experimental studies as well as those supported by other research. Since the major purpose of the current study is to determine the influence of teaching methodology on student achievement on the End of Course SOL Test for Algebra I, the research question displayed in Table 22 will guide the research design.

This investigation began with an extensive review of literature ranging from 1980 to 2001, with studies chosen based on criteria established to include those that pertain to algebra teaching methods where an effect size could be calculated. Teaching methods were then grouped into categories, further focusing the review of literature so that its results could be channeled into a regression study. In order to enhance the categories for the purposes of designing a questionnaire, teaching methods obtained from literature on algebra instruction were added to the categories and tested for their content validity. This process culminates with the exploration of the combination of independent variables, teaching method types, resulting in a more accurate explanation of their relationship to student achievement in algebra, using the End of Course SOL Test for Algebra I as the dependent variable.

Table 22

Methodology Summary Table

Research Question	Data Collection	Analysis	Data Reported
To what extent and in what manner is student achievement on the SOL assessment for Algebra I explained by usage of teaching method categories: CL, CS, TAI, PBL, MMR, DI	Dependent Variable: Algebra I SOL assessment Predictors: Mean frequency of usage of each teaching method category	hierarchical multiple regression (blockwise)	descriptive statistics for all variables inferential statistics including a correlation matrix, multiple regression table, and unstandardized regression equation

Setting and Participants

For the purpose of K-12 public education, the Commonwealth of Virginia is divided into eight Regional Study Groups. Seven of the 19 school districts in Region VII, the mountainous, rural region in the most southern and western corner of the Commonwealth, were selected as research sites. The 19 school districts within Region VII were ranked according to their pass rates on the end of course Algebra I SOL assessment for the 2000 – 2001 school year. A random number was then chosen (n), and every n^{th} district was selected. This number is not revealed here in order to maintain confidentiality for the school districts, schools, and teachers who participated in the study. This sampling method allowed for a wide range (68%) in pass rates from the 2000 – 2001 testing.

Before moving forward with the study, exemption from the Virginia Tech Institutional Review Board was obtained (Appendix AA). Each district superintendent was asked permission to conduct the study and asked to provide an approximate number of Algebra I teachers in the district. See Appendix CC. The first approximation of participants was 66. After contacting each high school and middle school principal by telephone in the seven selected school districts to provide information regarding the study and to ask permission to work with the teaching staff, the approximate number of participants was reduced to an estimate of 59 teachers currently teaching Algebra I. During the surveying process the number of participants was further reduced to 53. One declined. Another indicated that she was not teaching Algebra I during the spring of 2002, and did not complete the questionnaire. Four more teachers who completed the questionnaire were not teaching Algebra I during the spring of 2002. This reduced the sample of participants to 53 teachers. Research suggests that the number of participants be equal to six to 10 times the number of predictors (Pedhazer, 1997). Based on this guideline, a minimum of 36 teachers was needed to use multiple regression analysis.

Data Collection

Two sources of data were used in this study. Data used to quantify independent variables was collected through the use of a researcher-designed questionnaire. The dependent variable for this study was each teacher's mean scale score for his or her students on the End of Course SOL Test for Algebra I for 2002. This information was requested from each school district participating in the study.

Data Gathering and Management Procedures

The researcher-designed questionnaire was posted as a web site developed in collaboration with Mr. Terry Hawthorne, the Smyth County Schools' technology director:

http://www.scsb.org/algebra_survey_new.asp. See appendix X. This web site, hosted on the Smyth County School Board's web site, linked each item of the questionnaire to a field in a Microsoft Access data file. As participants logged onto the web site using personal identification numbers, the information they provided was coded as data within the Access fields. Access data was then imported into a Microsoft Excel file and manipulated for importing into an SPSS 11.0 (SPSS, 2001) file. The timeline for this process is presented in Table 23.

Table 23

Timeline for Data Collection Procedures

Procedure	Time Range
Contacting School District Superintendents by Telephone and Letter	February 28 through March 8, 2002 (Appendix CC)
Developing Web Page for Questionnaire	March 4 through March 9, 2002
Contacting School Principals by Telephone	April 4 through 8, 2002
Pre-Contacting Teachers and Reminding Principals by Postcard	April 11 (Principals) and 12 (Teachers), 2002 (Appendix EE)
Contacting Teachers by Letter	April 18, 2002 (Appendix DD)
Data Collection and Follow Up with Non-Respondents by Post Card and Telephone	April 15 through May 9, 2002 (Appendix FF)
Obtaining Algebra End of Course SOL Test Scores for Participating Teachers	June 10 through June 27, 2002
Analyzing Data	June 28 through July 5, 2002

This researcher traveled to each selected school district's school board office to obtain End of Course SOL Test for Algebra I scores reported by teacher. A mean scale score for each teacher was recorded and entered into the SPSS 11.0 database with the questionnaire data for conducting the multiple regression analysis.

Instrumentation Design

The following two sections describe the designs for the researcher developed questionnaire and the End of Course SOL Test for Algebra I.

Researcher Developed Questionnaire

The questionnaire was developed using Dillman's (1978) Total Design Method for surveys from the categories of teaching methods derived from the meta-analysis of research studies in Chapter II. After initially assembling the studies and effect sizes, seven categories and 114 items were derived, as displayed in Appendix T. After the first round of content validation, the "homework and practice" category was dropped because it appeared ambiguous to the content validation experts. Forty-nine items and one complete category from the first round were found acceptable using the criteria described in the instrument validation process. Thus, the remaining 65 items were included in the second round of content validation with five categories, as displayed in Appendix U.

Under each of the six category headings, eight specific statements were included pertaining to teaching methods that define the category. These items were those with the strongest association and clarity ratings from the content validation process. See Appendix X. Hafner's (1993) survey consisted of five categories with item totals ranging from four to eight. Items were designed as close-ended statements with ordered answer choices. The teacher was asked to consider five typical class periods and decide how many times he or she used a teaching method during these five periods. The choice range was from zero to five. As described by Dillman (1978), this type of item is designed to offer a choice, which will represent "the graduation of a single dimension of some concept. This structure is ideally suited for determining such things as … frequency of participation” (p. 89). This determined the extent to which each teacher differed from the others in terms of usage of a particular teaching method. Dillman stated that responses to this type of item are well suited for regression analysis.

In order to provide background information for the sample, the questionnaire contains items that ask for information pertaining to quantity of instruction and the teaching-learning environment, including the number of years of teaching experience the teacher has with Algebra I in Virginia, on what type of schedule is his or her class (4 x 4 block, alternating days block, seven period day), and whether the Algebra I course is being taught for one unit of credit or two. Whether the teacher worked at a middle or high school was noted and included as a variable in the SPSS 11.0 file later.

Questionnaire Validation Process

Categories and items of the questionnaire were validated in cooperation with Dr. Skip Wilson and his 14 secondary mathematics teaching methods students at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. This course, EDCI 4744 & 5744, Teaching Mathematics in the Secondary School II, is the final preparation for teacher candidates before they begin student teaching. Students learn about, practice, and discuss teaching methods for secondary mathematics. For example, when this researcher visited the class, the students explored the possibilities of an electric data collection device for representing data depicting linear relationships graphically.

The first round of the validation process was completed on January 24, 2002. This researcher visited the class and administered the content validation instrument displayed in Appendix V. Students took from 30 to 45 minutes to complete the instrument. Data from the completed instruments were entered into SPSS 11.0 file and descriptive statistics were calculated for each item. In order for an item to be retained, 80% of the participants had to place it in a category, preferably the expected category. Further, the item had to produce a mean association score for that category of three or higher on a scale of one to four. Finally, the item had to have a clarity rating of 2.5 or higher on a scale of one to three.

After the first round of content validation, one category was dropped, “Homework and Practice,” because it appeared to be inclusive of the other categories, distracting one or two experts away from the expected category for several items. In order to drop this category, the researcher returned to Chapter II and distributed the studies from it into other appropriate categories. The meta-analysis was then recalculated before the questionnaire content validation process could be resumed with six categories. Another category, “Technology Aided Instruction,” was completely validated by the students, so it was removed from the validation process for the second round. Forty-nine items met the criteria for inclusion from the first round, so they were removed for the second round.

The second round of the validation process was completed on February 18, 2002. To avoid taking up more of Dr. Wilson’s class time, the instrument displayed in Appendix W was distributed via e-mail to the students, and they were asked to complete and return it by February 18, 2002. All 14 students returned their instruments. Data from the completed instruments were entered into SPSS 11.0 and descriptive statistics were calculated for each item. In order for an item to be retained, 80% of the participants had to place it in a category, preferably the expected category. Further, the item had to produce a mean association score for that category of three or higher on a scale of one to four. Finally, the item had to have a clarity rating of 2.5 or higher on a scale of one to three. Appendices Y and Z present tables summarizing the content validation by experts process.

Of the 101 items that met the criteria for inclusion in the six questionnaire categories, 48 were retained. The eight items with the strongest association and clarity ratings and the least redundancy were retained under each category. When the questionnaire was posted, items were organized under each category and converted to “I” statements (Dillman, 1978). See Appendix X for the current draft of the questionnaire categories and items or use this hot link: http://www.scsb.org/algebra_survey_new.asp.

Questionnaire Reliability

Reliability data for the questionnaire was obtained in cooperation with a sample of 15 high school mathematics teachers employed by Virginia Beach City Public Schools. See Appendix BB. Participants completed the questionnaire during the week of April 1 to April 5, 2002. Data from the respondents was analyzed using the split-half technique, a measure of internal consistency. This resulted in a reliability coefficient of r = .89, after applying the Spearman-Brown prophecy formula.

End of Course SOL Test for Algebra I

The End of Course SOL Test for Algebra I is designed to allow each student to demonstrate skills and knowledge acquisition in Algebra I. The Virginia Department of Education (2001b; 2002) has provided a scope and sequence and curriculum framework for Algebra I instruction. This test is untimed and conducted with a multiple-choice format. The Blueprint for the Algebra I test (1997) states that the test includes a total of 60 items. Table 25 displays the reporting categories and the number of items associated with each. Fifty of the items are operational, while ten are field test items. The Virginia Department of Education has released the Spring 2001 End of Course Algebra I Test (2001a).

Each student's score is reported first by category and then by a scale score from zero to 600 points. A scale score of 400 or higher is required to pass the test. A scale score of 500 or greater is required for a designation of advanced proficiency.

Table 24

Reporting Categories for the End of Course SOL Test for Algebra I

Reporting Categories	Expressions and Operations	Relations and Functions	Equations and Inequalities	Statistics	Total Items
Number of Items	12	12	18	8	50

Reliability and Validity Data for Algebra I End of Course SOL Test

According to the Virginia Department of Education (1999), the Algebra I test was developed with the cooperation of a Content Review Committee composed of Virginia Educators who have experience and expertise in the content area of the test. The Content Review Committee works with the testing contractor and the Department to review each item based on strict criteria before the item can be field-tested. After items are field tested, the Content Review Committee reconvenes to review the items using field test statistics: traditional item statistics, Rasch Item Statistics, and Differential Item Functioning. The Mantel-Haenzel Alpha procedure was used to measure item bias. Test reliability was measured using the Kuder-Richardson Formula #20. Values for this measurement range from 0 to .99. The Kuder-Richardson is a traditional measure designed to measure the degree to which the test items consistently measure the same body of content and skills. The Kuder-Richardson #20 reliability coefficient for Algebra I was .88 (Virginia Department of Education, 1999).

Data Analysis and Reporting Results

Data collected from the questionnaire was imported into an SPSS 11.0 data file for analysis. Mean End of Course Algebra I SOL scale scores for each teacher's students were added to the file along with responses to the questionnaire. Once this process was completed, data was not associated with a teacher by name, and data and results were not associated with schools or school districts. Descriptive statistics were calculated for the teachers participating in the study. Descriptive statistics for questionnaire responses include the mean and standard deviation for individual teaching method frequencies, as well as a mean and standard deviation of frequency of usage for each teaching method category. Descriptive statistics were also calculated for the participants' students' mean scale scores for the End of Course SOL Test for Algebra I.

Hierarchical multiple regression analysis was used to determine the extent and manner in which the use of each teaching method category can explain the teacher's students' mean scores on the SOL test. Results reported from the hierarchical multiple regression include a correlational matrix displaying correlations for teaching method categories, teacher mean scale scores on the SOL test, and background characteristics. A regression table is displayed to explain the variance contributed by each teaching method category along with an unstandardized regression equation to demonstrate the manner in which each teaching method type relates to student performance on the End of Course SOL Test for Algebra I.

Pedhazer (1997) and Huck (2000) discuss the use of multiple regression analysis for correlational studies where the researcher seeks to determine the "amount of ingredient" equated to the size of the bivariate correlation between the given independent variable and the dependent variable. Multiple regression analysis takes into account that the independent variables may be intercorrelated or that they may interact in their effects on the dependent variable. “Multiple regression analysis is eminently suited for analyzing collective and separate effects of two or more independent variables on a dependent variable” (Pedhazer, 1997, p. 3). In hierarchical multiple regression, the researcher will “determine the order in which the independent variables become a part of the regression equation” (Huck, 2000, p. 584).

Interpretation of the regression table and correlational matrix determines the extent and manner the variation in the criterion variable (dependent variable) can be explained and/or predicted by the predictors (independent variables). The extent of the correlation or shared variation is represented by Mult R or R^2; while the manner in which the shared variation is explained or predicted is represented by the relative size or magnitude of the *B* value (Beta Weight) for each step. Beta weight is defined as the standardized regression coefficient; it is the change in “y” dependent variable) for each unit change in “x”(independent variable).

Methodology Summary

Teaching method categories derived in Chapter II were used as variables known to be correlates of the criterion for this study, student achievement on the End of Course SOL Test for Algebra I, in order to conduct hierarchical multiple regression analysis. The culmination of this process is the exploration of the combination of independent variables, teaching method categories, in Algebra I classes currently in session for the 2001-2002 school year, resulting in a more accurate prediction or explanation of their effects on student achievement in algebra, using the End of Course SOL Test for Algebra I as the dependent variable.

CHAPTER IV
RESULTS OF THE STUDY

> "We educators stand at a special point in time. This is not because a new decade, century, and millennium have begun. Rather, it is because the 'art' of teaching is rapidly becoming the 'science' of teaching, and this is a relatively new phenomenon. "
>
> (Marzano, Pickering, & Pollock, 2001, p. 1)

The purpose for this quantitative study was to investigate the influence of teaching methodology on student achievement on the End of Course SOL Test for Algebra I. Specifically, six categories of teaching methods, cooperative learning; communication and study skills; technology aided instruction; problem-based learning; manipulatives, models, and multiple representations; and direct instruction, were derived from the meta-analysis in Chapter II. The categories were used to develop a questionnaire to measure the frequency with which Algebra I teachers use these teaching methods. Algebra I teachers in seven school districts in Region VII of Virginia were surveyed, and their responses to the questionnaire were aggregated to comprise the independent variables for the present regression analysis. The dependent variable for this analysis, as previously outlined, was the mean scale score on the End of Course SOL Test for Algebra I for each participating teacher's students. The results of this analysis are offered here.

The analysis of data and results are presented in four sections. First, there is a description of the sample of participants, including background characteristics, mean frequency of use for each teaching method category, and a mean End of Course SOL Test scale score. Next, a correlation matrix is provided to display relationships between variables. A table describing the results of the regression analysis presents the relationship between teacher usage of each teaching method category and the mean scale score on the End of Course SOL Test for Algebra I. This is followed by a summary of findings for each teaching method category, including mean frequencies for teaching method categories in light of background characteristics.

Description of the Participants

Descriptive statistics and measures of dispersion were calculated to represent the background characteristics of participating Algebra I teachers, as reported on the questionnaire. Mean scores were calculated for interval data, including frequencies for use of each teaching method category, years of teaching experience for Algebra I in Virginia, and the scale score for the End of Course SOL Test for Algebra I. Table 25 displays the background characteristics of participating teachers. Percentages were used to describe categorical data, such as school grade level, school schedule type, and credit value for the Algebra I class taught.

Table 25

Descriptive Statistics for Participating Algebra I Teachers (n=53)

Characteristic		M or %	SD
Years of Experience Teaching Algebra I in Virginia		9.32	8.89
School Grade Level	Middle School	20.8%	—
	High School	79.2%	
School Schedule Type	Alternating Day Block	--	
	4 x 4 Block	37.7%	
	Seven Period Day	62.3%	—
Credit Value for Class Taught	One Credit	83%	
	Two Credits	17%	—
Scale Score for the End of Course SOL Test for Algebra I		438.01	32.67
Frequency of Use of Cooperative Learning		*2.63	0.98
Frequency of Use of Communication and Study Skills		*3.08	1.07
Frequency of Use of Technology Aided Instruction		*3.20	0.95
Frequency of Use of Problem-Based Learning		*2.66	1.08
Frequency of Use of Manipulatives, Models and Multiple Representations		*2.56	0.95
Frequency of Use of Direct Instruction		*3.75	0.75

*Represents the mean number of times teachers used this method, given five typical class periods (0-5)

Participant Background Characteristics

Initially, 59 teachers were asked to participate in the study by completing the questionnaire based on their principals' indication that they were teaching Algebra I during the spring of 2002. A minimum of 36 teachers was needed to meet the requirement of six to ten participants per independent variable in the multiple regression analysis. One of the initial 59 declined. Another indicated that she was not teaching Algebra I during the spring of 2002 and did not complete the questionnaire. Four more teachers who completed the questionnaire were not teaching Algebra I during the spring of 2002, so their responses were deleted from the database. This reduced the sample of participants to 53 teachers representing 1,538 students. The teachers ranged in experience teaching Algebra I in Virginia from one year to 32 years, with a mean of 9.8 years. More than half the teachers have been teaching Algebra I in Virginia for less than five years.

The majority (79.2%) of the participating teachers work at the high school level. Three schedule types were offered on the questionnaire to describe the participants' schools: alternating day block, 4 x 4 block, and seven period day. On the alternating day, or A – B day block schedule, four 90-minute class periods are scheduled each day. On one day, the student takes one set of classes, and on the next day, he takes another set of classes. No participating teachers worked at alternating day block scheduled schools. The majority (62.3%) of the teachers work at schools with the traditional seven period day. On this schedule, seven class periods are offered each day, all year. The remaining teachers (37.7%) worked at schools with a 4 x 4 block schedule. Students attend four 90-minute class periods each day. Students take one set of four classes for one half of the school year and a second set of four classes during the next half.

Credit value for the class taught indicates the duration for the Algebra I class. A one-credit Algebra I class is either offered for one semester on the 4 x 4 block schedule or one full year on the seven period day schedule. The two credit Algebra I class is broken into two parts. Each part is taken as a full year course on the seven period day schedule, and each part is taken for one half the school year on the 4 x 4 block schedule. Thus, students taking Algebra I for two credits have twice the time to learn the knowledge and skills required in the SOLs. Eighty-three percent of the participating teachers teach Algebra I for one credit, while relatively few (17%) teach the course for two credits.

Algebra I SOL Test Score Distribution for Participants

The mean scale End of Course SOL test for Algebra I score for the sample of participants was 438.11 with a standard deviation of 32.67. Mean scores for individual teachers' students ranged from 350.57 to 511.56. A scale score of 400 or higher is required to pass the test. A scale score of 500 or greater is required for a designation of advanced proficiency. A histogram displaying the distribution of mean test scores in comparison to a normal curve is presented in Figure 8. Scores are represented with 10 intervals to give an identifiable shape to the bar distribution.

The distribution of scores is slightly positively skewed, as the mean (438.01) is greater than the median (437.06). In other words, the mean is skewed or pulled in the direction of the extreme scores, while the median is not. The lowest scores fall well outside two standard deviations to the left of the mean (372.66). All teachers with student mean scores within one standard deviation to the left or right of the mean (405 – 470.67) had passing student mean scores. Just less than71% of the teachers' students achieved mean scores of at least 400, and most with means in the advanced proficiency range of 500 or above were beyond two standard deviations to the right of the mean (503).

