Rowan University
Rowan Digital Works

Theses and Dissertations

5-31-2000

Evaluating the effectiveness of a new mathematics problem-solving program

Audrey L. Becker
Rowan University

Follow this and additional works at: https://rdw.rowan.edu/etd

Part of the Curriculum and Instruction Commons

Recommended Citation
Becker, Audrey L., "Evaluating the effectiveness of a new mathematics problem-solving program" (2000). *Theses and Dissertations*. 1631.
https://rdw.rowan.edu/etd/1631

This Thesis is brought to you for free and open access by Rowan Digital Works. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of Rowan Digital Works. For more information, please contact graduateresearch@rowan.edu.

المنارة للاستشارات

www.manaraa.com

EVALUATING THE EFFECTIVENESS OF A NEW
MATHEMATICS PROBLEM-SOLVING
PROGRAM

by
Audrey L. Becker

A Thesis

Submitted in partial fulfillment of the requirement of the
Master of Arts Degree in The Graduate School of
Rowan University
April 14, 2000

Approved by
Ronald L. Capasso, Ed.D.

Date Approved May 2000

Abstract

Audrey L. Becker

Evaluating the Effectiveness of a New
Mathematics Problem-Solving Program
2000
Ronald L. Capasso, Ed.D.
Supervision and Curriculum Development

The purpose of this study was to implement and evaluate the effectiveness of a mathematical problem-solving program for eighth grade students in the Margate School District. The researcher used a quantitative quasi-experimental design in correlation with a qualitative case study design. The subjects consisted of low to average ability students enrolled in a preexisting skills development course. The students were separated to form an experimental and a control group. A pretest/posttest instrument was used to determine the quantitative results, and daily field notes were recorded to evaluate the qualitative conclusions.

The level of student growth due to the completion of the mathematics program was shown to be statistically insignificant. The mean gain in scores of the experimental group was actually less than the mean gain demonstrated in the control group. Although there was no conclusive improvement in student performance attributed to the program, all the subjects participating in the activities did reveal an increase in motivation, interest, and general enthusiasm regarding problem solving.

Mini-Abstract

Audrey L. Becker

Evaluating the Effectiveness of a New Mathematics Problem-Solving Program
2000
Ronald L. Capasso, Ed.D.
Supervision and Curriculum Development

The purpose of this study was to implement and evaluate the effectiveness of a mathematical problem-solving program for eighth grade students in the Margate School District. The researcher used a quantitative quasi-experimental design in correlation with a qualitative case study design. The level of student growth due to the completion of the mathematics program was shown to be statistically insignificant; conversely, the subjects did demonstrate an increase in motivation, interest, and general enthusiasm regarding problem solving.

Acknowledgements

This study was completed as one requirement of the Educational Leadership Department of Rowan University for obtaining a Master's Degree in Supervision and Curriculum Development.

The intern would like to acknowledge the Margate School District for granting her a half year sabbatical leave so that she could dedicate her time and efforts on the completion of this project.

Table of Contents

List of Tables

Chapter 1

Introduction

Focus of the Study

A pyramid of accountability is growing within our public schools. The state government is mandating achievement tests to measure proficiency levels for students in fourth, eighth, and eleventh grades. The local school board and the community members are demanding high student scores throughout the district. Administrators are pressuring teachers to challenge and inspire children to reach and exceed the school's expectations. Students are feeling the weight of these expectations and striving to succeed on the exam. All these elements are influencing the educational atmosphere present in today's school community.

First, the role of the teacher is evolving to address this movement. Teachers are being called upon to act as change agents in the classrooms. As the school curriculum continues to expand and encompass more challenging subject matter and skills, time spent on instruction must be continuously evaluated as to its effectiveness and efficiency. Every educational program and teaching technique is reviewed for productiveness. Publishing companies have responded to the growing curriculum requirements by creating and distributing a multitude of programs and materials to supplement existing practices. School administrators and teachers are faced with the time consuming task of selecting and evaluating, from the available resources, the programs that will best fulfill the needs of the students.

In response to these changes, educators are evaluating their students and searching for better ways to meet their needs. One area of weakness in the performance of the Margate students on the Grade Eight Proficiency Assessment (GEPA) correlates with their poor critical thinking and problem-solving abilities. In an attempt to improve the students' skills and thereby increase their achievement on the eighth grade exam, the intern will implement and evaluate the effectiveness of a mathematical problem-solving program with lower ability students. Both a quantitative pretest posttest design and a qualitative case study design will be incorporated in the data collection and analysis procedures. An evaluation of the effectiveness of the program and a recommendation regarding its continuation will conclude the study.

Purpose of the Study

The purpose of this study is to implement and evaluate the effectiveness of a mathematical problem-solving program for eighth grade students using a quantitative quasi-experimental design and a qualitative case study design resulting in a feasibility report to inform teachers and administrators of the program's potential. At this stage in the research, the mathematical problem-solving program will be defined as a cognitive, individualized developmental program designed to improve thinking skills, with an emphasis on creativity, logic, quantitative analysis, and reading comprehension. If this program is successful, the students will increase their achievement on mathematics exams as well as improve their attitude regarding mathematics.

As past practice has shown, student scores on standardized tests are used to judge the effectiveness of the curriculum within a school. As the state mandated tests become more intensive, the instructional opportunities during the school day need to be examined for efficiency and appropriateness. The teachers and administrators in the Margate School District are constantly investigating better ways to instruct the students and refine their thinking capabilities. This study represents a trial implementation of a problem-solving program into our existing curriculum in an effort to improve the education our students receive. Any changes or additions to the curriculum should be based on thoughtful consideration and supported by research. Under ideal conditions, a new program should be introduced on a trial basis to one element of the population and undergo careful evaluation before widespread implementation. The aim of this study is to fulfill these conditions in an attempt to improve the students' education. After thorough research of the available programs that meet the requirements of this study, one was selected for implementation into the classroom this fall.

Definitions

An understanding of the following terms is necessary for the analysis of this study.

- *Accelerated Reader:* A school-wide program where students read from a selection of grade appropriate books. A computerized comprehension exam is required after the completion of a book and student achievement is monitored.
- *GEPA:* (Grade Eight Proficiency Assessment) A state mandated exam administered to all eighth grade students that attend a public New Jersey school. The results are utilized for early identification of students that may need additional support to pass the high school exam and subsequently graduate.