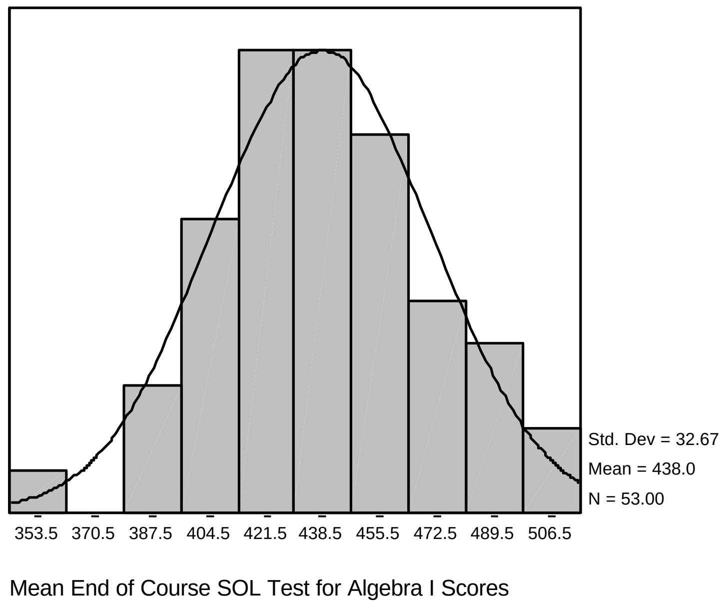


Figure 8. Distribution of mean scale End of Course SOL Test for Algebra I scores for participants.

Participant Usage of Teaching Methods

Of the teaching method categories, direct instruction was used most often by this sample of teachers with a mean usage of 3.75 times, given five typical class sessions. This method was followed by technology aided instruction (3.20), communication and study skills (3.08), problem-based learning (2.66), cooperative learning (2.63), and manipulatives, models, and multiple representations (2.56). These results indicate that as a group the sample of teachers uses each method at least half of the time they have for instruction. Mean frequencies for individual teaching methods that made up each category are found in Appendix HH.

Relationships Between Variables

Individual Pearson Product Moment Correlations were conducted to determine which variables possessed strong and statistically significant relationships. This procedure was done to determine the order in which independent variables would be entered into the regression analysis. Table 26 displays the results of the correlation analysis in the form of a correlation matrix. Positive numbers in the matrix indicate a relationship where as one variable increases, the related variable also increases. Negative numbers indicate an inverse of this relationship. The larger the number is, the stronger the relationship. Asterisks indicate whether the relationship was statistically significant given the null hypothesis that no relationship exists between the two variables in the population.

Table 26

Correlational Matrix for Mean End of Course Algebra I Test Scores, Teaching Method Categories, and Background Characteristics of Participants (n=53)

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Mean SOL Test Score	--										
2. CL	.09	--									
3. CS	-.01	.54**	--								
4. TAI	.19	.30*	.54**	--							
5. PBL	.10	.52**	.68**	.43**	--						
6. MMR	.002	.43**	.64**	.39**	.65**	--					
7. DI	.18	.33*	.38*	.32*	.41*	.35*	--				
8. Years Experience	.23	.16	.14	.13	.08	.17	.16	--			
9. School Level (0=middle school; 1=high school)	-.63**	.05	-.15	-.20	-.12	-.07	-.08	-.01	--		
10. Schedule Type (0=4x4 Block; 1=7Period)	-.19	.06	.09	-.17	-.006	.06	.18	.02	-.01	--	
11. Credit Value of Class (1 or 2)	-.46**	-.19	-.006	-.04	-.21	-.05	-.15	-.22	.23	.04	--

* Significant at $p < .05$
** Significant at $p < .01$

All of the teaching method categories showed a moderately strong and positive, statistically significant relationship to one another. This created a concern regarding the multicollinearity of independent variables with the strongest relationships for the multiple regression analysis. Ideally, independent variables will have strong relationships with the dependent variable and little or no relationship to each other. Independent variables that are highly correlated can appear statistically worthless in a multiple regression analysis (Huck, 2000).

The strongest relationship was found between the teacher's use of communication and study skills teaching methods and problem-based learning methods (r=.68). This relationship was statistically significant at $p<.01$. Other relationships found at this level of significance existed between usage of communication and study skills methods and cooperative learning (r=.54); technology aided instruction and communication and study skills (r=.54); problem-based learning and technology aided instruction (r=.43); problem-based learning and cooperative learning (r=.52); and between manipulatives, models and multiple representations and cooperative learning, communication and study skills, technology aided instruction, and problem-based learning (r=.43, .64, .39, and .65).

Technology aided instruction and cooperative learning teaching method usage showed a statistically significant relationship at $p<.05$ (r=.30). Direct instruction was related to every other teaching method category at the same level of statistical significance: CL, CS, TAI, PBL, and MMR (r=.16, .14, .13, .08, .17, and .16). These relationships were relatively weak when compared to the strength of relationships existing among the usage of the other teaching method categories.

School level and schedule type are categorical variables. In order to examine whether changing from one level of the categorical variable was related to variance in the interval scale variables, each level of the categorical variables was assigned a numerical value. A change from zero to one for these variables, however, does not indicate an increase in the level of the variable in any numerical sense. Credit value is on the interval scale by strict definition; however, a mean credit value has no meaning. It is appropriate to consider credit value as a categorical value serving as a proxy for duration of instruction. Moderately strong, negative relationships were found between school level and mean scale scores on the End of Course Algebra I Test (r=.63) and credit value and mean scale scores on the End of Course Algebra I Test (r=.46). Both of these relationships were statistically significant at $p<.01$.

Multiple Regression Analysis Results

Hierarchical, or blockwise, multiple regression analysis was used to determine the extent and manner in which the frequency of use of each teaching method category can explain the teachers' students' mean scale scores on the End of Course SOL Test for Algebra I. Independent variables were entered into the regression equation in predetermined steps based on the strength of their correlations to the dependent variable.

Multiple regression analysis was used to determine the "amount of ingredient" equated to the size of the bivariate correlation between the teacher's usage of the teaching method categories and the mean SOL test score. The collective and separate effects of the teaching method categories on teachers' students' mean scores were analyzed. In this case, hierarchical multiple regression was used to determine the order in which teaching method categories became a part of the regression equation. Table 27 displays the results of this analysis.

Interpretation of the regression table and correlational matrix determines the extent and manner in which variation in the criterion variable (dependent variable) can be explained and/or predicted by the predictors (independent variables). The extent of the correlation or shared variation is represented by Mult R or R^2; while the manner in which the shared variation is explained or predicted is represented by the relative size or magnitude of the *B* value (Beta Weight) for each step. Beta weight is defined as the standardized regression coefficient; it is the change in “y” (dependent variable) for each unit change in “x” (independent variable).

Table 27

Regression Table for Multiple Regression Analysis

Hierarchical Multiple Regression Results for the Prediction of End of Course Algebra I Mean Test Score by Teacher from the Teacher’s use of TAI, DI, PBL, CL, CS, and MMR.

Step	Variable	Mult R	R^2	S_{est}	Adj. R^2	Increase in R^2	*B*	b	t_b	Prob.
1	TAI	0.187	0.035	32.410	0.016	--	0.239	8.229	5.83	0.165
2	DI	0.226	0.051	32.455	0.013	0.016	0.156	6.808	6.925	0.331
3	PBL	0.227	0.052	32.776	-0.006	0.000	0.138	4.167	6.513	0.525
4	CL	0.228	0.052	33.113	-0.027	0.000	0.086	2.859	5.762	0.622
5	CS	0.304	0.093	32.730	-0.004	0.041	-0.279	-8.468	6.865	0.224
6	MMR	0.312	0.097	33.009	-0.021	0.004	-0.093	-3.212	6.822	0.640

Unstandardized regression equation:

$$\hat{y} = 401.849 + 8.229(TAI) + 6.808(DI) + 4.167(PBL) + 2.859(CL) - 8.468(CS) - 3.212(MMR)$$

Regression Table Explanation

The R^2, or Mult R values, represented in Table 27 illustrate the extent to which variance in each independent variable explains variance in the dependent variable. For this sample, the group of independent variables shared nearly 10% of variance with the dependent variable as indicated by the final R^2 of 0.097. Note, however, that this result has no statistical significance when referred to the population. None of the probability values indicated that variance shared between any given independent variable and the dependent variable was statistically significant at $p<.05$. In other words, the assumption that none of the variance in the dependent variable is explained by the collection of independent variables for the population was not overcome in this case.

The R^2 values for independent variables increased according to the order in which the variables were entered into the regression analysis. A relatively large increase in R^2 occurred between steps four and five; however, this was tempered by examining the negative values for adjusted R^2 used to anticipate the amount of reduction that would occur in the value of R^2 had a much larger sample of participants been used. None of the changes in R^2 were statistically significant at $p<.05$.

Unstandardized Regression Equation

The unstandardized regression equation accompanying Table 27 conveys the manner in which the set of independent variables explains variance in the dependent variable. It is the equation for a line, where the “$\hat{y}$” value indicates a teacher’s mean scale SOL score, given the values calculated in the regression equation. The constant value of 401.849 specifies the point at which the line would intercept the “y” axis if the teacher indicated a zero usage for all teaching methods.

The number preceding each independent variable in the equation is referred to as the unstandardized regression coefficient. This value is taken from the “*b*” column in Table 27. It indicates the amount of slope that each independent variable will contribute to the regression line. Of course, the slope of the line will vary, given the values of the independent variables. Each independent variable represents an "x" value and contributes to the slope of the line, just as a point on the "x" axis contributes to the slope of a given line. The "*b*" value indicates the rise, while the independent variable's "x" value indicates the run of the line.

Summary of Results for Each Category

This final section of Chapter IV presents a summary of findings for each teaching method category. These results are reported in light of the background characteristics of the participants in Table 28. The participants' usage of teaching methods is described in terms of their background characteristics and instructional setting to provide a context. A mean frequency from zero to five is presented for each item along with the standard deviation. This score represents the mean number of times participants used this teaching method, given typical five class periods. Participants' years of experience teaching Algebra I in Virginia ranged from one to thirty-two years. Rather than attempting to give a mean usage for each level of this variable, a correlation between years experience and method usage is presented. Information pertaining to individual questionnaire items is found in Appendix HH.

Cooperative Learning

For the purposes of this study, cooperative learning is defined as a method of instruction characterized by students working together to reach a common goal. Cooperative learning produced the third largest mean effect size (0.34) and a percentile gain of 13% for all studies and the fourth largest mean effect size (0.26) and a percentile gain of 11% for "good" studies in the meta-analysis presented in Chapter II. This indicated a small effect (Cohen, 1988) for this teaching method on student achievement in algebra.

Table 28

Usage of Teaching Methods Reported by Background Characteristic

Category	All n=53		Middle School n=11		High School n=42		4 x 4 Schedule n=20		7 Period Day n=33		One Credit n=44		Two Credits n=9		Teacher's Experience n=53
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	r
CL	2.63	0.98	2.53	0.97	2.66	0.99	2.56	0.99	2.68	0.99	2.72	1.00	2.22	0.78	0.16
CS	3.08	1.08	3.38	1.06	3.00	1.08	2.96	0.97	3.16	1.14	3.09	1.13	3.07	0.78	0.14
TAI	3.20	0.95	3.56	0.63	3.10	1.00	3.40	0.58	3.07	1.10	3.22	0.98	3.11	0.87	0.13
PBL	2.66	1.08	2.92	0.98	2.59	1.11	2.67	1.05	2.65	1.12	2.76	1.06	2.17	1.13	0.08
MMR	2.56	0.95	2.68	0.92	2.52	1.00	2.48	0.86	2.60	1.01	2.57	0.99	2.45	0.75	0.17
DI	3.75	0.74	3.86	0.82	3.72	0.73	3.58	0.84	3.90	0.67	3.80	0.71	3.50	0.90	0.16

As displayed in Table 28, the teachers participating in this study used cooperative learning about half of the time, 2.63 times out of five class periods with a standard deviation of 0.98. The two most used cooperative learning methods from the questionnaire were collaboration with the whole class in finding the solution to a problem and allowing students to begin homework in class with peer assistance. Each had a mean of 3.72 and standard deviations of 1.46 and 1.47, respectively. The least used method for this category was the assignment of students to work in homogeneous groups (M = 0.98, SD =1.31). Cooperative learning was most used by teachers who taught Algebra I for one credit: 2.72 times out of five class periods with a standard deviation of one. CL was least used by middle school Algebra I teachers (M = 2.53, SD = 0.97).

Cooperative learning showed the fourth largest correlation to the teacher mean scale End of Course Test for Algebra I scores (r=.09) and was entered fourth into the multiple regression analysis. CL produced no change in R^2 in the regression analysis and a *B* value, or beta weight, of 0.086. The location of CL in the unstandardized regression equation is similar to its rank in the meta-analysis results.

Communication and Study Skills

For the purposes of this study, communication and study skills is defined as a method of instruction characterized by teaching students to read and study mathematical information effectively and providing opportunities for students to communicate mathematical ideas verbally or in writing. Communication and study skills produced the fifth smallest mean effect size (0.07) and a percentile gain of three percent for all studies and the smallest mean effect size (0.16) and a percentile gain of six percent for "good" studies in the meta-analysis presented in Chapter II. This indicated a small effect (Cohen, 1988) for this teaching method on student achievement in algebra.

Communication and study skills teaching methods were used more than half of the time, 3.08 times out of five class periods with a standard deviation of 1.08, by the teachers participating in this study. The most used CS strategy was encouraging students to ask questions when difficulties or misunderstandings arise ($M = 4.62$, $SD = 1.10$). This item had the highest mean score of all questionnaire items. The least used CS strategy was having students write about their problem solving strategies ($M = 1.28$, $SD = 1.47$). CS was most used by middle school Algebra I teachers: 3.38 times out of five class periods with a standard deviation of 1.06. CS was least used by teachers on the 4x4 block schedule with a mean score of 2.96 and standard deviation of 0.97.

Communication and study skills showed the second smallest correlation to the teacher mean scale End of Course Test for Algebra I scores with a negative $r = 0.01$. CS was entered fifth into the multiple regression analysis. This teaching method produced a change of 0.041 in

R^2 in the regression analysis and a *B* value, or beta weight, of negative 0.28. The location of CS in the unstandardized regression equation is similar to its rank in the meta-analysis results.

Technology Aided Instruction

For the purposes of this study, technology aided instruction is defined as a method of instruction characterized by the use of computer software applications and/or hand-held calculators to enhance instruction. Technology aided instruction produced the fifth smallest mean effect size (0.07) and a percentile gain of three percent for all studies and the third largest mean effect size (0.41) and a percentile gain of 16% for "good" studies in the meta-analysis presented in Chapter II. This indicated a small to near medium effect (Cohen, 1988) for this teaching method on student achievement in algebra.

Technology aided instruction was used well more than half of the time, 3.20 times out of five class periods with a standard deviation of 0.95, by the teachers participating in this study. It was second only to direct instruction in terms of usage. Allowing students to use calculators during tests or quizzes was the most used TAI method (M = 4.60, SD = 1.10). The least used TAI method with the lowest score on the total questionnaire was having the students use computer spreadsheets for problem solving instruction (M = 0.26, SD = 0.76). TAI was most used by middle school Algebra I teachers: 3.56 times out of five class periods with a standard deviation of 0.63. TAI was least used by teachers on the seven period day schedule with a mean score of 3.07 and standard deviation of 1.10.

Technology aided instruction showed the largest correlation to the teacher mean scale End of Course Test scores for Algebra I (0.19). TAI was entered first into the multiple regression analysis. This teaching method produced an R^2 value of 0.035, representing 3.5% shared variance with the dependent variable. TAI produced a *B* value, or beta weight, of 0.24. The location of TAI in the unstandardized regression equation does not reflect its place in the meta-analysis results. This teaching method moved from either tied for last for all studies or third for "good" studies in the meta-analysis to first in the multiple regression analysis.

Problem-Based Learning

For the purposes of this study, problem-based learning is defined as a method of instruction characterized by teaching through problem solving where students apply a general rule (deduction) or draw new conclusions or rules (induction) based on information presented in the problem. Problem-based learning produced the second largest mean effect size (0.52) and a percentile gain of 20% for all studies and the second largest mean effect size (0.44) and a percentile gain of 17% for "good" studies in the meta-analysis presented in Chapter II. This indicated a medium effect (Cohen, 1988) for this teaching method on student achievement in algebra.

The teachers participating in this study used problem-based learning teaching methods about half of the time, 2.66 times out of five class periods with a standard deviation of 1.08. This category was ranked fourth in terms of usage. Emphasizing the problem solving process over the solution was the most used PBL method (M = 3.51, SD = 1.53). The least used PBL method was "I have students pursue open-ended and extended problem solving projects" (M = 1.58, SD = 1.51). PBL was most used by middle school Algebra I teachers: 2.92 times out of five class periods with a standard deviation of 0.98. PBL was least used in two-credit Algebra I classes (M = 2.17, SD = 1.13).

Problem-based learning showed the third largest correlation to the teacher mean scale End of Course Test scores for Algebra I (0.10) and the smallest correlation to the teacher's years of experience teaching Algebra I in Virginia (0.08). PBL was entered third into the multiple regression analysis. This teaching method produced no change in R^2 beyond the first two variables. PBL produced a *B* value, or beta weight, of 0.138. The location of PBL in the unstandardized regression equation does not reflect its place in the meta-analysis results. This teaching method moved from second place for all studies and “good” studies in the meta-analysis to third in the multiple regression analysis.

Manipulatives, Models, and Multiple Representations

For the purposes of this study, manipulatives, models, and multiple representations is a category of instruction where students are taught techniques for generating or manipulating representations of algebraic content or processes, whether concrete, symbolic, or abstract. The manipulatives, models, and multiple representations category produced the fourth largest mean effect size (0.23) and a percentile gain of nine percent for all studies and the fifth largest mean effect size (0.23) and a percentile gain of nine percent for “good” studies in the meta-analysis presented in Chapter II. This indicated a small effect (Cohen, 1988) for this teaching method on student achievement in algebra.

The MMR teaching method category was used the least frequently among participants, about half of the time, or 2.56 times out of five class periods with a standard deviation of 0.95. The most used MMR method from the questionnaire was teaching students to represent algebraic equations with graphs (M = 3.34, SD = 1.58). Using cubes or blocks to represent algebraic equations was least used (M = 1.15, SD =1.32). MMR was most used by middle school teachers: 2.68 times out of five class periods with a standard deviation of 0.92. This category was least used by those teaching Algebra I for two credits (M = 2.45, SD = 0.75).

The manipulatives, models, and multiple representations category had the largest correlation to the teacher’s years of experience with teaching Algebra I in Virginia (0.17). MMR had the smallest correlation to the teacher mean scale End of Course Test for Algebra I scores (r=.002) and was entered last into the multiple regression analysis. MMR produced an increase of 0.004 in R^2 in the regression analysis and a *B* value, or beta weight, of -0.093. The MMR category moved from fourth or fifth place in the meta-analysis to last place in the unstandardized regression equation.

Direct Instruction

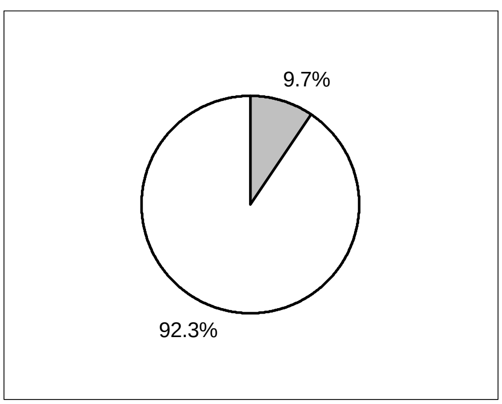
For the purposes of this study, direct instruction is defined as teaching through establishing a direction and rationale for learning by relating new concepts to previous learning, leading students through a specified sequence of instructions based on predetermined steps that introduce and reinforce a concept, and providing students with practice and feedback relative to how well they are doing. The direct instruction category produced the largest mean effect size (0.51) and a percentile gain of 21% for all studies and the largest mean effect size (0.67) and a percentile gain of 25% for “good” studies in the meta-analysis presented in Chapter II. This indicated a medium effect (Cohen, 1988) for this teaching method on student achievement in algebra.

Direct instruction teaching methods were used the most by the participants: 3.75 times out of five class periods with a standard deviation of 0.74. Requiring students to indicate a one-step-at-a-time process in working equations was the most used DI method (M = 4.19, SD = 1.19). The least used DI method was “I grade homework to provide feedback” (M = 3.23, SD = 1.79). DI was most used by Algebra I teachers at schools with seven period day schedules: 3.90 times out of five class periods with a standard deviation of 0.67. DI was least used in two-credit Algebra I classes (M = 3.50, SD = 0.90).

Direct instruction had the second largest correlation to the teacher mean scale End of Course Test scores for Algebra I (0.18). DI was entered second into the multiple regression analysis. This teaching method produced a 0.016 change in R^2 beyond the first variable. DI produced a *B* value, or beta weight, of 0.156. The location of DI in the unstandardized regression equation does not reflect its place in the meta-analysis results. This teaching method moved from first place for all studies and "good" studies in the meta-analysis to second in the multiple regression analysis.

Summary of Results

As a group, the 53 Algebra I teachers' 1,538 students included in this study produced a passing mean scale SOL test score of 438.01. Participating teachers' students passed the SOL test within one standard deviation of this score (SD = 32.67). Mean frequencies for teaching method categories were entered into a blockwise multiple regression analysis, ranked according to the strength of their correlation to the dependent variable. Teaching method categories accounted for 9.7% of the variance in teachers' students' mean scale scores for the End of Course SOL Test for Algebra I. See figure 9.



Shaded area represents variance explained by teaching method categories.

Figure 9. Variance explained by teaching method categories for participating teachers (N=53).

Some of the teaching method categories changed their ranking in the from the meta-analysis results presented in Chapter II to new places in the multiple regression analysis. A summary of this trend is presented in Table 29. Most notably, technology aided instruction moved from tied for last place for all studies and third place for "good" studies in the meta-analysis to first place in the regression study.

Table 29

Rank Comparisons of Teaching Method Categories from Meta-Analysis to Regression Analysis

Place (Strongest First)	Meta-Analysis "Good" Studies	Regression Analysis
1	Direct Instruction	Technology Aided Instruction
2	Problem-Based Learning	Direct Instruction
3	Technology Aided Instruction	Problem-Based Learning
4	Cooperative Learning	Cooperative Learning
5	Manipulatives, Models, and Multiple Representations	Communication and Study Skills
6	Communication and Study Skills	Manipulatives, Models, and Multiple Representations

CHAPTER V
SUMMARY AND CONCLUSIONS

"Teaching mathematics well is a complex endeavor, and there are no easy recipes. "
(NCTM, 2000)

I conducted this study in an effort to provide a resource for school leaders and mathematics teachers as they face the challenge of helping all students to learn algebra knowledge and skills as set forth in Virginia's Standards of Learning (1995). I sought to derive teaching methods for algebra from a research base and to determine the influence of these teaching methods on algebra student achievement. Replicating Marcucci's (1980) methodology for meta-analysis, I reviewed experimental research on teaching methods for secondary level algebra from 1980 to 2001, and I categorized these methods to create generalized domains of instructional practices. Each category was expanded to include teaching methods found in non-experimental reports. Results from the meta-analysis were reported in Chapter II and used to develop a questionnaire designed to determine the frequency with which teachers use the teaching methods under investigation.

After conducting validity and reliability studies, I administered the questionnaire to a sample of Algebra I teachers in Region VII of the Commonwealth of Virginia. Data gathered from the questionnaire was aggregated to provide a mean frequency score for each teaching method category, along with background characteristics of participants. These teaching method categories became independent variables in a multiple regression analysis, where the dependent variable was the participating teacher's students' mean scale score on the spring, 2002, administration of the End of Course SOL Test for Algebra I. Results from this analysis were reported in Chapter IV.

Presented here is a summary of the findings and a discussion. In the context of this discussion, I will put forward both the limitations and implications of the research results. This information is followed by recommendations for practitioners, suggestions for future studies, final reflections, and a conclusion to this dissertation.

Summary of Results Addressing Research Questions

In Chapter I, the following research questions were posed for the meta-analysis review of literature, the extent of teacher usage of reform- and research-based teaching methods under study, and the multiple regression analysis.

For the review of literature, the central question addressed is similar to that found in Marcucci's (1980) dissertation: Based upon available research evidence, which type of teaching methodologies appear to be the most effective in teaching algebra knowledge and skills to students at the secondary school level?

Regarding usage of reform- and research-based teaching methods, the question addressed is to what extent mathematics education reform is being carried out in the classroom by Virginia's Algebra I teachers. In other words, are Algebra I teachers in Virginia using teaching methods endorsed by the NCTM as well as methods explored in research?

The culminating research question for this study is addressed with the use of teaching method categories developed in the meta-analysis as independent variables in a multiple regression analysis: To determine the extent and manner in which the teaching method categories explain variance in student achievement on Virginia's End of Course SOL Test for Algebra I. A summary of the results for each research question is presented here.

Review of Literature

Based upon a thorough review of research reports including anecdotal reports, technical reports for refereed journals, master's theses, and doctoral dissertations, the teaching methods I studied in the meta-analysis appear to be the most effective in teaching algebra knowledge and skills to students at the secondary school level. Considering the limitations affecting the interpretation of these results, including correlations between effect sizes and study characteristics discussed in Chapter II, the meta-analysis I conducted establishes a reasonable basis for defining - and ranking as to their effect sizes - the following teaching method categories: direct instruction (.55), problem-based learning (.52), cooperative learning (.34), manipulatives, models, and multiple representations (.23), technology aided instruction (.07), and communication and study skills (.07).

These methods produced effect sizes for "good" studies ranging from a small 0.16 for communication and study skills to a near-large 0.67 effect size for direct instruction. The latter effect translates into a 25-point percentile gain in a normal distribution of scores. Further, I conducted extensive content validation by experts to ensure that individual teaching methods discovered in the 34 studies used for meta-analysis, along with non-experimental reports, were appropriately placed under general teaching method categories.

Usage of Research and Reform Based Teaching Methods

At the turn of the century, the NCTM released *Principles and Standards for School Mathematics*. Although this document and others like it are intended to be resource guides for educational decision makers as they plan for curriculum changes in mathematics (NCTM, 2000), the question looms as to what extent mathematics education reform is being carried out in the classroom by Virginia's Algebra I teachers. Based on the results of this study, it is apparent that

Algebra I teachers are embracing teaching methods endorsed by the NCTM as well as methods explored in research.

With a passing mean scale score of 438.01 (SD = 32.67) and just less than71% of the teachers' students achieving a mean score of at least 400 for spring, 2002, this group of teachers is apparently experiencing increasing success with the standards of learning. Their respective school districts had a mean pass rate of 64% for the full year of 2000-2001. Participating teachers indicated that they used all of the teaching method categories more than half of the time with mean frequencies ranging from 2.56 to 3.75 times out of five class sessions for use of manipulatives, models, and multiple representation and direct instruction, respectively. Direct instruction had the largest effect size in the meta-analysis, and it is the teaching method category most used by the participants in this study.

Regression Analysis of Teaching Methods and Student Achievement

Teaching method categories under investigation were used as independent variables in a multiple regression analysis, where the dependent variable was the participating teacher's students' mean scale score on the spring, 2002 administration of the End of Course SOL Test for Algebra I. The categories were entered into a blockwise multiple regression analysis, ranked according to the strength of their correlations to the dependent variable. For this sample of teachers, the teaching method categories accounted for 9.7% of the variance in teachers' students' mean scale scores for the End of Course SOL Test for Algebra I. These results convey the extent and manner in which teaching method categories explain variance in mean scale SOL scores for this sample. Several of the teaching method categories changed their ranking from the meta-analysis results to new places in the regression analysis. Particularly, technology aided instruction moved from tied for last place for all studies and third place for “good” studies in the meta-analysis to first place in the regression study.

Limitations and Cautions

Results obtained from the regression analysis convey the extent and manner in which teaching method categories explain variance in mean scale SOL scores for this sample, not the general population. The assumption that shared variance between independent variables and the dependent variable in the population is zero was not overcome, since no R^2 values were statistically significant at $p<.05$. Further, a causal link between the independent variables and the dependent variable should not be inferred. In other words, teaching methods did not “cause” 9.7% of the variance in teachers’ students’ mean SOL test scores for this sample of 53 teachers. There is an association or relationship between the two.

Implications

According to Pedhazer (1997), in explanatory research, the purpose of data analysis is to “shed light on theory” (p. 8). The choice of research design is based on a theoretical framework that explains the relationship(s) between variables. That is the case in this study. I selected a theory of educational productivity as proposed by Walberg (1984) and further selected one small piece of the theory to explore. This study was not an effort to find a “magic bullet” that causes students to achieve. It was a methodical attempt to “shed light” on a small part of a theory by making it more specific and focused; thus, allowing educators to make practical decisions about teaching methods.

Theory of Educational Productivity

Walberg determined nine factors that “require optimization to increase affective, behavioral, and cognitive learning” (1984, p. 20). Walberg states that these factors fall into three groups: student aptitude, instruction, and environment. Instruction includes the amount of time students engage in learning and the quality of the instructional experience, including psychological and curricular aspects. Referring back to figure 9, the pie chart would be cut into nine slices in accordance with Walberg's model. These slices would vary in size, of course, as the factors they represent would vary in their impact on student learning.

Now consider a particular sample of 53 teachers with one measure of student learning, the End of Course SOL Test for Algebra I. Suppose that one of the factors, quality of instruction, could account for nine to ten percent of the impact of the entire model, given that there are eight other factors accounting for the remaining 90 to 91%. Within the factor labeled "quality of instruction," the usage of six teaching methods that vary in their influence on student learning is quantified in terms of their frequency of usage by the sample of teachers. These methods are generalized categories that contain several specific practices found in comparative research and theory based reports.

In light of Walberg's theory of educational productivity and the limitations discussed previously, there is one clear implication of the results of this study. Teaching methods can influence student learning as it is measured by a single outcome, such as the Standards of Learning test. The effect sizes for the teaching methods displayed in Table 29 give an order of impact from near large to small for an aggregate of diverse studies with single outcome measures: direct instruction, problem-based learning, technology-aided instruction, cooperative learning, manipulatives, models, and multiple representations, and communication and study skills. The multiple regression analysis gives a different order based on variance shared between the teaching methods and one outcome measure: TAI, DI, PBL, CL, CS, and MMR.

Given that within Walberg's model, the principal and Algebra I teacher can only control instructional factors, it would be enlightening for these practitioners to consider the research findings presented here in order to make instructional decisions that optimize their integrated usage of research-based teaching methods.

Mathematics Education Reform

One of the premises of the NCTM's 1989 *Curriculum and Evaluation Standards* is that "instruction in mathematics must be significantly revised" (NCTM, 1989, p. 1). According to Romberg (1998), "Revised instruction implies that classrooms must become discourse communities where conjectures are made, arguments presented, strategies discussed, and so forth. In 1998, Romberg painted a bleak description of the typical mathematics classroom. Instruction follows a five step pattern involving reviewing homework, explanation and examples of a new problem type by the teacher, seat work where students work independently to practice the new problem type, summarization of work and a question and answer period conducted by the teacher, and teacher-assigned homework consisting of similar problems. Invariably, the next class period begins with a review of these homework problems.

Now consider the following scenario. The teacher identifies a new skill or concept at the beginning of instruction and provides a rationale for learning it (DI). The teacher then moves on to present the class with instruction and related problem-solving activities derived from "real-life" situations that are meant to be interesting to the students (PBL). In the context of these activities, students use calculators to develop problem-solving strategies or to represent linear relationships in equations with graphs (TAI and MMR). During the course of the lesson, the teacher encourages students to use mathematics vocabulary, to share their thinking by conjecturing, arguing, and justifying ideas orally or in written form, and to ask questions when difficulties or misunderstandings arise (CS). The class concludes with the teacher providing feedback and reviewing concepts with students, emphasizing comparisons to previously covered concepts. Students do practice work at home that reviews previously covered material as well as the day's target objective (DI).

This scenario is much more optimistic, and it is another implication from the present study, where the participants indicated that they use all of the teaching method categories more than half the time. Regardless of whether this change from Romberg's 1989 description to the one implied by the results of this study is based on reform or research and theory, the promising aspect of it in terms of Walberg's model is that it appears to be a productive change.

Recommendations for Practitioners

Sergiovanni and Starratt (1993) discussed teaching effectiveness in terms of teaching as decision-making. If we view teaching effectiveness in terms of the teacher's ability to bring about desired student learning or educational outcomes, then we must consider two dimensions of teaching.

1) The teacher's ability to teach in a way in which learning is viewed by students as meaningful and significant
2) The teacher's ability to adjust teaching strategies as warranted by changes in the teaching and learning situation (p. 107)

According to the authors, "teaching approaches…seem less an issue of which is the best way than of which is the best way for what purpose" (p.109). The key recommendation to be considered by practitioners in the case of the present study is to consider first the teaching and learning situation. Currently, Algebra I teachers in Virginia are faced with a great challenge:

teaching all students algebra so that they may successfully complete Algebra I and earn a verified credit toward graduation for this course by passing the SOL test associated with it.

Which teaching methods will produce the strongest influence on algebra student learning? To prioritize teaching methods based on the results of this study would suggest a recipe for teaching; however, the results do suggest that three teaching methods should be prioritized: direct instruction, problem-based learning, and technology aided instruction.

Direct Instruction

Direct instruction landed in the top two places in both analyses and had the largest effect size in the meta-analysis. Direct instruction is defined as teaching through establishing a direction and rationale for learning by relating new concepts to previous learning, leading students through a specified sequence of instructions based on predetermined steps that introduce and reinforce a concept, and providing students with practice and feedback relative to how well they are doing. The direct instruction category produced the largest mean effect size (0.51) and a percentile gain of 21% for all studies and the largest mean effect size (0.67) and a percentile gain of 25% for "good" studies in the meta-analysis presented in Chapter II. This indicated a medium effect (Cohen, 1988) for this teaching method on student achievement in algebra.

Direct instruction teaching methods were used the most by the participants: 3.75 times out of five class periods with a standard deviation of 0.74. Requiring students to indicate a one-step-at-a-time process in working equations was the most used DI method (M = 4.19, SD = 1.19). Direct instruction had the second largest correlation to the teacher mean scale End of Course Test scores for Algebra I (0.18). DI was entered second into the multiple regression analysis. This teaching method produced a 0.016 change in R^2 beyond the first variable.

The approach associated with this method lends itself to teaching Virginia's SOLs: starting with an objective (an SOL) and focusing instruction on it while making assessments of student progress and providing feedback. Direct instruction forms a solid foundation for using other strategies.

Problem-Based Learning

Problem-based learning ranked in the top three in both analyses. It was second in the meta-analysis and third in the regression analysis. Problem-based learning is defined as teaching through problem solving where students apply a general rule (deduction) or draw new conclusions or rules (induction) based on information presented in the problem. Problem-based learning produced the second largest mean effect size (0.52) and a percentile gain of 20% for all studies and the second largest mean effect size (0.44) and a percentile gain of 17% for "good" studies in the meta-analysis presented in Chapter II. This indicated a medium effect (Cohen, 1988) for this teaching method on student achievement in algebra.

The teachers participating in this study used problem-based learning teaching methods about half of the time, 2.66 times out of five class periods with a standard deviation of 1.08. This category was ranked fourth in terms of usage. Emphasizing the problem solving process over the solution was the most used PBL method (M = 3.51, SD = 1.53).

Problem-based learning activities provide a context for learning and create a situation where students actively construct their knowledge of algebra. When a teacher engages students with contextual problems and encourages multiple approaches and solutions, he is fostering learning with understanding. Algebra knowledge and skills are intended for problem solving, and the End of Course Test for Algebra I is intended to be primarily a problem-solving test; thus, it is sensible to use this mode of teaching in an Algebra I class.

Technology Aided Instruction

Technology aided instruction ranked in the top three methods in the meta-analysis of "good" studies and in the regression analysis. Technology aided instruction is defined as a method of instruction characterized by the use of computer software applications and/or hand-held calculators to enhance instruction. Technology aided instruction produced third largest mean effect size (0.41) and a percentile gain of 16% for "good" studies in the meta-analysis presented in Chapter II. This indicated a near medium effect (Cohen, 1988) for this teaching method on student achievement in algebra.

Technology aided instruction was used well more than half of the time, 3.20 times out of five class periods with a standard deviation of 0.95, by the teachers participating in this study. It was second only to direct instruction in terms of usage. Allowing students to use calculators during tests or quizzes was the most used TAI method (M = 4.60, SD = 1.10).

Technology aided instruction showed the largest correlation to the teacher mean scale End of Course Test scores for Algebra I (0.19). TAI was entered first into the multiple regression analysis. This teaching method produced an R^2 value of 0.035, representing 3.5% shared variance with the dependent variable.

TAI can facilitate problem solving skills development by allowing students to concentrate on the problem instead of calculations, or in the case of studying linear relationships, plotting points. Students may be able to define and understand problems and solutions more readily if they are not bogged down with mechanics that they have already mastered. The NCTM (2000) discusses technology as a matter of principle in mathematics instruction, "electronic technologies – calculators and computers – are essential tools for teaching, learning, and doing mathematics. They furnish visual images of mathematical ideas, they facilitate organizing and analyzing data, and they compute efficiently and accurately” (p. 24).It is instructive to note that the most frequently used individual teaching method within the TAI category was allowing students to use calculators during testing situations. Practice with the calculator during testing situations may aid the student in using this tool during the SOL testing.

Integration of Teaching Methods

This research study supports an emphasis on direct instruction, problem-based learning, and technology aided instruction as a foundation for instruction. Teachers may use a variety of teaching methods within the framework of the top three teaching methods. Participants’ students achieved a passing mean scale score of 438.01 (SD = 32.67), and just less than71% of the students achieved a score of at least 400 for spring, 2002. Their respective school districts had a mean pass rate of 64% for the full year of 2000-2001. In light of these results, this group of teachers is apparently experiencing increasing success with the standards of learning. Thus, their teaching methodologies can enlighten us.

The 53 teachers participating in this study indicated that they used each of the teaching method categories more than half of the instructional time, given five class periods. Further, frequencies of usage for all of the teaching method categories showed positive correlations to each other in the correlation matrix. This indicates that as the teachers’ usage of one teaching method category increased, so did their usage in others. For example, The strongest relationship was found between the teacher’s use of problem-based learning and communication and study skills teaching methods ($r=.68$). This relationship was statistically significant at $p<.01$. This indicates an integration of methodology.

As participating teachers tended to teach through problem solving, where students apply a general rule or draw new conclusions based on information presented in a problem, the teachers also emphasized teaching students to read and study mathematical information effectively and provided opportunities for students to communicate mathematical ideas verbally or in writing. To solve a problem, a student must be able to analyze it and pull out pertinent information. Next, the student must understand what the problem is asking and develop a plan for solving the problem. The student must act, verify the results, and communicate these results to others. Further, the student must be able to articulate any difficulties in solving the problem to get the right help. As a teacher emphasizes problem solving, he must facilitate it with communication and study skills.

Cooperative learning; manipulatives, models, and multiple representations; and communication and study skills teaching methods all ranked in the lower half of the six teaching method categories studied in both analyses. These teaching methods apparently make less of a difference in terms of effect sizes where comparative studies were concerned. They probably best serve as ways to enhance the other teaching method categories through integration. According to the results of this study, their usage should not form the foundation for instruction, nor should they be used outside the context of direct instruction.

Final Recommendation

Emphasize direct instruction. Focus on the desired learning outcome and make decisions about pacing and curriculum emphasis so that students may have every opportunity to learn what they are expected to learn. Use teaching methods that suit both the concept and the students who must learn it within the framework of direct instruction, such as problem-based learning and technology aided instruction. Assess whether students are learning the instructional objectives with methods that are similar to the End of Course SOL Test for Algebra I. Make decisions to adjust teaching methods based on assessment results. This statement presented in Chapter I from the NCTM (2000) regarding effective teaching bears repeating here:

> Teachers need several different kinds of mathematical knowledge – knowledge about the whole domain; deep, flexible knowledge about curriculum goals and about the important ideas that are central to their grade level; knowledge about the challenges students are likely to encounter in learning these ideas; knowledge about how ideas can be represented to teach them effectively; and knowledge about how students' understanding can be assessed. (p. 17)

Suggestions for Future Studies

This study focused on one small piece of a much larger puzzle involving student achievement in mathematics in general and algebra specifically. Other avenues of research that address some of the limitations discussed in the context of my research deserve attention.