- *NCTM:* (National Council of Teachers of Mathematics) A nationwide association of educators that develop and assess educational curricula and movements.
- *SRA:* (Science Research Associates) A group that designs educational materials for classroom use.
- *Thinklab 2:* An individualized mathematical program developed by K. J. Weber and published by SRA. The program is designed to encourage critical thinking and problem solving through the completion of various mathematical tasks.

Limitations of the Study

This study involves eighth grade students in a skill development course at Eugene A. Tighe Middle School in the Margate School District. Most of the students concerned are low achievers who have historically scored poorly on standardized test and who display a low level of interest in academic growth. Many of the subjects are classified as disabled and participate in the learning resource room or basic skills programs. The challenge of this project is to improve their critical thinking abilities and consequently improve their chances on the GEPA.

A few limitations should be noted concerning this project. The time allowed for completion of this study limits its capability to measure success on the GEPA test; therefore the intern will apply a pretest and posttest instrument reflecting the components of the state exam. Two groups of students will complete the testing, although only one group will participate in the mathematics problem-solving program. The groups will be determined according to the schedule already developed for this school year, and the intern will select which class will complete the program and be the experimental group and which group will not complete the program and be the control group. Unfortunately, the groups will not be truly equal in ability level due to the predetermined nature of the scheduling process.

This study is likewise limited because of the small size and location of the sample population, as well as the restricted amount of time allocated for the investigation of the mathematical problem-solving program. Internal validity should be high so the conclusions from this study should be relevant for other eighth grade classes of similar composition in the Margate School District. External validity will be questionable, but transferability may be applicable in other similar circumstances. Each case should be evaluated for appropriateness according to the narrative accounts of this study.

Setting of the Study

Margate City, New Jersey is a small, summer resort town a few miles south of Atlantic City on Absecon Island. According to the 1998 census estimate obtained from Margate City Hall, there are 8591 residents of Margate and the average household income is $75,989. Ninety-seven percent of the residents are Caucasian, and 57% of the workers in the town are in the professional, executive and sales fields. The average age of a resident is 48 years, and 78% of the children live in two parent households. Four times as many children attend public schools than private or parochial schools. The average property value for a home in Margate is $180,494.

Two commissioners and a mayor run city government, and the Republican Party has historically controlled the political atmosphere of the town. Education and senior citizen issues have always held a high priority in town politics. The school board is comprised of citizens appointed by the mayor for unlimited terms. The school budget is not a part of the public election process.

Margate School District is a K-8 district run by one superintendent and two building principals. The child study team consists of one director and two specialists. There are 631 students in the district, with an average class size of 19 students. Sixty-two teachers are employed by the district and close to two-thirds of them hold master's degrees or higher. Productivity and achievement are highly valued in the schools and the community. The average spending per student is $10,381, which is well above the state average of $7,956. Most of our students attend Atlantic City High School, although approximately one-fourth of each class opts for a parochial or private high school.

The two existing schools are currently undergoing a multi-million dollar renovation project to expand and upgrade the educational facilities. In addition, a third school is presently being constructed in response to the growing number of students in the district. Construction at all three locations began last spring and is expected to continue throughout this upcoming school year. Teachers and students alike have been inconvenienced by the construction, yet the resulting facilities should help carry the district into the twenty-first century.

Significance of the Study

Margate City is a middle to upper class community that values the importance of a strong educational foundation. The parents closely monitor the achievements of the students and demand high instructional expectations. These factors influence the quality and quantity of skills that make up the children's learning experiences. Whenever possible, the teachers and administrators review new teaching materials and implement programs that appear to be worthwhile to the curriculum.

The GEPA test has further added to the already full curriculum. Changes must be made in the present classrooms to meet these new demands. In an attempt to improve the scores of the less able students, the intern will incorporate a mathematical problem-solving program into an existing skill improvement class. This class contains all the eighth grade students that do not qualify for Spanish, primarily due to academic requirements. Currently, these students work on language arts developmental skills one day each week and read Accelerated Reader books the other three days of the week that the course meets. The intern plans for the students to develop their problem-solving skills through the addition of this mathematics program one day each week.

The program that was selected for implementation is Thinklab 2. It is an individualized student-centered program that is intended to supplement a regular mathematics curriculum. Student progress cards are included to assist in management. There are 160 non-consumable task cards focusing on six cognitive abilities. Object manipulation requires the students to solve visual challenges with the use of manipulatives. Creative insight asks students to draw conclusions and develop insights from given information. Logical analysis directs the student to analyze data and draw conclusions. Quantitative thinking prompts the student to interpret and synthesize facts. Just for Fun activities draw upon a variety of problem-solving situations and are intended to encourage a positive attitude and improve student motivation. The kit also contains brainstorming activities to help students generate ideas and evaluate reasonableness of solutions. Most of the cards are intended for either individual or small group use, except for the brainstorming activities that require group participation. An instructor can modify the program to meet the specific needs of the students.

Students need a variety of learning opportunities in the classroom that address varied learning styles. The students being studied have the chance to receive supplementary academic assistance in addition to their regular math and reading classes. The skill development course in which these students are enrolled has historically concentrated only on reading comprehension. It is the intent of this study to successfully implement a mathematical component to the course, which should aid the children in developing their critical thinking skills. If the results are favorable, then the mathematics program will become a permanent part of the skill development course.

Organization of the Study

The following chapters will further investigate this study. Chapter 2 will explore the current literature related to implementing a new program and requirements of a quality mathematics curriculum. Chapter 3 will supply a detailed description of the design of the study, including data collection techniques and data analysis procedures. Chapter 4 will present the research findings and describe what events occurred during the study. Chapter 5 will evaluate the study and draw necessary conclusions regarding the success or failure of the project. Implications of the study will be explored, along with a petition for further study. References, appendices, and biographical information follow chapter 5.

Chapter 2

Review of the Literature

Why should a new program be implemented to enhance the problem-solving skills of lower-ability middle school students? As we enter the twenty-first century the new social goals for education focus on four essential components: developing mathematically literate workers, encouraging life-long learning, providing opportunities for all, and producing an informed electorate (Carlson, 1992). The focal point in education is to link theory with reality. Rote memorization and the repetition of simple facts are being replaced with higher level thinking skills like analysis, synthesis and evaluation. The National Council of Teachers of Mathematics (NCTM) has emphasized the importance of mathematical problem solving in the curriculum and the need for students to actively explore, develop, and justify their findings (NCTM, 1989).