The questionnaire developed for this study has extensive research behind it. Content validation by experts and a high reliability coefficient add to its strength as a research instrument. Further, I feel that this study may build trust and confidence that mathematics teachers can place in similar research where they indicate their instructional choices, and their students' SOL test scores are analyzed. Another researcher could use the questionnaire to study Algebra I teachers in Virginia on a much larger scale. Rather than using the teaching method categories as predictors in a regression analysis with a looming threat of multicollinearity, a researcher could use the factor analytic method to develop composite teacher types to be used as predictors. This would be a close replication of Hafner (1993) and would reveal combinations of teaching method types that influence student achievement.

Another possibility is to study the influence of teaching method categories on individual reporting categories for the SOL test: expressions and operations, relations and functions, equations and inequalities, and statistics. Discovering which teaching methods influence achievement for specific reporting categories would assist teachers in developing individualized instruction for remediation and recovery programs, as test results are reported by category.

Another use for the questionnaire developed here would be to adapt it to an observational scale. A researcher could use the methods applied by Leclerc, Bertrand, and Dufour (1986) and Seifert and Beck (1984) to conduct observations in the instructional setting, coding teacher behaviors according to the questionnaire items and categories. Continuing in this qualitative vein, the observations would make a sound basis for either interviews or focus group discussions with the purpose of examining the factors that affect algebra teachers' instructional decision-making.

Two fairly large, negative correlations appeared in the correlational matrix for two background variables in this study. School level (middle or high school) and credit value of the course (one or two) presented correlations of $r = -0.63$ and -0.46 with the teacher's students' mean scale SOL scores, significant at $p<.01$. The cause for these correlations may seem obvious: "brighter" students take Algebra I in middle school and "brighter" students take Algebra I for one credit at the middle or high school level. The researcher must ask, though, if this is a case of "brightness" or readiness. Are these students simply more ready to handle the type of abstract thinking and problem solving necessary for algebra study? Are there students who may not be ready to learn algebra during their K-12 educations? What factors affect a student's readiness to learn algebra? These questions deserve further attention.

Web-Page Based Survey

I highly recommend using active server page technology to post a questionnaire on the internet for surveying participants. The use of this technology makes survey data collection faster and more accurate, as all responses are automatically entered from a web-based "front end" into a spread sheet program, such as Microsoft Access. It is also easier to track responses because there is no mail delay. The researcher can know immediately each day how many respondents completed the questionnaire. Survey completion and response time is greatly reduced for participants because their participation only requires logging onto a web-site, entering data, and submitting it.

I recommend using a personal approach in entreating participants to complete the web-based questionnaire. It is important to pre-contact the sample with hand-signed post cards and letters. It is also recommended that the researcher use telephone contacts to pre-contact the sample and to follow up with non-respondents. The use of the telephone and color post cards and letters will add to the cost and time associated with the surveying process; however, these techniques indicate to the participant that the researcher has invested effort and resources. The web-based questionnaire is a great time-saving measure for the researcher and respondent, but it still requires a personalized approach.

Reflections

As I worked on this study and became increasingly aware of the complexities involved in teaching and learning algebra, I also became increasingly concerned with our current emphasis on testing as a means for accountability. In 1957, the launching of Sputnik apparently catalyzed our national interest in improving the quality of its educational agenda. The federal government infused school systems with funding for all sorts of programs in mathematics and science so that we could –for want of a better term – beat the Soviet Union to the moon and retain our status as the world's preeminent superpower. While there is no doubt that testing was a part of this reform movement in education, test results are not the first aspect on which we focus when we highlight its success. Our greatest outcomes from this era include NASA and other "space-age" technological programs, the superior U.S. military, the survival of our democratic form of government and the demise of the Soviet Union, and our world-leading economy.

The current reform movement apparently resulted from a publication, *A Nation at Risk* (1983), and other criticisms like it. This document states, among other ideas, that we would never allow a foreign invader to force an educational system like ours on our children. I must also submit that we would not allow a foreign invader to seize our children, with all of their diverse strengths, needs, and backgrounds, and place them in a situation where they must answer to a single battery of tests, measuring a very specific set of educational outcomes.

Can we continue to focus on teaching and learning when we are becoming increasingly concerned with testing and test scores? It largely depends on how the tests are used. Tests make much better diagnostic tools than means for sanctions. Metaphorically speaking, to measure it is probably better to use a ruler than a hammer. Over time, a heavy-handed use of testing will undoubtedly produce fantastic results as test scores may be interpreted in many ways. Are test results, however, a true measure of a nation's strengths? As Berliner and Biddle (1995) have suggested, test scores and pass rates can be manipulated to demonstrate growth or to demonstrate failure, depending on the national agenda. In any case, one resulting impact on our teachers and students is likely: cynicism. Will we some day look around to see that other nations have surpassed us economically and technologically, only to wonder how they did it while our test scores were so high?

Conclusion

Teaching mathematics effectively has never been easy, and it has become more challenging for Virginia's Algebra I teachers in recent years. It is much like leading young people into the dark mansion described by Professor Andrew Wiles, the mathematician who astounded the mathematics community in1993 by proving *Fermat's Last Theorem* (Aczel, 1996). To paraphrase Wiles,

> We take algebra students into the first room and it's dark, completely dark. We stumble around, bumping into furniture. Gradually, they learn where each piece of furniture is. And finally, after months have passed, each student finds the light switch and turns it on. Suddenly, it's all illuminated and all can see exactly where they were. Then we all enter the next dark room…

Virginia's *Standards of Learning* initiative has provided a focus for teaching and learning algebra, and it has prompted reform in mathematics education in the Commonwealth. Simultaneously, the End of Course SOL Test for Algebra I has created a situation where all students must find their way quickly around the complexities of algebra, regardless of the many factors that can affect their learning of the knowledge and skills implicit within it. One factor in this process that the classroom teacher can control is the quality of instruction. As educators, we owe it to our students to make the most of this factor.

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Appendix A

Letter to Dr. Marcucci

543 South Meadowlark Lane
Marion, VA 24354

November 4, 2001

Dr. Robert Marcucci
TH 945
San Francisco State University
1600 Holloway Avenue
San Francisco, CA 94132

Dear Dr. Marcucci:

I want to thank you for taking the time to discuss your dissertation with me on September 10, 2001. Your comments helped me to focus my efforts and to critically examine the nature of my study.

I also want to thank you for allowing me to replicate your method for integrating research in a review of literature. As I mentioned, I think your method will help me to focus my review of literature as a preliminary study. From this preliminary integration of research, I will draw teaching method types for further study to determine their contributions to variance in student scale scores on Virginia's end of course test for Algebra I.

As we discussed, I will need to revise the categories for teaching method types to reflect more current practices. In addition, I will be focusing on student achievement in algebra in terms of developing knowledge and skills, rather than looking strictly at problem solving.

Once again, I thank you for your time, help, and encouragement. I appreciate it.

Respectfully,

Matthew S. Haas

Appendix B

Coding Sheet for Study Characteristics

Author		
Title		
Reference & Database		
Year		
Column	Identity Number	Value
1	Identity Number	
2	Year of the Study 1. 80-90 2. 91-00	
3	Source of the Study 1. Dissertation 2. Journal 3. Other	
4	algebra course 1. pre-algebra 2. algebra 3. advanced algebra	
5	Grade 7-12	
6	Ability Level 0. All 1. Low 2. Med. 3. High	
7	Weeks of Treatment	
8	Hours of Treatment	
9	Novelty Effect 0. No 1. Yes	
10	Teaching Method 1. CL 2. CS 3. TAI 4. PBL 5. M&M 6. DI 7. H&P	
Specific Method(s)		
11	Sample Size	
12	Outcome Measure 0. Standardized 1. Experimenter	
13	Assignment to Treatment 1. Random 2. Equivalent Groups 3. Non-Equivalent Groups	
14-18	Effect Size(s)	
19	Redundant Data 0. No 1. Yes	
20-24	Homogeneity of Variance	
	Adjusted Mean? 0. No 1. Yes	

Appendix C

Meta-Analysis Number of Studies of Each Teaching Method Classified by Year, Source, and Design Quality

	Method					
	CL	CS	TAI	PBL	MMR	DI
Year						
1980-90	1	3	3	--	1	6
1991-2001	2	--	4	7	3	4
Source						
Unpublished	2	3	5	7	3	8
Journal	1	--	2	--	1	2
Design Quality						
Good	2	1	4	4	4	7
Poor	1	2	3	3	--	3
Total	3	3	7	7	4	10

Appendix D

Meta-Analysis: Mean Sample Size, Weeks of Treatment, and Hours of Treatment of Each Teaching Method

	Method					
	CL	CS	TAI	PBL	MMR	DI
Sample Size						
Mean	145.33	102	168.57	188	111	83.70
Standard Deviation	108.30	58.59	161.17	158.30	71.91	63.30
Weeks of Treatment						
Mean	5.67	18.00	25.57	11	5.75	11.68
Standard Deviation	1.16	15.87	17.36	12.21	4.99	14.19
Hours of Treatment						
Mean	25.67	63.00	90.07	38.50	20.13	40.92
Standard Deviation	14.15	55.56	67.57	42.75	17.47	49.38
Number of Studies	3	3	7	7	4	10

Appendix E

Meta-Analysis: Effect Size of Each Teaching Method for All Studies

	Method					
	CL	CS	TAI	PBL	MMR	DI
Mean	0.34	0.07	0.07	0.52	0.23	0.55
Standard Deviation	0.16	0.26	0.69	0.70	0.26	0.59
Number of Effect Sizes	3	5	12	14	9	19
Number of Studies	3	3	7	7	4	10

Appendix F

Meta-Analysis: Effect Size of Each Teaching Method for "Good" Studies

	Method					
	CL	CS	TAI	PBL	MMR	DI
Mean	0.26	0.16	0.41	0.44	0.23	0.67
Standard Deviation	0.12	--	0.74	0.51	0.26	0.54
Number of Effect Sizes	2	2	6	9	9	16
Number of Studies	2	1	4	4	4	7

Appendix G

Meta-Analysis: Effect Size of Each Teaching Method Classified by Algebra Course for All Studies

	Method					
Course	CL	CS	TAI	PBL	MMR	DI
Pre-Algebra						
Mean	0.34	--	0.44	0.74	0.14	0.16
Standard Deviation	--	--	0.50	0.73	0.26	0.15
Number of Effect Sizes	1	--	2	9	3	2
Algebra						
Mean	0.33	0.01	-0.29	-0.22	.028	0.59
Standard Deviation	0.22	0.35	0.59	0.02	0.27	0.60
Number of Effect Sizes	2	3	7	3	6	17
Advanced Algebra						
Mean	--	0.16	0.65	0.64	--	--
Standard Deviation	--	--	0.66	--	--	--
Number of Effect Sizes	--	2	3	2	--	--
Number of Studies	3	3	7	7	4	10

Appendix H

Meta-Analysis: Effect Size of Each Teaching Method Classified by Algebra Course for "Good" Studies

	Method					
Course	CL	CS	TAI	PBL	MMR	DI
Pre-Algebra						
Mean	0.34	--	0.44	0.62	0.14	0.16
Standard Deviation	--	--	0.05	0.50	0.26	0.15
Number of Effect Sizes	1	--	2	5	3	2
Algebra						
Mean	0.18	--	0.63	-0.21	0.28	0.74
Standard Deviation	--	--	0.82	0.01	0.27	0.54
Number of Effect Sizes	1	--	3	2	6	14
Advanced Algebra						
Mean	--	0.16	1.42	0.64	--	--
Standard Deviation	--	--	--	--	--	--
Number of Effect Sizes	--	2	1	2	--	--
Number of Studies	2	1	4	4	4	7

Appendix I

Meta-Analysis: Effect Size of Each Teaching Method Classified by Ability Level for All Studies

	Method					
Ability Level	CL	CS	TAI	PBL	MMR	DI
Low						
Mean	--	--	0.20	0.577	--	0.84
Standard Deviation	--	--	0.382	0.99	--	0.476
Number of Effect Sizes	--	--	2	3	--	6
High						
Mean	--	--	0.31	-0.24	--	0.76
Standard Deviation	--	--	0.08	--	--	--
Number of Effect Sizes	--	--	3	1	--	3
Number of Studies	--	--	5	1	--	3

Appendix J

Meta-Analysis: Effect Size of Each Teaching Method Classified by Ability Level for "Good Studies"

	Method					
Ability Level	CL	CS	TAI	PBL	MMR	DI
Low						
Mean	--	--	0.20	--	--	0.84
Standard Deviation	--	--	0.382	--	--	0.476
Number of Effect Sizes	--	--	2	--	--	6
High						
Mean	--	--	0.40	--	--	0.76
Standard Deviation	--	--	--	--	--	--
Number of Effect Sizes	--	--	1	--	--	1
Number of Studies	--	--	3	--	--	3

Appendix K

Meta-Analysis: Effect Size by Source for All Studies

	Source	
	Journal	Unpublished
Mean	0.41	0.33
Standard Deviation	0.64	0.57
Number of Effect Sizes	17	45
Number of Studies	6	28

Appendix L

Meta-Analysis: Effect Size by Source for "Good Studies"

	Source	
	Journal	Unpublished
Mean	0.56	0.40
Standard Deviation	0.51	0.51
Number of Effect Sizes	15	29
Number of Studies	5	17

Appendix M

Meta-Analysis: Effect Size by Novelty Effect for All Studies

	Novelty Effect	
	Yes	No
Mean	0.40	0.33
Standard Deviation	0.50	0.63
Number of Effect Sizes	20	42
Number of Studies	7	27

Appendix N

Meta-Analysis: Effect Size by Novelty Effect for “Good” Studies

	Novelty Effect	
	Yes	No
Mean	0.41	0.48
Standard Deviation	0.38	0.58
Number of Effect Sizes	16	28
Number of Studies	6	16

Appendix O

Meta-Analysis: Effect Size by Outcome Measure for All Studies

	Outcome Measure	
	Standardized	Experimenter
Mean	0.17	0.42
Standard Deviation	0.67	0.55
Number of Effect Sizes	16	46
Number of Studies	11	23

Appendix P

Meta-Analysis: Effect Size by Outcome Measure for "Good" Studies

	Outcome Measure	
	Standardized	Experimenter
Mean	0.54	0.46
Standard Deviation	0.59	0.50
Number of Effect Sizes	9	35
Number of Studies	6	16

Appendix Q

Meta-Analysis: Correlation Between Effect Size and Study Characteristics for All Studies

Characteristic	Correlation
Source (0=unpublished, 1=journal)	0.06
Weeks of Treatment	-0.40**
Hours of Treatment	-0.43**
Novelty Effect (0=no, 1=yes)	0.06
Sample Size	-0.34**
Outcome Measure (0=standardized, 1=experimenter)	0.19
Homogeneity of Variance	-0.49**
Design Quality (0=poor, 1=good)	0.28*

*p<.05. **p<.01.

Appendix R

Meta-Analysis: Correlation Between Effect Size and Study Characteristics for "Good" Studies

Characteristic	Correlation
Source (0=unpublished, 1=journal)	0.15
Weeks of Treatment	-0.18
Hours of Treatment	-0.19
Novelty Effect (0=no, 1=yes)	-0.07
Sample Size	-0.28
Outcome Measure (0=standardized, 1=experimenter)	-0.08
Homogeneity of Variance	-0.49*

*p<.05.

Appendix S

Letter to Dr. McCracken

[Date]

Dr. Robert C. McCracken
Superintendent
Giles County Public Schools
151 School Road
Pearisburg, VA 24134

Dear Dr. McCracken:

I writing to request your help in addressing a research issue that I think will be of benefit to the school divisions of Region 7 as well as others around the Commonwealth. As a high school principal, I am constantly looking for ways for my students to improve their achievement, especially in the area of mathematics. As a doctoral candidate at Virginia Tech, I am proposing a research study for my dissertation that will explore teaching practices that may contribute to student achievement on the end of course SOL test for Algebra I.

I have conducted a meta-analysis to synthesize the last two decades of research on teaching practices for algebra. From this meta-analysis, I am developing a questionnaire designed to determine the extent to which Algebra I teachers in Region 7 use research-based teaching practices. Using Algebra I teachers' mean scores for this year's SOL test administration(s), I will seek to determine the effect of each teaching practice on student achievement on the end of course test for Algebra I.

Please share this letter with the other superintendents in Region 7. I plan to randomly select seven school divisions and contact the superintendent of each to personally ask permission to survey Algebra I teachers and to gain access to their mean SOL scores. The information I collect will be aggregated into group data for analysis. No identifiable information will be maintained to link school divisions, schools, teachers, or students to responses on the questionnaire or SOL assessment scores. I will share the results of the study with the superintendents of Region 7 and make them available through the Virginia Tech database.

I thank you for taking the time to talk with me in January and for your consideration of this letter. I believe that this research will be of benefit to our students, teachers, and school leaders as they strive to achieve in mathematics.

Respectfully,

Matthew S. Haas
Principal
Northwood High School
Smyth County

Dr. Travis Twiford
Director
Tidewater Doctoral Program
Virginia Polytechnic Institute
and State University

Appendix T

Domains and Items from the Questionnaire for an Investigation of Instructional Practices for Algebra I (Prior to first content validity study)

Domain 1: Cooperative Learning

11. Allow students to collaborate (Davis, 1998)
17. Approach new problem-solving scenarios in a collaborative setting with other learners (Davis, 1998) (Hawkins, 1982)
29. Allow students to engage in cooperative problem solving (McCoy, Baker, & Little, 1996)
102. Pair students to work as peer tutors (Allsop, 1999) (Parham, 1993)
105. Reward group performance in the cooperative setting (Yueh, 1988)
106. Reward individual performance in the cooperative setting (Yueh, 1988)
110. Assign students to work in homogeneous groups (Yueh, 1998)
111. Assign students to work in heterogeneous groups (Yueh, 1998)

Domain 2: Communication Skills

2. Students construct and write their own original word problems for some other learner or audience (Davis, 1998)
3. Students explain their thought processes in solving equations verbally or in writing to discover any fallacies or confusions (Davis, 1998)
5. Encourage students to use mathematics vocabulary terms in class discussions (Davis, 1998)
6. Teach mathematics vocabulary terms directly with definitions (Davis, 1998)
10. Teach students reading comprehension skills in the context of algebra class (Pippen & Carr, 1989)
12. Give students opportunities to make oral and written presentations in class (Davis, 1998)
14. Give the students opportunities to communicate using mathematical terms (Davis, 1998)
15. Model and encourage “thinking aloud” about mathematical concepts and processes (Davis, 1998)
19. Have students describe thought processes orally or in writing during problem solving (Davis, 1998)
30. Require students to share their thinking by conjecturing, arguing, and justifying ideas (McCoy, Baker, & Little, 1996)
33. Teach students to translate problems into written expressions (McCoy, Baker, & Little, 1996)
36. Have students write their own explanations of problem solving strategies (McIntosh, 1997)
37. Provide reading guides for students to list facts, ideas, and numerical depictions for word problems (McIntosh, 1997)
38. Provide students with opportunities to make connections between mathematics and other subjects (McIntosh, 1997)
53. Encourage students to verbalize the steps of an algebraic process to themselves or other students (Feigenbaum, 2000)
56. Insist that students use the correct vocabulary and terminology in the algebra context (Feigenbaum, 2000)

57. Require that all written mathematics indicate a one-step-at-a-time process (Feigenbaum, 2000)
58. Practice proper reading of word phrases so that students can achieve an accurate translation of both the symbols and meaning of language in algebra (Feigenbaum, 2000)
59. Emphasize proper reading and writing of algebraic terms (Fiegenbaum, 2000)
60. Treat algebra as a foreign language with its own alphabet and grammar (Feigenbaum, 2000)
63. Have students write about their work in problem solving or about their thought processes in algebra (Gordon, 1988)
64. Promote discussion and verbalization of thought processes and mathematical relationships (Gordon, 1988)
81. Have students write observations of what they see happening in worked examples of problems (Carroll, 1995)
95. Assign students to write about algebra (Wilson & Blank, 1999)
97. Encourage students to communicate explanations of responses and procedures in both verbal and written formats (Wilson & Blank, 1999)
100. Encourage students to explain the reasoning behind their ideas (Wilson & Blank, 1999)
109. Use reading-to-learn in the content area strategies (Pippen & Carr, 1989)

Domain 3: Technology Aided Instruction

9. Give simple instructions for calculators and allow students time with guided practice to examine the technology and discover some of its capabilities (Davis, 1998)
20. Students use calculators during testing situations (Hembree & Dessart, 1986)
21. Students use calculators for problem solving instruction and activities (Hembree & Dessart, 1986) (Heath, 1987)
22. Students use hand-held electronic calculators as a pedagogical device to help develop mathematical concepts (Hembree & Dessart, 1986)
23. Students use hand-held electronic calculators as a pedagogical device to help develop problem-solving strategies (Hembree & Dessart, 1986)
24. Students use calculators for computations (Hembree & Dessart, 1986)
61. Students use the graphing calculator to explore linear relationships (Patterson, 1999)
65. Use computer spreadsheets, such as Microsoft excel, for problem solving instruction (Sutherland & Rojano, 1993)
94. Assign students to use calculators (Wilson & Blank, 1999)
103. Use computer software to provide practice opportunities (Allsop, 1999) (Heath, 1987) (Geshel-Green, 1986) (Wohlgehagen, 1992) (Smith, 2001) (Johnson & Rickhuss, 1992) (Schumacker, Young, & Bembry, 1995)
107. Provide graphing calculators for student use (Arcavi, 1995) (Rich, 1990)

Domain 4: Problem-Based Learning

8. Involve the whole class in finding a the solution to a problem (Davis, 1998)
13. Engage the students in solving “real world” problems (Davis, 1998)
16. Ask students for similarities and differences between types of equations and problems (Davis, 1998)
18. Have students recall and use individually constructed schema (rules) in new problem-solving situations (Davis, 1998)

26. Teach generalizable methods for solution (algorithms) by which students can solve mathematically formulated problems (Price & Martin, 1997)
28. Start with a real life situation and draw a mathematical concept out of it with students (Price & Martin, 1997) (Makanong, 2000)
39. Students investigate and formulate problems from given situations (McIntosh, 1997)
40. Students pursue open-ended and extended problem-solving projects (McIntosh, 1997)
50. Teach students to derive a formula for a given problem using arithmetic theory before assigning and manipulating algebraic symbols (Philipp & Schappelle, 1999)
54. Emphasize understanding of algebraic concepts over reliance on rules (Feigenbaum, 2000) (Watson, 1996) (Cyrus, 1995)
62. Use equations derived from "real life" for instruction on graphing linear equations (Patterson, 1999)
68. Return to familiar problem settings by modifying them to enrich students' understanding of algebra (Choike, 2000)
72. Allow students to discuss their own problem solving processes and recognize many alternatives (Brenner et al., 1997) (Hodgkins, 1994)
73. Emphasize the problem solving process, rather than the solution (Brenner et al., 1997)
74. Anchor problem solving skills instruction within a meaningful thematic situation (Brenner et al., 1997) (Elshafei, 1998)
78. Encourage students to experiment with alternative methods for solving problems (Carroll, 1995) (Wilkins, 1993)
83. Analyze already worked out examples of problems with students (Carroll, 1995)
96. Discuss solutions to algebra problems as a class (Wilson & Blank, 1999)
99. Assign students to work on problems that have no immediate solution (Wilson & Blank, 1999)
108. Students observe worked examples of algebraic equations to derive rules for solving future equations (Zhu & Simon, 1987)

Domain 5: Manipulatives, Models, and Multiple Representations

1. Students use cubes or blocks to represent algebraic equations (Raymond & Leinenbach, 2000) (McClung, 1998)
4. Provide a classroom environment with colorful posters demonstrating mathematical concepts and processes (Davis, 1998)
25. Use realistic metaphors to aid students in visualizing an equation and its parts (Price & Martin, 1997)
27. Illustrate mathematical concepts for students with pictures (Price & Martin, 1997)
31. Teach students to translate algebraic expressions into graphs (McCoy, Baker, & Little, 1996)
32. Teach students to translate problems into tables (McCoy, Baker, & Little, 1996) (Keller, 1984) (St. John, 1992)
44. Show students how to make charts for solving problems to break information into smaller pieces (Matthews, 1997)
45. Teach students to use two variables when there are two unknowns in solving algebraic word problems (Matthews, 1997)
47. Describe a model by thinking aloud and including students in the thinking aloud process (Maccini & Hughes, 2000)

52. Teach students to create templates or patterns for evaluating algebraic expressions (Feigenbaum, 2000)
55. Teach students to use colored pencils to highlight relevant information or to draw specific sign and symbols in algebraic expressions (Feigenbaum, 2000)
69. Emphasize use of multiple representations: words, tables, graphs, and symbols (Choike, 2000)
75. Emphasize problem representation skills using tables, graphs, and symbols (Brenner et al., 1997)
91. Use symbols to help students learn to solve equations (Austin, 1989)
92. Use diagrams to help students learn to solve equations (Austin, 1989)
93. Use physical objects to help students learn to solve equations (Austin, 1989)

Domain 6: Direct Instruction: Setting objectives and providing feedback

7. Engage students in discussions of how new concepts relate to previously learned concepts (Davis, 1998)
41. Begin instruction with a target problem type to simplify (London, 1983)
42. Give students one increasingly difficult problem at a time to simplify during instruction (London, 1983)
43. Close instruction by discussing problem solutions with students, emphasizing comparisons to preceding problems (London, 1983)
46. When providing feedback, target incorrect responses and error patterns (Maccini & Hughes, 2000)
48. Identify a new skill or concept at the beginning of instruction and provide a rationale for learning it (Maccini & Ruhl, 2000)
49. Provide a graduated sequence of instruction, moving students from the concrete to the abstract in defined steps (Maccini & Ruhl, 2000) (Hutchinson & Hemingway, 1987)
66. Mold lessons around the interests of individual students (Choike, 2000) (Lwo, 1992) (Farrell, 1980)
67. When giving feedback, recognize correct thinking in students even when it may be incomplete or lacking closure Choike, 2000)
84. When a student responds incorrectly, provide a new cue or explanation, giving the student a chance to try again (Tenenbaum, 1986)
86. Encourage students to ask questions when difficulties or misunderstandings arise (Tenenbaum, 1986)
87. Administer quizzes to indicate student mastery of unit content and for feedback purposes (Tenenbaum, 1986)
88. Provide cues to indicate to students what is to be learned and what actions are required of students (Tenenbaum, 1986)
89. Following each learning task, provide time for error correction (Tenenbaum, 1986)
90. Follow feedback to students with methods for correcting errors (Tenenbaum, 1986)
104. Tell students what skill they will learn, linking the current lesson to past lessons, and providing a rationale for the importance of learning the skill (Allsop, 1999) (Collazo, 1987)

Domain 7: Homework and Practice

34. Grade homework (Dick, 1980)
35. Allow students time to work on homework in class (Dick, 1980)
51. Allow students to use index cards as flash cards with basic algebraic processes, necessary formulas, or needed reminders (Feigenbaum, 2000)
70. Assign goal-free problems to students for practice (Sweller & Cooper, 1985)
71. Provide students with worked examples along with their practice work (Sweller, 1985)
76. Use worked examples to accompany homework assignments (Carroll, 1994)
77. Use worked examples to accompany class work assignments (Carroll, 1995)
79. Provide worked examples with homework (Carroll, 1995)
80. Have students find errors in worked examples (Carroll, 1995)
82. Use worked examples to introduce or reinforce topics (Carroll, 1995)
85. Provide math games for students to practice algebraic skills (Tenenbaum, 1986)
98. Provide practice in computational skills (Wilson & Blank, 1999)
101. Allow students time to begin homework in class (Wilson & Blank, 1999)
112. Provide students with study skills instruction (Hodo, 1989)
113. Review only homework problems requested by the students (Dick, 1980)
114. When assigning practice work, ensure that the majority of problems assigned review previously covered material (Clay, 1998) (Pierce, 1984) (Denson, 1989)

Appendix U

Domains and Items from the Questionnaire for an Investigation of Instructional Practices for Algebra I (Prior to the second content validation study)

Domain 1: Cooperative Learning

8. Collaborate with the whole class in finding the solution to a problem (Davis, 1998)
11. Allow students to collaborate (Davis, 1998)
17. Approach new problem-solving scenarios in a collaborative setting with other learners (Davis, 1998) (Hawkins, 1982)
29. Allow students to engage in cooperative problem solving (McCoy, Baker, & Little, 1996)
96. Allow students to discuss solutions to algebra problems with peers (Wilson & Blank, 1999)
101. Allow students time to begin homework in class with peer assistance (Wilson & Blank, 1999)
102. Pair students to work as peer tutors (Allsop, 1999) (Parham, 1993)
105. Reward group performance in the cooperative setting (Yueh, 1988)
106. Reward individual performance in the cooperative setting (Yueh, 1988)
110. Assign students to work in homogeneous groups (Yueh, 1998)
111. Assign students to work in heterogeneous groups (Yueh, 1998)

Domain 2: Communication and Study Skills

2. Students write original word problems. (Davis, 1998)
3. Students explain their thought processes in solving equations verbally or in writing to discover any fallacies or confusions (Davis, 1998)
5. Encourage students to use mathematics vocabulary terms in class discussions (Davis, 1998)
6. Provide mathematics vocabulary terms and definitions (Davis, 1998)
10. Provide strategies for reading comprehension. (Pippen & Carr, 1989)
12. Give students opportunities to make oral and written presentations in class (Davis, 1998)
14. Give the students opportunities to communicate verbally and in writing using mathematical terms (Davis, 1998)
15. Model and encourage “thinking aloud” about mathematical concepts and processes (Davis, 1998)
19. Have students describe thought processes orally or in writing during problem solving (Davis, 1998)
30. Require students to share their thinking by conjecturing, arguing, and justifying ideas (McCoy, Baker, & Little, 1996)
36. Have students write about problem solving strategies (McIntosh, 1997)
37. Provide reading guides for students to improve their word problem comprehension (McIntosh, 1997)
53. Encourage students to verbalize the steps of an algebraic process to themselves or other students (Feigenbaum, 2000)
56. Insist that students use the correct vocabulary and terminology in the algebra context (Feigenbaum, 2000)
58. Practice proper reading of word phrases so that students can achieve an accurate translation of both the symbols and meaning of language in algebra (Feigenbaum, 2000)

59. Emphasize proper reading and writing of algebraic terms (Fiegenbaum, 2000)
60. Treat algebra as a foreign language with its own alphabet and grammar (Feigenbaum, 2000)
63. Have students write about their work in problem solving or about their thought processes in algebra (Gordon, 1988)
64. Promote discussion and verbalization of thought processes and mathematical relationships (Gordon, 1988)
81. Have students write observations of what they see happening in worked examples of problems (Carroll, 1995)
86. Encourage students to ask questions when difficulties or misunderstandings arise (Tenenbaum, 1986)
95. Assign students to write about algebra (Wilson & Blank, 1999)
97. Encourage students to communicate explanations of responses and procedures in both verbal and written formats (Wilson & Blank, 1999)
100. Encourage students to explain the reasoning behind their ideas (Wilson & Blank, 1999)
109. Use reading instructional strategies to help students with comprehension (Pippen & Carr, 1989)
112. Provide students with study skills instruction (Hodo, 1989)
113. Review only homework problems requested by the students (Dick, 1980)

Domain 3: Technology Aided Instruction

9. Give simple instructions for the calculator and allow students time with guided practice to examine the technology and discover some of its capabilities (Davis, 1998)
20. Students use calculators during testing situations (Hembree & Dessart, 1986)
21. Students use calculators for problem solving instruction and activities (Hembree & Dessart, 1986) (Heath, 1987)
22. Students use hand-held electronic calculators as a pedagogical device to help develop mathematical concepts (Hembree & Dessart, 1986)
23. Students use hand-held electronic calculators as a pedagogical device to help develop problem-solving strategies (Hembree & Dessart, 1986)
24. Students use calculators for computations (Hembree & Dessart, 1986)
61. Students use the graphing calculator to explore linear relationships (Patterson, 1999)
65. Use computer spreadsheets, such as Microsoft excel, for problem solving instruction (Sutherland & Rojano, 1993)
94. Assign students to use calculators as a course requirement (Wilson & Blank, 1999)
103. Use computer software to provide practice opportunities (Allsop, 1999) (Heath, 1987) (Geshel-Green, 1986) (Wohlgehagen, 1992) (Smith, 2001) (Johnson & Rickhuss, 1992) (Schumacker, Young, & Bembry, 1995)
107. Provide graphing calculators for student use (Arcavi, 1995) (Rich, 1990)

Domain 4: Problem-Based Learning

13. Engage the students in solving problems based on relevant situations (Davis, 1998)
16. Engage students in finding similarities and differences between types of equations and problems (Davis, 1998)
18. Have students create their own rules in new problem-solving situations (Davis, 1998)

26. Teach general methods for students to solve mathematically formulated problems (Price & Martin, 1997)
28. Draw mathematical concepts from "real-life" problems (Price & Martin, 1997) (Makanong, 2000)
39. Students investigate and create problems from given situations (McIntosh, 1997)
40. Students pursue open-ended and extended problem-solving projects (McIntosh, 1997)
50. Derive a formula for a given problem from theory before assigning and manipulating algebraic symbols (Philipp & Schappelle, 1999)
54. Emphasize understanding of algebraic concepts over reliance on rules for problem solving (Feigenbaum, 2000) (Watson, 1996) (Cyrus, 1995)
62. Use linear equations derived from "real life" relationships for instruction on graphing (Patterson, 1999)
66. Create problems from the interests of individual students (Choike, 2000) (Lwo, 1992) (Farrell, 1980)
70. Assign goal-free problems to students (Sweller & Cooper, 1985)
72. Recognize many alternative problem-solving practices (Brenner et al., 1997) (Hodgkins, 1994)
73. Emphasize the problem solving process, rather than the solution (Brenner et al., 1997)
74. Anchor problem solving skills instruction within a meaningful situation (Brenner et al., 1997) (Elshafei, 1998)
78. Encourage students to experiment with alternative methods for solving problems (Carroll, 1995) (Wilkins, 1993)
99. Work on problems that have no immediate solution (Wilson & Blank, 1999)
108. Students examine pre-worked examples of algebraic equations to derive rules for solving future equations (Zhu & Simon, 1987)

Domain 5: Manipulatives, Models, and Multiple Representations

1. Students use cubes or blocks to represent algebraic equations (Raymond & Leinenbach, 2000) (McClung, 1998)
4. Provide a classroom environment with colorful posters representing mathematical concepts and processes (Davis, 1998)
25. To aid students in visualizing an equation and its parts, compare it to everyday, familiar things. (Price & Martin, 1997)
27. Illustrate mathematical concepts for students with pictures (Price & Martin, 1997)
31. Teach students to represent algebraic expressions with graphs (McCoy, Baker, & Little, 1996)
32. Teach students to represent problems with tables (McCoy, Baker, & Little, 1996) (Keller, 1984) (St. John, 1992)
33. Teach students to represent problems with written expressions (McCoy, Baker, & Little, 1996)
38. Make connections between mathematics and other subjects (McIntosh, 1997)
44. Teach students to represent problems with charts to break information into smaller pieces (Matthews, 1997)
45. Teach students to use two variables when there are two unknowns in solving algebraic word problems (Matthews, 1997)

47. Describe a model by thinking aloud and including students in the thinking aloud process (Maccini & Hughes, 2000)
52. Teach students to create templates or patterns for representing and evaluating algebraic expressions (Feigenbaum, 2000)
55. Use colored pencils to highlight relevant information or to draw specific signs and symbols in algebraic expressions (Feigenbaum, 2000)
69. Emphasize the use of multiple representations: words, tables, graphs, and symbols (Choike, 2000)
75. Represent problems using tables, graphs, and symbols (Brenner et al., 1997)
85. Provide math games for students to practice algebraic skills (Tenenbaum, 1986)
91. Use symbols to help students learn to solve equations (Austin & Vollrath 1989)
92. Use diagrams to help students learn to solve equations (Austin & Vollrath, 1989)
93. Use physical objects to help students learn to solve equations (Austin & Vollrath, 1989)

Domain 6: Direct Instruction: Setting objectives and providing feedback

7. Relate new algebra concepts to previously learned concepts (Davis, 1998)
34. Grade homework to provide feedback (Dick, 1980)
35. Allow students time to work on homework in class, while providing assistance (Dick, 1980)
41. Begin instruction with a target skill or concept for students to master (London, 1983)
42. Work one increasingly difficult problem at a time to simplify during instruction (London, 1983)
43. Close instruction by reviewing concepts with students, emphasizing comparisons to previously covered concepts (London, 1983)
46. When providing feedback, target incorrect responses and error patterns (Maccini & Hughes, 2000)
48. Identify a new skill or concept at the beginning of instruction and provide a rationale for learning it (Maccini & Ruhl, 2000)
49. Provide a graduated sequence of instruction, moving students from the concrete to the abstract in defined steps (Maccini & Ruhl, 2000) (Hutchinson & Hemingway, 1987)
51. Allow students to use index cards as flash cards with basic algebraic processes, necessary formulas, or needed reminders (Feigenbaum, 2000)
57. Require students to indicate a one-step-at-a-time process in working equations (Feigenbaum, 2000)
67. When giving feedback, recognize correct thinking in students although it may be incomplete or lacking closure (Choike, 2000)
68. Return to familiar problem settings when introducing a new problem type (Choike, 2000)
71. Provide students with worked examples along with their practice work (Sweller, 1985)
76. Give pre-worked examples to accompany homework assignments (Carroll, 1994)
77. Give pre-worked examples to accompany class work assignments (Carroll, 1995)
79. Provide pre-worked examples with homework (Carroll, 1995)
80. Have students find errors in worked examples (Carroll, 1995)
82. Use worked examples to introduce or reinforce topics (Carroll, 1995)
83. Analyze already worked out examples of problems with students (Carroll, 1995)

84. When a student responds incorrectly, give the student a chance to try again after providing a cue (Tenenbaum, 1986)
87. Administer quizzes to indicate student mastery of unit content and for feedback purposes (Tenenbaum, 1986)
88. Provide cues to indicate to students what is to be learned and what actions are required of students (Tenenbaum, 1986)
89. Following each learning task, provide time for error correction (Tenenbaum, 1986)
90. Follow feedback to students with methods for correcting errors (Tenenbaum, 1986)
98. Provide practice and feedback in computational skills (Wilson & Blank, 1999)
104. Tell students what skill they will learn, linking the current lesson to past lessons, and providing a rationale for the importance of learning the skill (Allsop, 1999) (Collazo, 1987)
114. When assigning practice work, ensure that the majority of problems assigned review previously covered material (Clay, 1998) (Pierce, 1984) (Denson, 1989)

Appendix V

Instrument for First Content Validation Study

Statements Assessing the Teacher's Use of Instructional Practices for Algebra I

Name:________________________________
E-Mail Address: ______________________
Phone Number: ________________________

Directions: Circle the appropriate response.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning*
(2) *Communication Skills*
(3) *Technology Aided Instruction*
(4) *Problem-Based Learning*
(5) *Manipulatives, Models, and Multiple Representations*
(6) *Direct Instruction: Setting Objectives and Providing Feedback*
(7) *Homework and Practice*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong
Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

- **For any items you rate as 1 or 2 for clarity or association, please edit or make revisions for improvement directly on this page.**

Questionnaire Statements	Domain	Association	Clarity
1) Students use cubes or blocks to represent algebraic equations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
2) Students construct and write their own original word problems for some other learner or audience.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
3) Students explain their thought processes in solving equations verbally or in writing to discover any fallacies or confusions.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
4) Provide a classroom environment with colorful posters demonstrating mathematical concepts and processes.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
5) Encourage students to use mathematics vocabulary terms in class discussions.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
6) Teach mathematics vocabulary terms directly with definitions.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
7) Engage students in discussions of how new concepts relate to previously learned concepts.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
8) Involve the whole class in finding the solution to a problem.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
9) Give simple instructions for calculators and allow students time with guided practice to examine the technology and discover some of its capabilities.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
10) Teach students reading comprehension skills in the context of algebra class.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
11) Allow students to collaborate.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
12) Give students opportunities to make oral and written presentations in class.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
13) Engage the students in solving "real world" problems.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
14) Give the students opportunities to communicate using mathematical terms.	1 2 3 4 5 6 7	1 2 3 4	1 2 3