The "back to basics" movement, which accentuated the mastery of computational skills through memorization and simple algorithms, has been replaced with a need for students to understand mathematical processes and be encouraged to think in a multitude of ways (Chisko, 1985). This was supported by a 1992 nationwide assessment conducted by the National Assessment of Educational Progress (NAEP) (Dossey, 1993). Students in 4^{th}, 8^{th}, and 12^{th} grades were presented with a mathematics test containing multiple-choice, single constructed-response, and extended-response tasks. Overwhelmingly, student scores were higher when they received daily instruction in classrooms that placed a heavy emphasis on developing reasoning ability and learning how to communicate mathematics effectively. The student answers on the extended-response questions showed that many did not understand the problems they were asked to solve and had difficulty in explaining their work.

Coley and Gant (1991) published another study that presented disturbing results related to the mathematical attitudes of low achieving and disadvantaged students (Coley and Gant, 1991). When asked how much they liked math, 28% of the low achieving students answered very much compared to 41% of the high achievers. Only ten percent of the low group of students felt they were good at mathematics. Is math class usually fun? Close to one-half of the low group of students disagreed when describing their classes. Student attitudes along with their achievement need to be analyzed and improved.

Wilderman and Sharky (1980) reported that the National Institute of Education found a major problem with our schools in that the students are learning computational skills but not the ability to apply them. Skills in isolation will not equip our students with the necessary competence to compete in the world.

So who is best suited to address this issue and find a solution? The burden is placed upon the schools and the teachers within them. Teachers need to take some initiative and become researchers and change agents. By combining investigation with efforts to solve practical problems, educators can develop new programs to meet the needs of their students. Sauli (1994) describes educational action research as a process where teachers discover and define a problem and think of alternatives. Activities are observed, documented, and reflected upon. Changes are evaluated and practices are modified, all in an attempt to improve the education received by the students. This is the basis of effective educational change.

Cognitive Processes and Instructional Strategies

Problem solving is an issue that has historically been investigated in educational literature. The NCTM addressed the causes of failure in problem solving and detailed the psychology of problem solving in both their yearbooks during the 1920's (NCTM 1926, 1928). Educators and researchers have searched for ways to describe and clarify the necessary skills required to be a good problem solver. Psychologists have developed many theories associated with the problem-solving process.

Research has identified three major perspectives on problem-solving theory: associationism, Gestalt psychology, and cognitive science. According to Mayer (1983), associationism can be suggested by the three laws of learning and memory theorized by Aristotle. Events that occur during the same time are stored together in one's memory because of association by contiguity. Similar events or objects are also stored together due to association by similarity. Events or objects that are opposites are likewise stored together owing to association by contrast. Thorndike (1911) further developed this theory in his behavioral studies. He believed that the first step in problem solving involved a succession of random guesses. As practice and experience increases, the subject becomes more likely to repeat the behaviors that worked in the past on previous problem-solving tasks. Identifying that successful responses tended to recur in subsequent situations, Thorndike summarized that earlier associations influence present behaviors.

The Gestalt theory of psychology has also had a strong influence on problem-solving approaches. Kohler (1925) defined problem solving as a "flash of insight" which he observed in his behavioral studies on animals. He believed a problem is considered and a solution is found simply due to a sudden insight on the part of the subject. Wertheimer (1925) elaborated this finding to include a "structural understanding" of the problem at hand. The method of problem solving is a search to relate one aspect of the problem to another in the subject's memory. The elements of the problem must be organized in such a manner as to ensure that they fit together and agree. The structure, organization, and insight components of the Gestalt theory of problem solving were described by Polya (1957). One must first understand the problem under examination, devise a plan for its solution, carry out that plan, and finally look back to check for accuracy and reasonableness. These steps are repeated and encouraged in many current textbooks.

Cognitive science may be the most contemporary and popular theory regarding problem solving. According to Mayer (1983), the cognitive theory entails finding a connection between a new problem and the ideas and concepts already present in one's memory. The preexisting links are referred to as schema. The new task must be assimilated into the individual's memory, and then translated into existing schemata. This process combines the elements found in Aristotle's associationism as well as Wertheimer's "structural understanding" explanation of Gestalt theory.

Davis (1984) took the cognitive science model and developed subprocesses to elaborate on the steps involved in the problem-solving method. Initially, an individual must examine a problem for clues to help guide retrieval of information. Reclamation of knowledge is accomplished and a representation of the problem is developed in the solver's mind. Matching schemata is identified from memory, and a mapping is achieved between the new problem and the existing knowledge. The problem solver must evaluate the acceptability of the mapping, and then both reject the solution and repeat the steps to find a more adequate schema or accept the mapping and conclude the task completed.

In a continuation of his studies on cognitive science, Mayer (1985) suggested four approaches for teaching mathematical problem solving. Translation training requires the problem solver to translate each part of the problem into an internal representation. This approach assumes the individual has the necessary vocabulary and preexisting schemata to work with. Schema training obligates the individual to place the elements of a new problem into a coherent whole. Of course, this method assumes that the student can comprehend and make connections with larger concepts, a skill that many young people find difficult. Strategy training demands that the solver be trained in the many techniques available for problem solving. Most mathematics textbook programs embrace this process. It assumes the student can successfully select the correct approach. The final procedure is labeled algorithm automaticity, whereby the solver relies upon an array of computational algorithms to find the solution. This method presupposes a mastery of the required algorithms and computational skills.

In an attempt to address the taxonomy of cognitive processes that are inherent in problem solving, the Project of the Learning Research and Development Center has developed a program entitled the Quantitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR) (Stecher and Mitchell, 1995). This project has been incorporated in many classrooms and it requires the students to follow a distinct set of steps for each problem-solving task. The solvers must first understand the problem, distinguish the mathematical relationships present, and organize the information they are given. Mathematical strategies are then applied, whereby conjectures are formulated and the reasonableness of the answer is evaluated. Results are generalized and finally, the students are required to justify their answers and communicate their findings with their peers. This process can be accomplished either individually or in cooperative groups.

Educators need to become experts in these theories. Cognitive psychology should drive the instructional process. Varied problem-solving techniques should be incorporated into the classroom.

Why Isn't It Working?