Questionnaire Statements	Domain	Association	Clarity
15) Model and encourage “thinking aloud” about mathematical concepts and processes.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
16) Ask students for similarities and differences between types of equations and problems.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
17) Approach new problem-solving scenarios in a collaborative setting with other learners.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
18) Have students recall and use individually constructed schema (rules) in new problem-solving situations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
19) Have students describe thought processes orally or in writing during problem solving.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
20) Students use calculators during testing situations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
21) Students use calculators for problem solving instruction and activities.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
22) Students use hand-held electronic calculators as a pedagogical device to help develop mathematical concepts.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
23) Students use hand-held electronic calculators as a pedagogical device to help develop problem-solving strategies.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
24) Students use calculators for computations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
25) Use realistic metaphors to aid students in visualizing an equation and its parts.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
26) Teach generalizable methods for solution (algorithms) by which students can solve mathematically formulated problems.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
27) Illustrate mathematical concepts for students with pictures.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
28) Start with a real life situation and draw a mathematical concept out of it with students.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
29) Allow students to engage in cooperative problem solving.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
30) Require students to share their thinking by conjecturing, arguing, and justifying ideas.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
31) Teach students to translate algebraic expressions into graphs.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
32) Teach students to translate problems into tables.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
33) Teach students to translate problems into written expressions.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
34) Grade homework.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
35) Allow students time to work on homework in class.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
36) Have students write their own explanations of problem solving strategies.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
37) Provide reading guides for students to list facts, ideas, and numerical depictions for word problems.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
38) Provide students with opportunities to make connections between mathematics and other subjects.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
39) Students investigate and formulate problems from given situations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
40) Students pursue open-ended and extended problem-solving projects.	1 2 3 4 5 6 7	1 2 3 4	1 2 3

41) Begin instruction with a target problem type to simplify.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
42) Give students one increasingly difficult problem at a time to simplify during instruction.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
43) Close instruction by discussing problem solutions with students, emphasizing comparisons to preceding problems.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
Questionnaire Statements	Domain	Association	Clarity
44) Show students how to make charts for solving problems to break information into smaller pieces.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
45) Teach students to use two variables when there are two unknowns in solving algebraic word problems.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
46) When providing feedback, target incorrect responses and error patterns.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
47) Describe a model by thinking aloud and including students in the thinking aloud process.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
48) Identify a new skill or concept at the beginning of instruction and provide a rationale for learning it.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
49) Provide a graduated sequence of instruction, moving students from the concrete to the abstract in defined steps.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
50) Teach students to derive a formula for a given problem using arithmetic theory before assigning and manipulating algebraic symbols.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
51) Allow students to use index cards as flash cards with basic algebraic processes, necessary formulas, or needed reminders.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
52) Teach students to create templates or patterns for evaluating algebraic expressions.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
53) Encourage students to verbalize the steps of an algebraic process to themselves or other students.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
54) Emphasize understanding of algebraic concepts over reliance on rules.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
55) Teach students to use colored pencils to highlight relevant information or to draw specific sign and symbols in algebraic expressions.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
56) Insist that students use the correct vocabulary and terminology in the algebra context.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
57) Require that all written mathematics indicate a one-step-at-a-time process.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
58) Practice proper reading of word phrases so that students can achieve an accurate translation of both the symbols and meaning of language in algebra.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
59) Emphasize proper reading and writing of algebraic terms.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
60) Treat algebra as a foreign language with its own alphabet and grammar.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
61) Students use the graphing calculator to explore linear relationships.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
62) Use equations derived from “real life” for instruction on graphing linear equations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
63) Have students write about their work in problem solving or about their thought processes in algebra.	1 2 3 4 5 6 7	1 2 3 4	1 2 3

64) Promote discussion and verbalization of thought processes and mathematical relationships.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
65) Use computer spreadsheets, such as Microsoft excel, for problem solving instruction.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
66) Mold lessons around the interests of individual students.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
67) When giving feedback, recognize correct thinking in students even when it may be incomplete or lacking closure.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
68) Return to familiar problem settings by modifying them to enrich students' understanding of algebra.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
Questionnaire Statements	Domain	Association	Clarity
69) Emphasize use of multiple representations: words, tables, graphs, and symbols.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
70) Assign goal-free problems to students for practice.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
71) Provide students with worked examples along with their practice work.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
72) Allow students to discuss their own problem solving processes and recognize many alternatives.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
73) Emphasize the problem solving process, rather than the solution.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
74) Anchor problem solving skills instruction within a meaningful thematic situation.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
75) Emphasize problem representation skills using tables, graphs, and symbols.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
76) Use worked examples to accompany homework assignments.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
77) Use worked examples to accompany class work assignments.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
78) Encourage students to experiment with alternative methods for solving problems.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
79) Provide worked examples with homework.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
80) Have students find errors in worked examples.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
81) Have students write observations of what they see happening in worked examples of problems.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
82) Use worked examples to introduce or reinforce topics.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
83) Analyze already worked out examples of problems with students.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
84) When a student responds incorrectly, provide a new cue or explanation, giving the student a chance to try again.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
85) Provide math games for students to practice algebraic skills.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
86) Encourage students to ask questions when difficulties or misunderstandings arise.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
87) Administer quizzes to indicate student mastery of unit content and for feedback purposes.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
88) Provide cues to indicate to students what is to be learned and what actions are required of students.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
89) Following each learning task, provide time for error correction.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
90) Follow feedback to students with methods for correcting errors.	1 2 3 4 5 6 7	1 2 3 4	1 2 3

91) Use symbols to help students learn to solve equations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
92) Use diagrams to help students learn to solve equations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
93) Use physical objects to help students learn to solve equations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
94) Assign students to use calculators.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
95) Assign students to write about algebra.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
96) Discuss solutions to algebra problems as a class.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
97) Encourage students to communicate explanations of responses and procedures in both verbal and written formats.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
98) Provide practice in computational skills.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
99) Assign students to work on problems that have no immediate solution.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
Questionnaire Statements	Domain	Association	Clarity
100) Encourage students to explain the reasoning behind their ideas.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
101) Allow students time to begin homework in class.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
102) Pair students to work as peer tutors.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
103) Use computer software to provide practice opportunities.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
104) Tell students what skill they will learn, linking the current lesson to past lessons, and providing a rationale for the importance of learning the skill.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
105) Reward group performance in the cooperative setting.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
106) Reward individual performance in the cooperative setting.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
107) Provide graphing calculators for student use.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
108) Students observe worked examples of algebraic equations to derive rules for solving future equations.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
109) Use reading-to-learn in the content area strategies.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
110) Assign students to work in homogeneous groups.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
111) Assign students to work in heterogeneous groups.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
112) Provide students with study skills instruction.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
113) Review only homework problems requested by the students.	1 2 3 4 5 6 7	1 2 3 4	1 2 3
114) When assigning practice work, ensure that the majority of problems assigned review previously covered material.	1 2 3 4 5 6 7	1 2 3 4	1 2 3

Appendix W

Instrument for Second Content Validation Study

An Investigation of Instructional Practices

for Algebra I

Domains and Descriptions

Domain 1: Cooperative Learning

A method of instruction in which students work together to reach a common goal.

Domain 2: Communication and Study Skills

Teaching students techniques to read and study mathematical information effectively and providing opportunities for students to communicate mathematical ideas verbally or in writing (thinking aloud).

Domain 3: Problem-Based Learning

Teaching through problem solving where students apply a general rule (deduction) or draw new conclusions or rules (induction) based on information presented in the problem.

Domain 4: Manipulatives, Models, and Multiple Representations

Teaching students techniques for generating or manipulating representations of algebraic content or processes, whether concrete, symbolic, or abstract.

Domain 5: Direct Instruction: Setting objectives and providing feedback

Teaching through establishing a direction and rationale for learning by relating new concepts to previous learning, leading students through a specified sequence of instructions based on predetermined steps that introduce and reinforce a concept, and providing students with feedback relative to how well they are doing.

Statements Assessing the Teacher's Use of Instructional Practices for Algebra I

Name:________________________________

E-Mail Address: ______________________

Phone Number: ________________________

Directions: Delete the number for the appropriate response using the backspace key.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning*
(2) *Communication & Study Skills*
(3) *Problem-Based Learning*
(4) *Manipulatives, Models, and Multiple Representations*
(5) *Direct Instruction: Setting Objectives and Providing Feedback*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong

Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

- **For any items you rate as 1 or 2 for clarity or association, please make notes at the bottom of this page.**

Questionnaire Statements	Domain	Association	Clarity
1) Students write original word problems.	1 2 3 4 5	1 2 3 4	1 2 3
2) Provide a classroom environment with colorful posters representing mathematical concepts and processes.	1 2 3 4 5	1 2 3 4	1 2 3
3) Provide mathematics vocabulary terms with definitions.	1 2 3 4 5	1 2 3 4	1 2 3
4) Relate new algebra concepts to previously learned concepts or skills.	1 2 3 4 5	1 2 3 4	1 2 3
5) Collaborate with the whole class in finding the solution to a problem.	1 2 3 4 5	1 2 3 4	1 2 3
6) Provide strategies for reading comprehension.	1 2 3 4 5	1 2 3 4	1 2 3
7) Engage the students in solving problems based on relevant situations.	1 2 3 4 5	1 2 3 4	1 2 3
8) Give the students opportunities to communicate verbally or in writing using mathematical terms.	1 2 3 4 5	1 2 3 4	1 2 3

* Notes:

Directions: Delete the number for the appropriate response using the backspace key.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning*
(2) *Communication & Study Skills*
(3) *Problem-Based Learning*
(4) *Manipulatives, Models, and Multiple Representations*
(5) *Direct Instruction: Setting Objectives and Providing Feedback*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong

Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

- **For any items you rate as 1 or 2 for clarity or association, please make notes at the bottom of this page.**

Questionnaire Statements	Domain	Association	Clarity
10) Engage students in finding similarities and differences between types of equations and problems.	1 2 3 4 5	1 2 3 4	1 2 3
11) Have students create their own rules in new problem-solving situations.	1 2 3 4 5	1 2 3 4	1 2 3
12) To aid students in visualizing an equation and its parts, make comparisons to things familiar to the students.	1 2 3 4 5	1 2 3 4	1 2 3
13) Teach general methods for students to solve mathematically formulated problems.	1 2 3 4 5	1 2 3 4	1 2 3
14) Draw mathematical concepts from "real life" problems.	1 2 3 4 5	1 2 3 4	1 2 3
15) Require students to share their thinking by conjecturing, arguing, and justifying ideas.	1 2 3 4 5	1 2 3 4	1 2 3
16) Teach students to represent algebraic expressions with graphs.	1 2 3 4 5	1 2 3 4	1 2 3
17) Teach students to represent problems with tables.	1 2 3 4 5	1 2 3 4	1 2 3
18) Teach students to represent problems with written expressions.	1 2 3 4 5	1 2 3 4	1 2 3

*Notes:

Directions: Delete the number for the appropriate response using the backspace key.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning* (3) *Problem-Based Learning* (5) *Direct Instruction: Setting Objectives and Providing Feedback*
(2) *Communication & Study Skills* (4) *Manipulatives, Models, and Multiple Representations*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong

Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

- **For any items you rate as 1 or 2 for clarity or association, please make notes at the bottom of this page.**

Questionnaire Statements	Domain	Association	Clarity
19) Grade homework to provide feedback.	1 2 3 4 5	1 2 3 4	1 2 3
20) Allow students time to begin homework in class while providing assistance.	1 2 3 4 5	1 2 3 4	1 2 3
21) Have students write about their problem solving strategies.	1 2 3 4 5	1 2 3 4	1 2 3
22) Provide reading guides for students to improve their word problem comprehension.	1 2 3 4 5	1 2 3 4	1 2 3
23) Make connections between mathematics and other subjects.	1 2 3 4 5	1 2 3 4	1 2 3
24) Students investigate and create equations from given problem situations.	1 2 3 4 5	1 2 3 4	1 2 3
25) Students work on open-ended and extended problem-solving projects.	1 2 3 4 5	1 2 3 4	1 2 3
26) Begin instruction with a target skill or concept for students to master.	1 2 3 4 5	1 2 3 4	1 2 3

*Notes:

Directions: Delete the number for the appropriate response using the backspace key.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning*
(2) *Communication & Study Skills*
(3) *Problem-Based Learning*
(4) *Manipulatives, Models, and Multiple Representations*
(5) *Direct Instruction: Setting Objectives and Providing Feedback*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong

Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

For any items you rate as 1 or 2 for clarity or association, please make notes at the bottom of this page.

Questionnaire Statements	Domain	Association	Clarity
27) Work one increasingly difficult problem at a time to simplify during instruction.	1 2 3 4 5	1 2 3 4	1 2 3
28) Close instruction by reviewing concepts with students, emphasizing comparisons to previously covered concepts.	1 2 3 4 5	1 2 3 4	1 2 3
29) Teach students how represent problems with charts to break information into smaller pieces.	1 2 3 4 5	1 2 3 4	1 2 3
30) Teach students to represent two unknowns with two variables when solving algebraic word problems.	1 2 3 4 5	1 2 3 4	1 2 3
31) When providing feedback, target incorrect responses and error patterns.	1 2 3 4 5	1 2 3 4	1 2 3
32) Describe a model by thinking aloud and including students in the thinking aloud process.	1 2 3 4 5	1 2 3 4	1 2 3
33) Derive a formula for a given problem from theory before assigning and manipulating algebraic symbols.	1 2 3 4 5	1 2 3 4	1 2 3
34) Allow students to use index cards as flash cards with basic algebraic processes, necessary formulas, or needed reminders.	1 2 3 4 5	1 2 3 4	1 2 3

*Notes:

Directions: Delete the number for the appropriate response using the backspace key.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning* (3) *Problem-Based Learning* (5) *Direct Instruction: Setting Objectives and Providing Feedback*
(2) *Communication & Study Skills* (4) *Manipulatives, Models, and Multiple Representations*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong

Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

For any items you rate as 1 or 2 for clarity or association, please make notes at the bottom of this page.

Questionnaire Statements	Domain	Association	Clarity
35) Teach students to create templates or patterns for representing and evaluating algebraic expressions.	1 2 3 4 5	1 2 3 4	1 2 3
36) Emphasize understanding of algebraic concepts over reliance on rules or solving problems or equations.	1 2 3 4 5	1 2 3 4	1 2 3
37) Use colored pencils to highlight relevant information or to draw specific sign and symbols in algebraic expressions.	1 2 3 4 5	1 2 3 4	1 2 3
38) Require that students indicate a one-step-at-a-time process in working equations.	1 2 3 4 5	1 2 3 4	1 2 3
39) Use linear equations derived from “real life” relationships for instruction on graphing.	1 2 3 4 5	1 2 3 4	1 2 3
40) Create problem situations from the interests of individual students.	1 2 3 4 5	1 2 3 4	1 2 3
41) When giving feedback, recognize correct thinking in students, although it may be incomplete or lacking closure.	1 2 3 4 5	1 2 3 4	1 2 3
42) Return to familiar problem settings when introducing a new problem type.	1 2 3 4 5	1 2 3 4	1 2 3

*Notes:

Directions: Delete the number for the appropriate response using the backspace key.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning* (3) *Problem-Based Learning* (5) *Direct Instruction: Setting Objectives and Providing Feedback*
(2) *Communication & Study Skills* (4) *Manipulatives, Models, and Multiple Representations*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong

Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

For any items you rate as 1 or 2 for clarity or association, please make notes at the bottom of this page.

Questionnaire Statements	Domain	Association	Clarity
43) Assign goal-free problems to students.	1 2 3 4 5	1 2 3 4	1 2 3
44) Provide students with pre-worked examples along with their practice work.	1 2 3 4 5	1 2 3 4	1 2 3
45) Recognize many alternative problem-solving practices.	1 2 3 4 5	1 2 3 4	1 2 3
46) Anchor problem solving skills instruction within a meaningful situation.	1 2 3 4 5	1 2 3 4	1 2 3
47) Represent problems using tables, graphs, and symbols.	1 2 3 4 5	1 2 3 4	1 2 3
48) Give pre-worked examples to accompany homework assignments.	1 2 3 4 5	1 2 3 4	1 2 3
49) Give pre-worked examples to accompany class work assignments.	1 2 3 4 5	1 2 3 4	1 2 3
50) Encourage students to experiment with alternative methods for problem solving.	1 2 3 4 5	1 2 3 4	1 2 3

*Notes:

Directions: Delete the number for the appropriate response using the backspace key.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning* (3) *Problem-Based Learning* (5) *Direct Instruction: Setting Objectives and Providing Feedback*
(2) *Communication & Study Skills* (4) *Manipulatives, Models, and Multiple Representations*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong

Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

For any items you rate as 1 or 2 for clarity or association, please make notes at the bottom of this page.

Questionnaire Statements	Domain	Association	Clarity
51) Provide pre-worked examples with homework.	1 2 3 4 5	1 2 3 4	1 2 3
52) Have students find errors in pre-worked examples.	1 2 3 4 5	1 2 3 4	1 2 3
53) Use pre-worked examples to introduce or reinforce topics.	1 2 3 4 5	1 2 3 4	1 2 3
54) Analyze already worked out examples of problems with students.	1 2 3 4 5	1 2 3 4	1 2 3
55) When a student responds incorrectly, give the student a chance to try again after providing a cue.	1 2 3 4 5	1 2 3 4	1 2 3
56) Provide math games for students to practice algebraic skills.	1 2 3 4 5	1 2 3 4	1 2 3
57) Encourage students to ask questions when difficulties or misunderstandings arise.	1 2 3 4 5	1 2 3 4	1 2 3
58) Allow students to discuss solutions to algebra problems with peers.	1 2 3 4 5	1 2 3 4	1 2 3
59) Provide practice and feedback in computational skills.	1 2 3 4 5	1 2 3 4	1 2 3

*Notes:

Directions: Delete the number for the appropriate response using the backspace key.

Domains

Algebra I Teacher use of instructional practices in the following categories:

(1) *Cooperative Learning* (3) *Problem-Based Learning* (5) *Direct Instruction: Setting Objectives and Providing Feedback*
(2) *Communication & Study Skills* (4) *Manipulatives, Models, and Multiple Representations*

Association Ratings: 1 = very weak, 2 = weak, 3 = strong, 4 = very strong

Clarity Ratings: 1 = very unclear, delete; 2 = somewhat unclear, revise; and 3 = clear, leave as written

For any items you rate as 1 or 2 for clarity or association, please make notes at the bottom of this page.

Questionnaire Statements	Domain	Association	Clarity
60) Allow students time to begin homework in class with peer assistance.	1 2 3 4 5	1 2 3 4	1 2 3
61) Students examine pre-worked examples of algebraic equations to derive rules for solving future equations.	1 2 3 4 5	1 2 3 4	1 2 3
62) Use reading instructional strategies to help students with reading comprehension skills.	1 2 3 4 5	1 2 3 4	1 2 3
63) Provide students with study skills instruction.	1 2 3 4 5	1 2 3 4	1 2 3
64) Review only homework problems requested by the students.	1 2 3 4 5	1 2 3 4	1 2 3
65) When assigning practice work, ensure that the majority of problems assigned review previously covered material.	1 2 3 4 5	1 2 3 4	1 2 3

***Notes:**

Appendix X

Selected Survey Items and Survey Design

VirginiaTech

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

The Influence of Teaching Methods on Student Achievement on Virginia's End of Course Standards of Learning Test for Algebra I

Thank you so much for taking the time to log onto this web site to complete this brief questionnaire regarding your teaching methods for Algebra I. By completing this 51-item questionnaire, you will be providing me with valuable information that I will use to determine the influence of teaching methods on student achievement on Virginia's End of Course Test for Algebra I.

As you begin the questionnaire, remember to enter your four-digit pin number so that I may keep this site secure and protect the information you provide. Once you have completed the survey (it will take about 20 minutes), don't forget to click on the submit button so that your responses are transmitted to a secure database for analysis. You will receive a confirmation that your responses were transmitted successfully.