In light of all this scientific study into problem solving, one might ask why students find these tasks difficult. It is the actual application of these theories that have continually challenged both educators and students. Hawkins (1987) interviewed 132 active mathematics teachers and found that many still rely on the easiest or least stressful approach to mathematical instruction. Time constraints, increasing job demands, and a lack of desire to implement new techniques have attributed to the situation. A typical math class begins with a review of the previous topic, usually accomplished by correcting the prior homework assignment, and then the teacher explains the next topic in the textbook. Lecture and teacher demonstrations tend to dictate the lesson. Students may be asked to try a few practice exercises individually at their seats. Finally, a homework assignment is given so the students can continue to practice the new skill outside of class. It is believed that this type of learning environment cultivates mindless manipulation and thoughtless repetition of skills. Students need to develop an understanding of the connections between math skills and computation, and actual applications should be encouraged. Guided discovery and more creative approaches to problem solving need to direct the mathematical instruction.

Gilbert-Macmillan and Leitz (1986) found that problem solving is often taught by the same methods as basic computation. Teachers traditionally have relied upon short lectures with demonstrations, followed by individual seatwork on practice problems when teaching problem solving. Although this method may be successful for basic computational skills, it is far from ideal for problem-solving tasks. Students must be encouraged to acquire higher level thinking skills and not simply rely on previously learned algorithms. DeVault (1981) parallels problem solving in mathematics to writing in language arts. Both require a fundamental knowledge in their respective basic skills, yet creativity and individual thought are necessary to truly be a victorious problem solver or writer. If educators began to explain problem solving in this manner, more students might grasp its importance and better understand its development.

Hill (1980) concludes that educators need to create a safe and relaxed environment for favorable problem-solving experiences. Students should feel comfortable when making choices and not be afraid to try new approaches. Attitudes in the classroom must encourage creative thought and peer discussion. Simply finding the correct answer does not guarantee that the student understands the solution, yet if he or she can justify and defend the process applied then true comprehension will be evident.

Johnson (1986) studied the need for new instructional strategies in mathematics, specifically the use of cooperative learning. Cooperative learning was found to improve the learning environment in the classroom. It was discovered that peer tutoring and group approaches allowed participants to share various problem-solving techniques and communicate their findings. It encouraged exploration and creative thought, and the students appeared less anxious and fearful of making mistakes. Although not practical in every situation, this technique should become an element of every teacher's instructional repertoire.

If the current situation is not satisfactory then changes must be implemented. Teachers cannot continue to use antiquated instructional techniques in a quickly metamorphosing learning environment. Knowledge of current standards and an up-to-date mathematics curriculum is necessary for educators to meet these demands.

Mathematics Curriculum and Standards

There are many groups responsible for the changing face of the mathematics curriculum. Specific subject matter organizations, such as the National Council of Teachers of Mathematics, have continually studied and influenced mathematical education. Testing requirements placed upon schools, like the Grade Eight Proficiency Assessment in New Jersey, have directed content focus and student assessment. Statewide curriculum standards have been adopted that must be adhered to by all public schools. Both national and global influences and student comparisons have forced schools to remain competitive and progressive in educational issues.

The National Council of Teachers of Mathematics (NCTM) has developed the Curriculum and Evaluation Standards for School Mathematics, which has dictated the direction of most schools' mathematics curriculum (NCTM, 1989). The NCTM has found that five goals are necessary to promote student self-confidence and growth in mathematics. Students must become mathematical problem solvers in all areas of learning. This includes both simple and complex assignments completed in both individual and group settings. Progressive technology, such as scientific calculators and computers, must be available for student use and encouraged through its applications. Secondly, students must learn how to communicate mathematically. This skill takes time to develop and perfect, and it depends upon a mature understanding of mathematical terms and concepts. Writing tasks and student oral presentations can encourage the evolution of this ability. Next, students must learn how to reason mathematically. Logical thought and critical discovery of related mathematical connections will improve an individual's reasoning competence.

Learning to value mathematics is another goal that should drive the curriculum. All children possess a natural curiosity for learning, but it is the responsibility of the instructor to encourage and direct this motivation into relevant learning experiences. This requires the mathematics teacher to exhibit a positive, enthusiastic, and creative attitude towards everyday classroom instruction. This leads into the final goal, which is for the students to become confident in their own abilities. Children must experience victory with new and unfamiliar problem-solving tasks in order to develop the insight and self-assuredness to make them successful problem solvers.

The NCTM's standards have also influenced the direction of mathematical instruction (Carl, 1991). Mathematics should be demonstrated in more meaningful ways and be applied in a wider range of contexts across the curriculum. Evaluation of students should focus more on the application of mathematical skills, rather than rote computation exercises. It is strongly believed that every student must have a well-developed core of mathematical knowledge, not limited to those students in the accelerated classes. As teachers develop their lessons the learning experiences should be conceptually oriented with a focus on understanding and relationships. Cooperative learning and other innovative teaching techniques should be applied. Real-world problem solving and practical applications should drive the learning. All students need to be continually challenged with advanced mathematical concepts, and appropriate technological tools should be implemented in the instruction.

Statewide organizations have also contributed to the development of curriculum and instruction. The New Jersey Mathematics Coalition, in a partnership with the New Jersey Department of Education, created the New Jersey Mathematics Curriculum Framework (1996). This framework is designed to assist classroom teachers in the practical implementation of the New Jersey Core Content Standards. Not only does this document thoroughly describe and delineate each of the standards, it also supplies sample vignettes (instructional activities) to help teachers supply the students with worthwhile learning experiences. The very first mathematics standard requires that "all students will develop the ability to pose and solve mathematical problems in mathematics, other disciplines, and everyday experiences"(p. 15). This standard is the fundamental building block of the fifteen subsequent standards, emphasizing the importance of problem solving in every realm of mathematics.

The Mathematical Sciences Education Board supports the need for instructional reform (Dossey, 1993). They stress the importance of active learning in the classroom and the use of a wide variety of assessment techniques. The Office of Educational Assessment of the New York City Board of Education has also regulated improvements in their mathematics classrooms (Jarvis, 1988). Their teachers have been instructed to combine both experimental and academic learning experiences in their mathematics programs. Instructors are required to make productive use of class time and adapt their teaching techniques to the needs of the children. Lessons are focused on the applications of the skills and the connections between disciplines.