Remember, you will not be identified, nor will your students, your school, or your school division. All information will be aggregated for statistical analysis. If you are interested in obtaining the results of this study, please e-mail me at matthaas@scsb.org, and I will gladly provide you with a copy upon its completion.

Thanks again, I greatly appreciate your participation in this project!

Matthew S. Haas	Dr. Travis W. Twiford
Principal	Director
Northwood High School	Tidewater Doctoral Program
Smyth County	Virginia Polytechnic Institute

NOTE: To begin, type the PIN and secret word I provided you in the boxes below. Please do not press the Enter key after typing your PIN or secret word. Pressing Enter will submit your responses. You should not press Enter until you have completed the survey. Then you may press Enter or click the Submit button to submit your responses.

Please type your PIN: [ ] Please enter your secret word: [ ]

Part I: For each of the following statements, please use the dropdown box to select the choice that best indicates the number of times you use this teaching method, given five typical class periods. For example, if you use this teaching method during every period, please select 5 from the dropdown box. If you never use this method, please select 0.

Cooperative Learning

1.	I collaborate with the whole class in finding a solution to a problem.	0
2.	I allow students to engage in cooperative problem solving.	0
3.	I allow students to discuss solutions to algebra problems with peers.	0
4.	I allow students to begin homework in class with peer assistance.	0
5.	I pair students to work as peer tutors.	0
6.	I reward group performance in the cooperative setting.	0
7.	I assign students to work in homogeneous groups.	0
8.	I assign students to work in heterogeneous groups.	0

Communication and Study Skills

9.	I encourage students to use mathematics vocabulary terms in class discussions.	0
10.	I have students describe their thought processes orally or in writing during problem solving.	0
11.	I require students to share their thinking by conjecturing, arguing, and justifying ideas.	0
12.	I have students write about their problem solving strategies.	0
13.	I encourage students to ask questions when difficulties or misunderstandings arise.	0
14.	I encourage students to explain the reasoning behind their ideas.	0
15.	I use reading instructional strategies to help students with comprehension.	0
16.	I provide students with study skills instruction.	0

Technology Aided Instruction

17.	I have students use calculators during tests or quizzes (given five typical test or quiz administrations).	0
18.	I have students use calculators for problem solving instruction and activities.	0
19.	I have students use calculators to help them develop problem-solving strategies.	0
20.	I have students use calculators for computations.	0
21.	I have students use graphing calculators to explore linear relationships.	0
22.	I have students use computer spreadsheets, such as Microsoft Excel, for problem solving instruction.	0
23.	I assign students to use calculators as a requirement for class participation.	0
24.	I use computer software to provide practice opportunities.	0

Problem-based Learning

25.	I have students create their own rules in new problem solving situations.	0
26.	I draw mathematical concepts from "real-life" situations.	0
27.	I have students pursue open-ended and extended problem solving projects.	0
28.	I create problems from the interests of individual students.	0
29.	I recognize many alternative problem-solving practices.	0
30.	I emphasize the problem solving process, rather than the solution.	0
31.	I anchor problem solving skills instruction within situations meaningful to the students.	0
32.	I encourage students to experiment with alternative methods for problem solving.	0

Manipulatives, Models, and Multiple Representations

33.	I have students use cubes or blocks to represent algebraic equations.	0
34.	I illustrate mathematical concepts for students with pictures.	0
35.	I teach students to represent algebraic equations with graphs.	0
36.	I teach students to represent problems with tables.	0
37.	I teach students to represent problems with charts to break information into smaller pieces.	0
38.	I emphasize the use of multiple representations: words, tables, graphs, and symbols.	0
39.	I provide math games for students to practice algebraic skills.	0
40.	I use diagrams to help students learn to solve equations.	0

Direct Instruction

41.	I grade homework to provide feedback.	0
42.	I close instruction by reviewing concepts with students, emphasizing comparisons to previously covered concepts.	0
43.	When providing feedback, I target incorrect responses and error patterns.	0
44.	I identify a new skill or concept at the beginning of instruction and provide a rationale for learning it.	0
45.	I provide a graduated sequence of instruction, moving students from concrete to abstract concepts in defined steps.	0
46.	I require students to indicate a one-step-at-a-time process in working equations.	0
47.	I use pre-worked examples to introduce or reinforce topics.	0
48.	When assigning practice work, I ensure that the majority of the problems review previously covered material.	0

Part II: Please help me to describe your classes. For items 49 and 50, please make a selection from the dropdown list boxes. For item 51, please type the number of years you have taught Algebra I in

Virginia.

49.	Indicate the type of schedule your school uses:	Please select your schedule.
50.	Indicate the credit value of your Algebra I class:	Please select number of credits.
51.	Please type the number of years you have taught Algebra I in Virginia:	

Please click the Submit button below ONCE to submit your survey responses. (If you double-click the button, your responses will be sent twice.)

Submit

Appendix Y

Content Validation of Survey Assessing the Teacher's Use of Instructional Practices for Algebra I: Classification of Items into Domains by Experts, Jan. and Feb. 2001 (N = 14)

		Domains											
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
1	M & M & MR									*13	92.9		
2	Communication & Study Skills	1	7.1	13	92.9								
3	Communication & Study Skills			12	85.7			2	14.3				
4	M & M & MR									14	100		
5	Communication & Study Skills			14	100								
6	Communication & Study Skills			14	100								
7	Direct Instruction									1	7.1	13	92.9

	Domains												
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
8	Cooperative Learning	13	92.9	1	7.1								
9	Tech. Aided Instruction					*12	85.7	1	7.1				
10	Communication & Study Skills			14	100								
11	Cooperative Learning	14	100										
12	Communication & Study Skills			*13	92.9								
13	Problem-Based Learning							13	92.9	1	7.1		
14	Communication & Study Skills			14	100								
15	Communication & Study Skills			*12	85.7					1	7.1		
16	Problem-Based Learning							6	42.9	6	42.9	2	14.3

	Domains												
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
17	Cooperative Learning	12	85.7					2	14.3				
18	Problem-Based Learning							14	100				
19	Communication & Study Skills			14	100								
20	Tech. Aided Instruction					14	100						
21	Tech. Aided Instruction					14	100						
22	Tech. Aided Instruction					13	92.9	1	7.1				
23	Tech. Aided Instruction					13	92.9	1	7.1				
24	Tech. Aided Instruction					*13	92.9						
25	M & M & MR									13	92.9	1	7.1

	Domains													
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction		
Item		n	%	n	%	n	%	n	%	n	%	n	%	
26	Problem-Based Learning							5	35.7	2	14.3	7	50	
27	M & M & MR									14	100			
28	Problem-Based Learning							13	92.9	1	7.1			
29	Cooperative Learning	14	100											
30	Communication & Study Skills			14	100									
31	M & M & MR									14	100			
32	M & M & MR									14	100			
33	M & M & MR			1	7.1					13	92.9			
34	Direct Instruction											14	100	

		Domains											
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
35	Direct Instruction											14	100
36	Communication & Study Skills			14	100								
37	Communication & Study Skills			14	100								
38	Communication & Study Skills							2	14.3	8	57.1	4	28.6
39	Problem-Based Learning							13	92.9	1	7.1		
40	Problem-Based Learning							13	92.9	1	7.1		
41	Direct Instruction											14	100
42	Direct Instruction							1	7.1			13	92.9
43	Direct Instruction											14	100

		Domains												
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
44	M & M & MR									14	100		
45	M & M & MR							1	7.1	12	85.7	1	7.1
46	Direct Instruction											14	100
47	M & M & MR			12	85.7					2	14.3		
48	Direct Instruction									2	14.3	12	85.7
49	Direct Instruction							1	7.1	1	7.1	12	85.7
50	Problem-Based Learning							10	71.4	2	14.3	2	14.3
51	Direct Instruction			2	14.3					4	28.6	8	57.1
52	M & M & MR							2	14.3	12	85.7		

		Domains											
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
53	Communication Skills	13	92.9							1	7.1		
54	Problem-Based Learning							13	92.9			1	7.1
55	M & M & MR			2	14.3					12	85.7		
56	Communication & Study Skills			13	92.9							1	7.1
57	Direct Instruction											14	100
58	Communication & Study Skills			*13	92.9								
59	Communication & Study Skills			13	92.9							1	7.1
60	Communication & Study Skills			13	92.9							1	7.1
61	Tech. Aided Instruction					14	100						

	Domains												
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
62	Problem-Based Learning							11	78.6	3	21.4		
63	Communication & Study Skills			*12	85.7					1	7.1		
64	Communication & Study Skills			14	100								
65	Tech. Aided Instruction					13	92.9			1	7.1		
66	Problem-Based Learning			1	7.1			92.9	100				
67	Direct Instruction											14	100
68	Direct Instruction							1	7.1	1	7.1	12	85.7
69	M & M & MR			1	7.1					13	92.9		
70	Problem-Based Learning							14	100				

	Domains												
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
71	Direct Instruction											14	100
72	Problem-Based Learning							13	92.9			1	7.1
73	Problem-Based Learning							13	92.9	1	7.1		
74	Problem-Based Learning							14	100				
75	M & M & MR									14	100		
76	Direct Instruction											14	100
77	Direct Instruction											14	100
78	Problem-Based Learning							14	100				
79	Direct Instruction											14	100

		Domains											
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
80	Direct Instruction			2	14.3			1	7.1			11	78.6
81	Communication & Study Skills			*12	85.7			1	7.1				
82	Direct Instruction											14	100
83	Direct Instruction			4	28.6			1	7.1			9	69.3
84	Direct Instruction			1	7.1							13	92.9
85	M & M & MR			1	7.1					13	92.9		
86	Communication & Study Skills											14	100
87	Problem-Based Learning											*13	92.9
88	Direct Instruction			1	7.1			1	7.1			12	85.7

		Domains											
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
89	Direct Instruction							1	7.1			*8	57.1
90	Direct Instruction			1	7.1							13	92.9
91	M & M & MR			1	7.1			1	7.1	12	85.7		
92	M & M & MR							1	7.1	13	92.9		
93	M & M & MR									13	92.9	1	7.1
94	Tech. Aided Instruction					14	100						
95	Communication & Study Skills			*13	92.9								
96	Cooperative Learning	14	100										
97	Communication & Study Skills			14	100								

	Domains												
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
98	Direct Instruction											14	100
99	Problem-Based Learning							14	100				
100	Communication & Study Skills			13	92.9							1	7.1
101	Cooperative Learning	14	100										
102	Cooperative Learning	14	100										
103	Tech. Aided Instruction					*13	92.9						
104	Direct Instruction									1	7.1	13	92.9
105	Cooperative Learning	13	92.9	1	7.1								
106	Cooperative Learning	12	85.7									2	14.3

	Domains												
	Expected Domain	Cooperative Learning		Communication & Study Skills		Tech. Aided Instruction		Problem-Based Learning		M & M & MR		Direct Instruction	
Item		n	%	n	%	n	%	n	%	n	%	n	%
107	Tech. Aided Instruction			1	7.1	13	92.9						
108	Problem-Based Learning			1	7.1			8	57.1			5	35.7
109	Communication & Study Skills			14	100								
110	Cooperative Learning	13	92.9	1	7.1								
111	Cooperative Learning	13	92.9	1	7.1								
112	Communication & Study Skills			14	100								
113	Communication & Study Skills			6	42.9							8	57.1
114	Direct Instruction											14	100

* Indicates that n < 14 because the item was not used in the second round and some experts chose “Homework and Practice” in the first round.

Appendix Z

Content Validation of Survey Assessing the Teacher's Use of Instructional Practices for Algebra I: Strength of Association and Clarity by Experts, Jan. and Feb. 2001 (N = 14)

		Domains											
	Expected Domain	Cooperative Learning (CL)			Communication & Study Skills (CS)			Tech. Aided Instruction (TAI)			Problem-Based Learning (PBL)		
Item		n	M	SD	n	M	SD	n	M	SD	n	M	SD
1	MMR												
2	CS	1	1	--	13	3.08	.64						
3	CS				12	3.75	.45				2	2.5	.71
4	MMR												
5	CS				14	3.64	.50						
6	CS				14	3.40	.55						
7	DI												
8	CL	13	3.31	.63	1	3.0	.60						
9	TAI							12	3.50	.80	1	3.0	--
10	CS				14	3.50	.65						
11	CL	14	3.71	.47									
12	CS				*13	3.62	.51						

Item	Expected Domain	Cooperative Learning (CL)			Communication & Study Skills (CS)			Tech. Aided Instruction (TAI)			Problem-Based Learning (PBL)		
		n	M	SD	n	M	SD	n	M	SD	n	M	SD
13	PBL										13	3.46	.66
14	CS				14	3.79	.43						
15	CS				12	3.58	.79						
16	PBL										6	3.0	.89
17	CL	12	3.33	.89							2	3.0	--
18	PBL										14	3.43	.94
19	CS				14	3.64	.5						
20	TAI							14	3.36	.74			
21	TAI							14	3.64	.50			
22	TAI							13	3.54	.52	1	4.0	--
23	TAI							13	3.38	.64	1	4.0	--
24	TAI							*13	3.46	.66			
25	MMR												
26	PBL										5	3.40	.89
27	MMR												

	Domains												
	Expected Domain	Cooperative Learning (CL)			Communication & Study Skills (CS)			Tech. Aided Instruction (TAI)			Problem-Based Learning (PBL)		
Item		n	M	SD	n	M	SD	n	M	SD	n	M	SD
28	PBL										13	3.40	.89
29	CL	14	3.5	.52									
30	CS				14	3.79	.43						
31	MMR												
32	MMR												
33	MMR				1	3.0	--						
34	DI												
35	DI												
36	CS				14	3.5	.52						
37	CS				14	3.07	.92						
38	MMR										2	3.0	--
39	PBL										13	3.38	.77
40	PBL										13	3.15	.89
41	DI												
42	DI										1	4.0	--

	Domains												
	Expected Domain	Cooperative Learning (CL)			Communication & Study Skills (CS)			Tech. Aided Instruction (TAI)			Problem-Based Learning (PBL)		
Item		n	M	SD	n	M	SD	n	M	SD	n	M	SD
43	DI												
44	MMR												
45	MMR										1	2.0	--
46	DI												
47	MMR				11	3.27	1.19						
48	DI												
49	DI										1	3.0	--
50	PBL										10	3.2	.79
51	DI				2	2.5	.71						
52	MMR										2	4.0	--
53	CS				14	3.5	.65						
54	PBL										13	2.67	.95
55	MMR				2	3.0	--						
56	CS				13	3.23	.73						
57	DI												

	Domains													
	Expected Domain	Cooperative Learning (CL)			Communication & Study Skills (CS)			Tech. Aided Instruction (TAI)			Problem-Based Learning (PBL)			
Item		n	M	SD	n	M	SD	n	M	SD	n	M	SD	
58	CS				13	3.13	.90							
59	CS				13	3.31	.75							
60	CS				13	3.0	1.22							
61	TAI							14	3.86	.36				
62	PBL										11	3.0	.89	
63	CS				12	3.58	.67							
64	CS				14	3.57	.51							
65	TAI							13	3.69	.48				
66	PBL				1	1.0	--				13	3.08	.86	
67	DI													
68	DI										1	4.0	--	
69	MMR				1	2.0	--							
70	PBL										14	2.64	1.0	
71	DI													
72	PBL										13	3.38	.51	

		Domains											
	Expected Domain	Cooperative Learning (CL)			Communication & Study Skills (CS)			Tech. Aided Instruction (TAI)			Problem-Based Learning (PBL)		
Item		n	M	SD	n	M	SD	n	M	SD	n	M	SD
73	PBL										13	3.58	.67
74	PBL										14	3.21	1.1
75	MMR												
76	DI												
77	DI												
78	PBL										14	3.29	.73
79	DI												
80	DI				2	3.0	--				1	4.0	--
81	CS				12	3.17	.87				1	2.0	--
82	DI												
83	DI				4	3.25	.96				1	3.0	--
84	DI				1	3.0	--						
85	MMR				1	3.0	--						
86	CS	1	4.0	--	13	3.31	.63						
87	DI												

	Domains												
	Expected Domain	Cooperative Learning (CL)			Communication & Study Skills (CS)			Tech. Aided Instruction (TAI)			Problem-Based Learning (PBL)		
Item		n	M	SD	n	M	SD	n	M	SD	n	M	SD
88	DI				1	1.0	--						
89	DI										1	2.0	--
90	DI				1	2.0	--						
91	MMR				1	3.0	--				1	2.0	--
92	MMR										1	2.0	--
93	MMR												
94	TAI							14	3.43	.65			
95	CS				*13	3.54	.66						
96	CL	14	3.71	.47									
97	CS				14	3.57	.65						
98	DI												
99	PBL										14	2.71	.99
100	CS				13	3.38	.87						
101	CL	14	3.45	.51									
102	CL	14	3.79	.45									

	Domains												
	Expected Domain	Cooperative Learning (CL)			Communication & Study Skills (CS)			Tech. Aided Instruction (TAI)			Problem-Based Learning (PBL)		
Item		n	M	SD	n	M	SD	n	M	SD	n	M	SD
103	TAI							*13	3.54	.52			
104	DI												
105	CL	13	3.54	.66	1	2.0	--						
106	CL	12	3.83	1.11									
107	TAI				1	4.0	--	13	3.46	.66			
108	PBL				1	4.0	--				8	3.5	.54
109	CS				14	3.57	.51						
110	CL	13	3.15	.99	1	4.0	--						
111	CL	13	3.46	.6	1	4.0	--						
112	CS				14	3.5	.52						
113	CS				6	2.8	1.3						
114	DI												

* Indicates that n < 14 because the item was not used in the second round and some experts chose “Homework and Practice” in the first round.

Content Validation of Survey Assessing the Teacher's Use of Instructional Practices for Algebra I: Strength of Association and Clarity by Experts, Jan. and Feb. 2001 (N = 14)

		Domains								
	Expected Domain	Manipulatives, Models, & Multiple Representations (MMR)			Direct Instruction (DI)			Clarity		
Item		n	M	SD	n	M	SD	n	M	SD
1	MMR	*13	3.77	.44				14	2.79	.43
2	CS							14	2.86	.36
3	CS							14	2.79	.43
4	MMR	14	2.86	.77				14	2.86	.36
5	CS							14	2.79	.58
6	CS							14	2.86	.36
7	DI	1	4.0	--	13	3.31	.75	14	2.71	.61
8	CL							14	2.79	.47
9	TAI							14	2.86	.36
10	CS							14	2.71	.47
11	CL							14	2.64	.47
12	CS							14	3.0	--

		Domains								
	Expected Domain	Manipulatives, Models, & Multiple Representations (MMR)			Direct Instruction (DI)			Clarity		
Item		n	M	SD	n	M	SD	n	M	SD
13	PBL	1	4.0	--				14	2.86	.36
14	CS							14	2.86	.36
15	CS	1	4.0	--				14	2.79	.43
16	PBL	6	2.67	.82	2	2.0	1.41	14	2.57	.65
17	CL							14	2.71	.47
18	PBL							14	2.64	.63
19	CS							14	2.86	.36
20	TAI							14	2.86	.36
21	TAI							14	2.86	.36
22	TAI							14	2.64	.43
23	TAI							14	2.86	.36
24	TAI							14	2.86	.36
25	MMR	13	2.77	.59	1	3.0	--	14	2.64	.49
26	PBL	2	3.5	.7	7	3.14	.69	14	2.86	.54
27	MMR	14	3.64	.5				14	2.71	.61

Item	Expected Domain	Manipulatives, Models, & Multiple Representations (MMR)			Direct Instruction (DI)			Clarity		
		n	M	SD	n	M	SD	n	M	SD
28	PBL	1	2.0	--				14	2.86	.36
29	CL							14	2.79	.53
30	CS							14	2.93	.27
31	MMR	14	3.71	.47				14	2.93	.27
32	MMR	14	3.79	.43				14	2.86	.54
33	MMR	13	3.62	.51				14	2.71	.61
34	DI				14	3.71	.61	14	2.93	.27
35	DI				14	3.0	1.03	14	2.86	.36
36	CS							14	2.79	.55
37	CS							14	2.71	.47
38	MMR	8	2.88	.64	4	3.25	.96	14	2.64	.63
39	PBL	1	4.0	--				14	2.71	.47
40	PBL	1	4.0	--				14	2.64	.63
41	DI				14	3.36	.75	14	2.79	.43
42	DI				13	3.23	.83	14	2.57	.76

	Domains									
	Expected Domain	Manipulatives, Models, & Multiple Representations (MMR)			Direct Instruction (DI)			Clarity		
Item		n	M	SD	n	M	SD	n	M	SD
43	DI				14	3.43	.65	14	2.71	.61
44	MMR	14	3.38	.74				14	2.64	.63
45	MMR	12	3.25	.87	1	3.0	--	14	2.93	.27
46	DI				14	3.29	.83	14	2.86	.36
47	MMR	3	2.67	1.15				14	2.79	.58
48	DI	2	3.0	1.41	12	3.42	.9	14	2.71	.43
49	DI	1	4.0	--	12	3.42	.79	14	2.64	.63
50	PBL	2	3.5	.71	2	3.0	--	14	2.64	.63
51	DI	4	3.38	.74	8	2.5	1.29	14	2.64	.63
52	MMR	12	3.15	.69				14	2.71	.61
53	CS							14	2.86	.86
54	PBL				1	3.0	--	14	2.79	.58
55	MMR	12	3.08	.79				14	2.86	.36
56	CS				1	3.0	--	14	2.79	.43
57	DI				14	3.29	.83	14	2.64	.63

		Domains								
	Expected Domain	Manipulatives, Models, & Multiple Representations (MMR)			Direct Instruction (DI)			Clarity		
Item		n	M	SD	n	M	SD	n	M	SD
58	CS							14	2.64	.5
59	CS				1	3.0	--	14	3.0	--
60	CS				1	4.0	--	14	2.64	.63
61	TAI							14	3.0	--
62	PBL	3	2.67	.58				14	2.71	.61
63	CS							14	2.79	.43
64	CS							14	2.93	.97
65	TAI	1	3.0	--				14	2.93	.27
66	PBL							14	2.79	.58
67	DI				14	3.14	.95	14	2.71	.47
68	DI	1	1.0	--	12	3.58	.67	14	2.64	.63
69	MMR	13	3.85	.38				14	2.93	.27
70	PBL							14	2.21	.8
71	DI				14	3.43	.51	14	2.93	.27
72	PBL				1	1.0	--	14	2.86	.54

	Domains									
	Expected Domain	Manipulatives, Models, & Multiple Representations (MMR)			Direct Instruction (DI)			Clarity		
Item		n	M	SD	n	M	SD	n	M	SD
73	PBL	1	2.0	--	1	3.0	--	14	2.79	.43
74	PBL							14	2.5	.76
75	MMR	14	3.64	.63				14	2.86	.36
76	DI				14	3.36	.63	14	2.79	.43
77	DI				14	3.5	.65	14	2.71	.47
78	PBL							14	2.86	.36
79	DI				14	3.29	.61	14	2.79	.43
80	DI				11	2.82	.75	14	2.86	.36
81	CS							14	2.57	.65
82	DI				14	3.21	.69	14	2.86	.36
83	DI				9	3.22	.67	14	2.79	.58
84	DI				13	3.31	.75	14	2.86	.36
85	MMR	13	3.08	1.03				14	2.93	.27
86	CS							14	2.86	.36
87	DI				13	3.31	.75	14	2.71	.61

	Domains									
	Expected Domain	Manipulatives, Models, & Multiple Representations (MMR)			Direct Instruction (DI)			Clarity		
Item		n	M	SD	n	M	SD	n	M	SD
88	DI	1	2.0	--	12	3.42	.67	14	2.64	.63
89	DI				8	3.13	.83	14	2.29	.61
90	DI				13	3.08	.76	14	2.5	.76
91	MMR	12	3.25	.75				14	2.64	.65
92	MMR	13	3.46	.78				14	2.79	.43
93	MMR	13	3.62	.65				14	2.79	.43
94	TAI							14	2.64	.5
95	CS							14	2.64	.5
96	CL							14	2.79	.43
97	CS							14	2.79	.58
98	DI				14	3.21	.8	14	2.79	.43
99	PBL							14	2.71	.61
100	CS				1	2.0	--	14	2.86	.36
101	CL							14	3.0	--
102	CL							14	2.86	.36

		Domains								
	Expected Domain	Manipulatives, Models, & Multiple Representations (MMR)			Direct Instruction (DI)			Clarity		
Item		n	M	SD	n	M	SD	n	M	SD
103	TAI							14	2.86	.36
104	DI	1	2.0	--	13	3.69	.75	14	2.79	.43
105	CL							14	2.64	.74
106	CL				2	3.5	.71	14	2.57	.65
107	TAI							14	2.71	.61
108	PBL				5	3.0	.71	14	2.93	.26
109	CS							14	2.79	.43
110	CL							14	2.79	.58
111	CL							14	2.79	.58
112	CS							14	2.79	.43
113	CS				8	3.22	.83	14	2.93	.26
114	DI				14	3.29	.91	14	2.93	.27

* Indicates that n < 14 because the item was not used in the second round and some experts chose "Homework and Practice" in the first round.

Appendix AA

IRB Exemption Approval

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Institutional Review Board

Dr. David M. Moore
IRB (Human Subjects) Chair
Assistant Vice Provost for Research Compliance
CVM Phase II - Duckpond Dr., Blacksburg, VA 24061-0442
Office: 540/231-4991; FAX: 540/231-6033
e-mail: moored@vt.edu

MEMORANDUM

DATE: April 4, 2002

TO: Matt Haas
Northwood High School
PO Drawer Y
Saltville, VA 24370

FROM: David M. Moore

SUBJECT: **IRB EXEMPTION APPROVAL** – "The Influence of Teaching Methods on Student Achievement on Virginia's End of Course Standards of Learning Test for Algebra I"– IRB # 02-211

I have reviewed your request to the IRB for exemption for the above referenced project. I concur that the research falls within the exempt status. Approval is granted effective as of April 4, 2002.

cc: File
Travis Twiford ELPS 0302

A Land-Grant University—The Commonwealth Is Our Campus
An Equal Opportunity / Affirmative Action Institution

Appendix BB

Virginia Beach City Public School Approval for Reliability Study

VIRGINIA BEACH CITY PUBLIC SCHOOLS

AHEAD OF THE CURVE

April 5, 2002

Mr. Matthew S. Haas
Northwood High School
305 Panther Lane
Saltville, VA 24370

Dear ~~Mr Haas~~: Matt

This letter serves as school division approval for your research project, "The Impact of Teaching Methods on Student Achievement on Virginia's End-of-Course SOL Test for Algebra I." Please include a statement that this research has been approved by the Department of Accountability in your cover letter. As always, the final decision to participate rests with the principal.

If you have any questions, I can be reached at 426-5730. Good luck with your study.

Sincerely,

E. Sidney Vaughn III, Ed.D.
Research Specialist

ESV/mm

pc: James R. Tucker, Assistant Superintendent for High School Education
Louis O. Tonelson, Principal, Kempsville High School

Department of Accountability
2512 George Mason Drive • P.O. Box 6038 • Virginia Beach, VA 23456-0038
757.427.4381 • 757.426.5880 Fax

Appendix CC

Permission Letter and Form Sent to Selected Region VII Superintendents

[date]

Superintendent
School Division
Street Address
City, State Zip Code

Dear [Superintendent]:

I am writing to request your help in addressing a research issue that I think will be of benefit to the school divisions of Region 7 as well as others around the Commonwealth. As a high school principal, I am constantly looking for ways for my students to improve their achievement, especially in the area of mathematics. As a doctoral candidate at Virginia Tech, I am proposing a research study for my dissertation that will explore teaching practices that may contribute to student achievement on the end of course SOL test for Algebra I.

I have conducted a meta-analysis to synthesize the last two decades of research on teaching practices for algebra. From this meta-analysis, I am developing a questionnaire designed to determine the extent to which Algebra I teachers in Region 7 use research-based teaching practices. Using Algebra I teachers' mean scores for this year's SOL test administration(s), I will seek to determine the effect of each teaching practice on student achievement on the end of course test for Algebra I.

I am contacting you to ask permission to survey Algebra I teachers in [school division] in April and to gain access to their mean SOL scores after the spring administration. Of course, if you grant this permission, I will also contact each school principal before moving forward. The information I collect will be aggregated into group data for analysis. No identifiable information will be maintained to link school divisions, schools, teachers, or students to responses on the questionnaire or SOL assessment scores. I will share the results of the study with the superintendents of Region 7 and make them available through the Virginia Tech database.

As we discussed in our telephone conversation, if you decide to grant your permission, please take a moment to complete the attached form and fax it to me at (276) 496 – 3216. If you have any questions, or concerns, please call me at (276) 496 – 7751. I believe that this research will be of benefit to our students, teachers, and school leaders as they strive to achieve in mathematics.

Respectfully,

Matthew S. Haas
Principal
Northwood High School
Smyth County

Dr. Travis W. Twiford
Director
Tidewater Doctoral Program
Virginia Polytechnic Institute
and State University

Please complete this form and fax it to Matt Haas at (276) 496 – 3216 by Thursday, March 13, 2002.

By signing this form, I am granting Matt Haas permission to conduct his research project, "An Investigation of Teaching Methods for Algebra I," with the participation of [school division] Algebra I teachers.

Matt Haas agrees to follow his research proposal as outlined in the attached letter.

1) Contact each school principal before moving forward.

2) The information I collect will be aggregated into group data for analysis.

3) No identifiable information will be maintained to link school divisions, schools, teachers, or students to responses on the questionnaire or SOL assessment scores.

4) The results of the study will be shared with the superintendents of Region 7 and made available through the Virginia Tech database.

____________________________ __________________________
superintendent Date

Please indicate the number of Algebra I teachers in your school division: _____________

Please complete this form and fax it to Matt Haas at (276) 496 – 3216 by Thursday, March 13, 2002.

Appendix DD

Letter to Individual Teacher Requesting Participation

[date]

«Prefix» «Last_Name»
Algebra I Teacher
«School»
«Address»
«City», «State» «Postal_Code»

Dear «Prefix» «Last_Name»:

Given Virginia's mandate that all high school students must pass Algebra I to graduate, there is a pressing need to provide assistance to Algebra I teachers across the commonwealth as they strive for success with their students. In order to make a useful contribution to this process, I am studying the influence of teaching methods on student achievement on Virginia's End of Course SOL Test for Algebra I. I need your help to do so.

I am asking you to complete a brief, research-based survey. You are one of 59 Algebra I teachers in Region VII asked to participate. As an Algebra I teacher, the information you can provide regarding your teaching methods is essential to the completion of this study. By analyzing responses to this survey along with results from the spring administration of the End of Course SOL Test for Algebra I, I am seeking to determine which teaching methods have the strongest influence on student achievement on this test.

Please log onto the following secure web site. Please remember to type the underline spaces between "algebra" and "survey" and between "survey" and "new." You will need your PIN and secret word to log on.

http://www.scsb.org/algebra_survey_new.asp

Your PIN is **«PIN»** The secret word is **newton**.

You can be assured of complete confidentiality. Your name will not appear in my database. Your PIN and the secret word are provided so that I may protect your responses. The information I collect will be aggregated into group data for analysis. **No identifiable information will be maintained to link school divisions, schools, teachers, or students to responses on the survey or SOL assessment scores.** «Division» superintendent, «Superintendent», has approved this project.

The results of this research will be made available through the Virginia Tech database. If you are interested in obtaining the results of this study, or if you have any questions or need assistance, please e-mail me at **matthaas@scsb.org,** or call me at **(276) 496-7751**. I would be most happy to answer any questions you might have.

Thanks again. I greatly appreciate your participation in this project!

Respectfully,

Matthew S. Haas
Principal
Northwood High School
Smyth County

Dr. Travis W. Twiford
Director
Tidewater Doctoral Program
Virginia Polytechnic Institute and State University

Appendix EE

Contents of Pre-Contact and Reminder Postcards for Teachers and Principals

Which Teaching Methods Influence Student Achievement on Virginia's End of Course SOL Test for Algebra I?

Dear «Prefix» «Last Name»:

Given Virginia's mandate that all high school students must pass Algebra I to graduate, there is a pressing need to assist Algebra I teachers as they strive for success with their students.

In about a week, I'll be asking you to complete a brief, completely confidential, research-based survey designed to determine which teaching methods have the strongest influence on student achievement on the Algebra I SOL Test. The information you can provide about your teaching methods is essential to the completion of this study. Thank you for your consideration.

Sincerely,

Matthew S. Haas	Dr. Travis W. Twiford
Northwood High School	Virginia Tech.

Which Teaching Methods Influence Student Achievement on Virginia's End of Course SOL Test for Algebra I?

Dear «Prefix» «LastName»:

Given Virginia's mandate that all high school students must pass Algebra I to graduate, there is a pressing need to assist Algebra I teachers as they strive for success with their students.

In about a week, I'll be asking your Algebra I staff to complete a brief, completely confidential, research-based survey designed to determine which teaching methods have the strongest influence on student achievement on the Algebra I SOL Test. The information your staff can provide about teaching methods is essential to the completion of this study. Thank you for any assistance you can provide.

Sincerely,

Matthew S. Haas	Dr. Travis W. Twiford
Northwood High School	Virginia Tech.

Appendix FF

Contents of Follow-Up Postcard to Teachers

Your Response is Critical!

Dear «Prefix» «Last Name»:

Last week, I mailed you a letter asking you to complete a brief, completely confidential survey designed to determine which teaching methods have the strongest influence on student achievement on the Algebra I SOL Test.

If you have already completed the survey, please accept my sincere thanks. If not, please do so today. Because only a small, representative sample of Algebra I teachers was asked to participate, it is extremely important that you respond so that the results of the study are accurate and complete.

If by some chance you did not receive my letter, or you have had technical difficulties with the web address for the survey, please call me now, collect (276-496-7751), or e-mail me (matthaas@scsb.org), and I will assist you in completing the survey in a matter of minutes.

Sincerely,

Matthew S. Haas	Dr. Travis W. Twiford
Northwood High School	Virginia Tech.

Appendix GG

Follow-Up Letter to Superintendents

[date]

«Name»
Superintendent
«School_Division»
«Street_Address»
«City», «State» «Zip_Code»

Dear «Name»:

I cannot thank you enough for allowing me to ask your Algebra I teachers to participate in my study concerning the influence of teaching methods on student achievement on the SOL test for Algebra I. Thanks to your endorsement and support and that of your secondary school principals, I was able to achieve a 98% response rate to my on-line questionnaire across the seven school divisions I asked to participate. All of the principals were accommodating and encouraging and expressed a real interest in instruction. Further, the fact that Algebra I teachers working for «School_Division» were so willing to participate conveys an impressive interest in research-based teaching methods.

During the second or third week in June, I will contact you by telephone to make an appointment to visit your school board office at your convenience. The purpose of my visit will be to obtain a mean scale SOL test score for this spring for each participating Algebra I teacher. I will accept the data I need in whatever format that is convenient for you. I have a Microsoft Access file that was developed by Smyth County's Technology Coordinator that converts text files sent by the testing company into fields for sorting. I would be happy to bring this software on my visit, and I have permission to share it.

This will be the final phase of my data collection process. I want to repeat that the information I collect will be aggregated into group data for analysis. No identifiable information will be maintained to link school divisions, schools, teachers, or students to responses on the questionnaire or SOL assessment scores. I will share the results of the study with you and make them available through the Virginia Tech database.

Thanks again for your support and encouragement in this research that I believe will be of benefit to our students, teachers, and school leaders as they strive to achieve in mathematics. I look forward to talking with you again and maybe meeting you in person in June.

Respectfully,

Matthew S. Haas
Principal
Northwood High School
Smyth County

Dr. Travis W. Twiford
Director
Tidewater Doctoral Program
Virginia Polytechnic Institute
and State University

Appendix HH

Mean Teaching Method Questionnaire Responses by Item (N=53)

Item	*Frequency	
	M	SD
I collaborate with the whole class in finding a solution to a problem.	3.72	1.46
I allow students to engage in cooperative problem solving.	2.83	1.61
I allow students to discuss solutions to algebra problems with peers.	3.55	1.51
I allow students to begin homework in class with peer assistance.	3.72	1.47
I pair students to work as peer tutors.	2.04	1.50
I reward group performance in the cooperative setting.	2.00	1.77
I assign students to work in homogeneous groups.	0.98	1.31
I assign students to work in heterogeneous groups.	2.23	1.76
I encourage students to use mathematics vocabulary terms in class discussions.	3.94	1.45
I have students describe their thought processes orally or in writing during problem solving.	2.92	1.64
I require students to share their thinking by conjecturing, arguing, and justifying ideas.	2.85	1.66
I have students write about their problem solving strategies.	1.28	1.47
I encourage students to ask questions when difficulties or misunderstandings arise.	4.62	1.10
I encourage students to explain the reasoning behind their ideas.	3.83	1.40
I use reading instructional strategies to help students with comprehension.	2.26	1.68
I provide students with study skills instruction.	2.94	1.52
I have students use calculators during tests or quizzes (given five typical test or quiz administrations).	4.60	1.10
I have students use calculators for problem solving instruction and activities.	4.40	1.29
I have students use calculators to help them develop problem-solving strategies.	4.06	1.51
I have students use calculators for computations.	4.30	1.38
I have students use graphing calculators to explore linear relationships.	4.04	1.44
I have students use computer spreadsheets, such as Microsoft Excel, for problem solving instruction.	0.26	0.76
I assign students to use calculators as a requirement for class participation.	2.98	2.18
I use computer software to provide practice opportunities.	0.96	1.41
I have students create their own rules in new problem solving situations.	1.62	1.61
I draw mathematical concepts from "real-life" situations.	3.15	1.47
I have students pursue open-ended and extended problem solving projects.	1.58	1.51
I create problems from the interests of individual students.	2.09	1.54
I recognize many alternative problem-solving practices.	3.34	1.61
I emphasize the problem solving process, rather than the solution.	3.51	1.53
I anchor problem solving skills instruction within situations meaningful to the students.	2.70	1.48
I encourage students to experiment with alternative methods for problem solving.	3.28	1.67
I have students use cubes or blocks to represent algebraic equations.	1.15	1.32
I illustrate mathematical concepts for students with pictures.	2.47	1.72
I teach students to represent algebraic equations with graphs.	3.34	1.58
I teach students to represent problems with tables.	3.06	1.43
I teach students to represent problems with charts to break information into smaller pieces.	2.72	1.67

I emphasize the use of multiple representations: words, tables, graphs, and symbols.	3.32	1.50
I provide math games for students to practice algebraic skills.	1.72	1.46
I use diagrams to help students learn to solve equations.	2.68	1.55
I grade homework to provide feedback.	3.23	1.79
I close instruction by reviewing concepts with students, emphasizing comparisons to previously covered concepts.	3.49	1.50
When providing feedback, I target incorrect responses and error patterns.	3.85	1.34
I identify a new skill or concept at the beginning of instruction and provide a rationale for learning it.	3.89	1.27
I provide a graduated sequence of instruction, moving students from concrete to abstract concepts in defined steps.	3.60	1.35
I require students to indicate a one-step-at-a-time process in working equations.	4.19	1.19
I use pre-worked examples to introduce or reinforce topics.	3.64	1.48
When assigning practice work, I ensure that the majority of the problems review previously covered material.	4.11	1.20

*Based on respondent's indication of usage, 0 – 5 times given five typical class sessions.

Vita

Matthew S. Haas

Academic Experiences

Ed.D. Educational Leadership and Policy Studies, Virginia Polytechnic Institute and State University, 2002

M.S. Ed. Administration (K-12), Supervision & Principalship, The College of William & Mary, 1997

B.S. Secondary Ed., Old Dominion University, 1990

Professional Experiences

2001- Present Principal, Northwood High School, Smyth County, VA

1998-2001 Assistant Principal, Kempsville High School, Virginia Beach, VA

1997-1998 Assistant Principal, Plaza Middle School, Virginia Beach, VA

1993-1997   English Teacher, Kellam High School, Virginia Beach, VA

1992-1993   English Teacher, The Literacy Center, Virginia Beach, VA

1990-1992   English Teacher, Plaza Junior High School, Virginia Beach, VA