The National Assessment of Educational Progress (NAEP) project assesses students nationwide (Mullis, 1994). In 1992, thirty-one thousand 13 year-olds took part in an assessment that found slight improvement in math and science performance compared to the results of the previous decade. Increases in operations on whole numbers, decimals, and fractions were noted, yet a decrease was found in the ability to solve multi-step problems. The NAEP recommended that schools foster a more challenging and broadly based curriculum that advances the understanding of mathematics through more active student learning experiences.

LeBlanc (1982) reported on the ten basic skills needed by students in mathematics according to the National Council of Supervisors of Mathematics. The components necessary in a winning mathematics curriculum include the following: creative problem-solving techniques, applying mathematics in everyday situations, the ability to judge the reasonableness of answers, the use of estimation and approximation, the mastery of computational skills, a foundation of geometry and measurement, the use of mathematical prediction, computer literacy, and the competency to read, interpret and construct tables, graphs, and charts. Students must understand that the entire reason for learning mathematics is to solve real-world problems.

In 1991, twenty countries surveyed the mathematics performance of a population of 13 year-olds as part of the second International Assessment of Educational Progress

(IAEP) (Lapointe, 1992). The project focused on the common elements in the countries' mathematics curricula. The students who performed highest came from China (80% correct), Korea and Taiwan (73% correct). The United States' students achieved 55% accuracy. The study attempted to identify the elements that were consistent in the curricula of the highest performing countries. Overall, the students from China, Korea, and Taiwan spent more days in school each year and completed more hours of homework each week. Surprisingly, the class sizes in these aforementioned countries were twice the average for the United States and these same students had fewer minutes of instruction each day. Eight out of the nine highest performing countries follow a national curriculum.

Comparisons have also been made with students from Japan (Dossey, 1997). Student performance of Japanese students has been found to be higher than that of their American counterparts. This has been attributed to the assessment techniques applied in Japanese schools. On average, Japanese students are asked problems that are more elaborate and intensive. Greater reading comprehension is required. Students are obliged to support their conclusions through justification and discussion. Many circumstances ask the student to take a problem one step further than previously learned to encourage insight and the ability to generate conclusions.

It is clear that the burden upon educators is to create a curriculum that addresses the needs of today's students. Instructional strategies must support and contribute to the success of the curriculum. Our students must be given the opportunity to learn what is necessary to compete in a local, national and global community.

Promising Mathematical Problem-Solving Programs

The National Education Longitudinal Study and Hopkins Enhancement Survey of NELS: 88 Middle Grades Practices studied different types of remedial activities for public school students in the middle grades (MacIver, 1991). Their findings suggest that extra subject periods and supplemental summer classes are effective in raising student achievement. Extra subject periods, when performed in correlation to the regular mathematics classes, was shown to create $15/100^{th}$ of a standard deviation better effect in student achievement. Summer classes in mathematics were only marginally better at improving performance. Pullout programs, mentoring, and before- and after-school classes were not found to show any change in student achievement.

The Johns Hopkins Center for Research on Elementary and Middle Schools (CREMS) has studied promising programs and has attempted to make recommendations for duplication (Epstein and Salinas, 1990). They have found that a program will either attempt to prevent problems by raising standards and improving the performance of all students, or it will treat problems to correct or accelerate the learning of those students who have fallen behind. Many programs are individualized to meet the needs of the students.

CREMS has isolated what they believe to be the necessary components for a successful achievement program. Coordination is essential between the regular instructional classes and the supplemental or pullout classes. The goal of the program is to help the disadvantaged student catch up and keep up with his or her peers. Efficient and comprehensive management systems must be selected to help regulate and document student growth and achievement. Supplemental workbooks or computer-based systems can be used for record keeping.

It is recommended that groups be established with a feeling of temporary membership. Grouping should be flexible and adjust according to the skills being taught and the abilities of the students. Children should not feel "pigeonholed" or labeled as one particular group. Attention should be given to supply a variety of different learning styles to the classroom. Each skill should be taught using as many styles as possible in order to reach the largest percentage of students.

Families need to be involved in the educational process. Parents should feel a partnership with their children's teachers and schools. Encouragement and guidance at home is essential in order for students to learn to value schoolwork and learning. Students need to take personal responsibility for their education. Programs should emphasize participation and make the children aware of their own roles.

Schools need to supply the extra staff and resources required for a program to flourish. These resources may include instructional aids, computer technology, supplemental materials, and even extra time in the student schedule. Last but definitely not least, staff development must be incorporated as part of any promising program. Teachers need to be supplied with appropriate and extensive opportunities for learning, which include both initial and follow-up support from program experts.

In 1989, a review was made of over 200 mathematical programs in the middle grades (Epstein and Salinas, 1992). The study identified some important questions that must be discussed before a school attempts the adoption of a new program. Will a balance be made between the use of a core curriculum, which meets the generalized needs of all students, and an individualized curriculum, which helps each student progress from his or her unique starting point? The use of time must be addressed. Will the students participate in the program in addition to their regular classes, or will the program replace the mainstreamed instruction? Regardless of which is selected, the time spent in the program should be seen as challenging and motivating, never tiresome and tedious.

Will the focus of the program be on basic skills or advanced thinking skills? Basic skills are simply the building blocks for higher level thinking skills, therefore a school is really only selecting the starting point within the mathematical skills continuum. Will high standards be upheld at all costs, even if it results in student retention? Although this point is highly debatable, many educators believe that the motivational damage to the student caused by detention is a higher price to pay than allowing some flexibility with achievement standards. Finally, should a program be started on a small scale or should it be adopted schoolwide? Starting small allows for close supervision and evaluation of the program, as well as the ability to tailor the program to the individual requirements of the school. School-wide adoption represents equal opportunities and learning experiences for all students along with greater support within the teaching staff and the community. Financial resources may need to be assessed before committing to this final question.

Having summarized the ingredients of a promising program, examples of real-life programs can be analyzed. Epstein and Salinas (1990) reviewed a number of promising mathematics programs incorporating various approaches. One program that applies the use of a management system is Systematic Teaching and Measuring Mathematics

(STAMM). It is a sequential K-12 individualized program comprised of a vast array of mathematical skills. Students complete problems with the assistance of manipulatives, and various assessment techniques are implemented. The program allows teachers to keep a detailed record of student achievement and progress, but it is also quite time consuming to properly manage.

A second program involves peer support and is entitled Team Accelerated Instruction (TAI). This approach can be incorporated into an existing classroom or used during an additional mathematics period. Students are assigned to small heterogeneous teams and must work cooperatively to solve problems. Individual student strengths are developed and communication is encouraged. Children monitor their own progress so there is no fear of failure. This program has shown significant improvement in student attitudes and behavior regarding problem-solving tasks.

A third program, Teaching Everyone About Math (T.E.A.M.), employs a pullout approach. Small groups of students meet for 45 minutes sessions, three times a week, in addition to their regular math classes. The class focuses on skill improvement, support, and eventual mastery. Weekly progress reports document achievement. This program has consistently shown student success and student achievement is higher than traditional remedial grouping practices.

A fourth and final program that encourages improvement in mathematical problem solving and student attitudes is the Comprehensive School Mathematics Program (CSMP). This program focuses on mathematical applications, predictions, and problem solving. Although this program has not demonstrated significant increases in student math skills, it has been shown to improve student motivation, attitude, and enjoyment of completing mathematical tasks.

Components of successful programs have been identified and many existing programs are available for review and implementation. Schools need to evaluate their requirements and carefully select the best program.

Implementing and Evaluating a New Program

In the process of identifying and evaluating programs that assist disadvantaged students, CREMS suggested steps that should be followed by any educator considering the implementation of a new program (Epstein and Salinas, 1990). During the first year of implementation, educators must decide upon a distinct goal, gather information, review materials and their costs, and select a program. A plan must be developed for the design or adaptation of the program, and staff development should occur. Only then should the new program be started in the classroom. One mistake many schools make is that they evaluate the program too soon after implementation. Ideally, CREMS suggests that evaluation take place during the second or third year of the program.

The Program Quality Review (PQR) process is a schoolwide action plan developed in California to assist educators with the implementation and evaluation of learning programs (CSDE, 1996). For successful implementation, the school leaders should identify the population of students who will take part in the program and specify the goals for student success through the development of learning outcomes. An analysis of the existing instructional programs and support groups should be completed, along with an inquiry into any schoolwide issues that may influence the direction or prosperity of the program. Once a list of priorities is finalized, all staff members that will be shareholders in the program should be involved in any subsequent decisions.

The PQR also suggests guidelines for evaluation of current programs. The growth of student learning should be monitored continually over time. Opportunities should be available for student self-assessment and feedback. If feasible, the students should also be interviewed, both individually and in groups, to help judge whether the original goals of the program are being realized.

Clark and Clark (1985) studied new program planning and found that program success relies upon careful research during the conception process. In the initial planning phase, student needs should be assessed including a detailed review of student characteristics such as grades, achievement on standardized tests, and self-concept. Parent and community desires can be analyzed to help gain further insight into the needs of the students. Current literature should be investigated and visitations to successful schools should be arranged. An evaluation of staff strengths and weaknesses needs to be performed.

During the next stage of planning, the participants should be identified. This includes the providers, the recipients, and the evaluators. The goals and objectives of the program must be established, stating specific skills and competencies that will be met. Evaluation procedures and a time line should be developed at this time.

Only now will the program be implemented in the classroom. The participants should all be notified of their involvement and informed as to the objectives and requirements of the program. Teachers must be given an appropriate amount of inservice and support, both initially and during the program.

After the program has had time to develop and mature, an evaluation should take place. Data can be collected through observations, surveys and questionnaires, and student scores. The success of the program should be measured according to student achievement, as well as student and teacher attitudes and behavior.

When implementing a new program, one must consider the factors that can affect its success. Students are often mistaken as the only barrier to a winning program, but the principal and staff of a school have as much, if not more, influence on the program outcome. The key to success with any new program lies with the principal (Clark and Clark, 1985). As the school leader, he or she must demonstrate a strong commitment to the project. There must be a feeling of trust and confidence placed upon the teachers involved in the program. It is the role of the principal to effectively delegate the responsibilities of the program and strengthen staff involvement and commitment.

Without staff commitment, a program will fail. Decay of a program may be attributed to the lack of understanding of mathematical problem solving on the parts of the teachers. When Stecher and Mitchell (1995) interviewed twenty middle school teachers, 40% of them struggled to define problem solving. Resistance may be experienced if teachers are asked to change their instructional practices. Unfortunately, many teachers lack a common vocabulary or consistent structure for teaching problem-solving skills. Staff development must be included with any new program. Educators need inservice opportunities so they can improve their skills and gain new ideas. Consistency and commitment, along with a stable base of knowledge, will assist teachers with the progress of any new program.

Careful research and planning is necessary when implementing a new program. Support is essential from the school leader, the teachers, and the students. Staff development should always be included in the project design. Clear, concise goals and objectives will assist the school in performing formative and summative evaluations of the program.

Chapter 3

The Design of the Study

The Research Design

This study applied both a quantitative and a qualitative research design. The quantitative research incorporated a quasi-experimental pretest-posttest, nonequivalent control group design. Two groups of eighth grade students were selected based upon the preexisting schedule for the school year. Both groups completed a pretest instrument, given under consistent conditions, to measure ability and the extent of group similarity at the onset of the study. One group, which became the experimental group, then took part in the mathematical problem-solving program that was being studied. The program, or experimental treatment, was used one day each week in place of an existing skills improvement class. The intern, who is a certified mathematics teacher, was the primary monitor of the students throughout the study. After sixteen weeks, the mathematics program was concluded, at which time both groups completed a posttest instrument that mirrored the original pretest. The results on the posttest were compared to the initial pretest, and a determination was concluded as to the effectiveness of the mathematical problem-solving program.

The qualitative research involved an ethnographic case study design. The experimental group was studied during each session to evaluate student motivation and interest arising from the experimental treatment. A hypothesis was formulated at the completion of the study based upon the holistic descriptions observed by the intern during the field research. These results, in combination with the quantitative findings, determined to what extent this program would be implemented in this school system in the future.

The Development and Design of the Research Instruments

The purpose of this study was to determine the effectiveness of a mathematical problem-solving program on eighth graders' critical thinking abilities in order to improve their preparation for the mathematics section of the Grade Eight Proficiency Assessment. Therefore, the pretest and posttest instruments used for the quantitative research component were both selected from sample tests for the GEPA. The sample tests, which came from The New Jersey GEPA Mathematics Coach developed by Mervine Edwards (1999), were chosen by the intern due to the relevance and scope of the questions they contained. (See Appendix A). Part One of each sample test was utilized as the testing instrument. This limited the subjects to seventeen multiple-choice questions on each test. A time threshold of thirty minutes allowed the testing to be accomplished during one class period. Scoring and analysis of the results was completely objective due to the nature of the questions and the consistency of the conditions in which the tests were conducted.

The data collection instrument for the qualitative research was field notes produced by the intern immediately following each observation of the program and the participants. The notes included the type of problems that were completed and any observations regarding student interest, attitudes, and overall perception of the experience. (See Appendix B).

The Sample

The sample was comprised of two groups of eighth grade students who were enrolled in a skill development course at Eugene A. Tighe Middle School. The students opted to participate in this course instead of the Spanish program that was available. The intern selected these groups because they are similar in size and basic academic ability. Random selection of individual students into the two groups was not possible due to the preexisting schedule that determined the classes. The two groups met during different periods each morning; so one group was designated as the control group while the other became the experimental group. Both groups completed the pretest and posttest instruments under consistent conditions, while only the experimental group took part in the mathematical program.

The Data Collection Approach

Two separate designs were employed for data collection. One approach was a quantitative pretest posttest, nonequivalent control group design using parallel test administration. The two groups participating in the study were given the multiple-choice mathematics tests on the same day under consistent conditions. Studying for the test was impossible, because the students were given no prior notice regarding the test or what it entailed. Thirty minutes was allocated for the testing procedure. The students were given scientific calculators and scratch paper for figuring. The intern explained the purpose of the test along with the necessary directions, and then she closely monitored the test until time expired. Students were unable to talk or see other subjects' tests during the testing process. Materials were collected, and the students were thanked for their willing participation.

The second data collection approach involved the observation of the experimental group during the sixteen-week trial implementation of the mathematics problem-solving program. Field notes were completed by the intern following each meeting with the group under study. Observations noted the specific category or type of mathematical activities that were attempted by the students, as well as a summary of student interest, participation, and attitudes.

The Data Analysis Plan

The quantitative results were analyzed twice during the study. The pretest and posttest instruments were both scored and the results of the two classes were compared. Statistical measurements including mean, median, mode, range, standard deviation, and variance were computed. Extensive evaluation of both individual student scores and group averages were analyzed to measure the effect of the experimental treatment. An assessment of the program's effectiveness for improving student performance was completed.

The qualitative observations were analyzed on an ongoing basis. The case study developed as the intern evaluated the behavior of the students as they participated in the mathematics program. Dated field notes documented the findings. A hypothesis was developed at the completion of the study to evaluate whether student motivation was improved as a result of the subjects' involvement in the program.

Chapter 4

Presentation of the Research Findings

Quantitative Results

Two quasi-experimental groups of eighth grade students completed a pretest and a posttest instrument selected to determine any noticeable growth in mathematical problem-solving ability. The two tests were given eighteen weeks apart. During the time period between the tests, the experimental group of students participated in a mathematical problem-solving program one day each week. The program was being evaluated as to effectiveness in raising student scores, as well as to see whether student motivation and interest improved.

The individual student results are presented in Table 1.

Table 1

Individual Student Results

Group A = Experimental Group

Group B = Control Group

Group A	Pretest	Posttest	Change	Group B	Pretest	Posttest	Change
Student #1	3	7	+4	*Student #1*	3	4	+1
Student #2	3	7	+4	*Student #2*	3	7	+4
Student #3	6	8	+2	*Student #3*	4	8	+4
Student #4	6	8	+2	*Student #4*	4	7	+3
Student #5	6	9	+3	*Student #5*	4	6	+2
Student #6	8	6	−2	*Student #6*	4	7	+3
Student #7	9	7	−2	*Student #7*	6	6	+0

After calculating the individual students results from the pretest and posttest, a statistical analysis was completed. The mean, median, mode, range, variance, and standard deviation were all computed. This analysis will be useful in determining an evaluation of the program. The experimental and control groups were calculated separately to enable comparison between groups, and a measure of positive or negative change was included for each statistical factor. See Table 2.

Table 2

Pretest and Posttest Statistical Analysis

Group A = Experimental Group

Group B = Control Group

	Pretest		Posttest		Change	
	Group A	Group B	Group A	Group B	Group A	Group B
Mean	5.85	4	7.43	6.43	+1.58	+2.43
Median	6	4	7	7	+1	+3
Mode	6	4	7	7	+1	+3
Range	6	3	3	4	–3	+1
Variance	4.41	0.86	0.82	1.39	–3.59	+0.53
Standard Deviation	2.10	0.93	0.90	1.18	–1.20	+0.25

In addition to studying the results of the tests as an entire group, it may also be helpful to examine the individual characteristics of the subjects within each group. A determination as to the effectiveness of the problem-solving program may be made more specific if it is shown to be more helpful for lower ability students or students of a particular sex. A description of each subject by sex and educational classification is found in Table 3. An analysis of student results by educational classification is found in Table 4, and an analysis of student results by sex is found in Table 5.

Table 3

Student Characteristics for Comparison

Experimental Group	Sex	Classified / Special Education Student
Student #1	M	No
Student #2	F	No
Student #3	F	Yes
Student #4	M	Yes
Student #5	M	No
Student #6	M	No
Student #7	M	No

Control Group	Sex	Classified / Special Education Student
Student #1	M	Yes
Student #2	F	Yes
Student #3	F	No
Student #4	M	Yes
Student #5	F	Yes
Student #6	M	Yes
Student #7	F	No

Table 4

Student Results by Educational Classification

Experimental Group	Percent of Group	Pretest Group Mean	Posttest Group Mean	Change Group Mean
Regular Education Students	71%	5.8	7.2	+1.4
Classified and Special Education Students	29%	6.0	8.0	+2.0

Control Group	Percent of Group	Pretest Group Mean	Posttest Group Mean	Change Group Mean
Regular Education Students	29%	5.0	7.0	+2.0
Classified and Special Education Students	71%	3.6	6.2	+2.6

Table 5

Student Results by Sex

Experimental Group	Percent of Group	Pretest Group Mean	Posttest Group Mean	Change Group Mean
Male Students	71%	6.4	7.4	+1.0
Female Students	29%	4.5	7.5	+3.0

Control Group	Percent of Group	Pretest Group Mean	Posttest Group Mean	Change Group Mean
Male Students	43%	3.7	6.0	+2.3
Female Students	57%	4.3	6.8	+2.5

Qualitative Results

In addition to the measurable statistical results obtained from the pretest and posttest instruments, a case study analysis was also completed to assist in determining any student gains in motivation or interest regarding mathematical problem solving. Holistic notes were logged for every meeting of the experimental and control groups during the eighteen-week period of the study. These notes include observations of student attitude, interest levels and cooperation. The specific type of activity is noted for each session. These field notes can be found in Appendix B.

Interpretation of Results

The individual student results from Table 1 show that all of the students in the control group and five out of seven students in the experimental group improved their scores from the pretest to the posttest. Two students in the experimental group actually decreased their scores from the pretest to the posttest. The change in posttest scores ranged from a decrease of two points to an increase of four points.

The statistical analysis in Table 2 displays that the mean of the control group increased 0.85 more than the mean of the experimental group. The median of the control group went up two points more than the median of the experimental group. The standard deviation, which measures how greatly scores vary from the mean, of the experimental group decreased from the pretest to the posttest. This demonstrated that the students in the experimental group had more similar scores on the posttest than on the pretest. The standard deviation of the control group showed an inverse correlation to the experimental group results. The control group standard deviation rose from the pretest to the posttest, which demonstrated that their scores on the posttest were more varied than their scores on the pretest.

Table 3 identifies specific characteristics of the fourteen eighth grade students that participated in the study. Table 4 shows that there was a much higher percentage of classified and special education students in the control group than in the experimental group. The average change in mean scores from both groups consistently presented that the classified and special education students achieved a higher rise in scores from the pretest to the posttest, when compared to the rise in scores of the regular education students.

Table 5 shows that although the number of males and females in the control group were close to equivalent, the percentage of males in the experimental group was significantly higher. The average increase in pretest to posttest scores was higher for the females than the males in the experimental group, and only marginally higher for females in the control group.

An analysis of the field notes displayed continued motivation and interest from the students in the experimental group while completing the mathematical problem-solving activities. Some decrease in motivation was noted with certain types of problems that were more challenging than others. The favorite types of problems were Object Manipulation and Just for Fun. The least liked problems came from the Quantitative Thinking and Creative Insight types. Some subjects demonstrated inconsistent levels of interest in the weekly activities. Overall, the majority of the students looked forward to working on the problems, and were disappointed to have the program draw to a close. Only minor preparation was necessary by the instructor to set up each week's activities. The individual student progress cards and the reusable sets of activity cards made for easy classroom management and administration.

Chapter 5

Conclusions, Implications and Further Study

All forms of educational change should be thoroughly and thoughtfully tested before full-scale implementation. It is this practice that enabled the intern to field-test a new mathematical problem-solving program with a small and controlled group of eighth grade students before the district considered commitment to the project. The results could then be adjusted and tailored to meet the needs of the students.

After a careful analysis of the quantitative research findings, the study demonstrated only a slight increase in problem-solving ability between the experimental group students and the control group subjects. In fact, even though the experimental group scores were higher on the pretest than the control group scores, these same students gained less on average between the pre- and posttests than their control group peers. The average increase in the group mean of the experimental group was +1.58, compared to an increase of +2.43 in the control group. Classified and special education students in the control group performed better and increased on average more than similar students in the experimental group. In both the experimental and control groups, the classified and special education students gained +0.6 more than the regular education students. Functioning between the sexes was similar, yet females appeared to improve more than males through the use of the problem-solving program. The mean increase of the males in the experimental group was only +1.0, contrasted to an increase of +3.0 for the female subjects in the group. These quantitative findings support only a minor increase in problem-solving abilities for the female students in the study.

The qualitative findings were slightly more promising. Interest and effort was consistently high throughout the duration of the sixteen-week program. Students looked forward to class and expressed a strong desire to complete the activities. The mathematical tasks were found by the students to be both challenging and enjoyable. Since the focus of each problem bank was slightly different, students had the opportunity to showcase their strengths while developing skills in their areas of weakness. The students favored the Object Manipulation problems and Just For Fun activities the best. Some of the Creative Insight and Quantitative Thinking exercises were simply too difficult for this level student. Students worked in pairs or small groups; therefore an atmosphere of cooperative learning was developed. The program was designed to make record management and monitoring of progress simple for the instructor and the students.

As a result of this study, the program will be used to supplement the existing classroom materials that already support the district's curriculum. Teachers may incorporate these problems into their instruction in a manner which they see most feasible. These problems have been proven to encourage student interest and motivation, and they should be used to integrate problem solving in everyday mathematics classes.

The school organization has experienced a change in the manner which programs are evaluated. In the past, new ideas have been implemented without proper experiment and assessment. This study can be used as a template for other similar programs presented to the district for consideration. If properly developed, new programs can enable teacher empowerment and "buy-in" to increase along with the realization of better student achievement and results.

The intern has completed a research study from initial conception to evaluation. She has experienced the process necessary to accomplish a task of this magnitude, and she has become a better student and scholar because of it. The development of the research proposal required the intern to concisely identify the purpose of the study, the anticipated research design and methodology, and the significance of the outcomes. The literature review informed the researcher of related contemporary theories, as well as the existence of similar studies. Skills and knowledge acquired during graduate studies guided the implementation of the study's design and methodology. She has had the opportunity to practice and develop her leadership skills on her way to becoming a quality school administrator. The intern has developed a greater respect and admiration for educational leaders and the difficult decisions which they must make each day. This study has been a learning experience for both herself as well as her students.

The need and desire for successful problem-solving experiences to present to our students will forever be found in education. It is for this reason that further study is necessary to investigate and discover more effective approaches and programs. This study has shown that student interest and motivation can be increased through the use of appropriate problem-solving activities. A program needs to be discovered that offers the skill development opportunities like those found in traditional mathematics textbooks, as well as providing challenging and useful applications of those concepts. The program focused upon in this study can only be applied as a supplement to an existing curriculum because it was too limited in its scope and instructional uses. A closer examination of problem-solving programs currently being used in school systems needs to be completed. Successfully implemented and proven programs, once identified, can be modeled and reproduced in other similar school settings.

References

California State Department of Education. (1996). Guide for Program Quality Review. Sacramento, CA: Author.

Carl, I. M. (1991, March). Better Mathematics for K-8. Streamlined Seminar, 9, 1-7.

Carlson, C. G. (1992). The Metamorphosis of Mathematics Education. FOCUS 27. Princeton, NJ: Educational Testing Service.

Chisko, A. M. (1985). Developmental Math: Problem Solving and Survival. Mathematics Teacher, 78, 592-596.

Clark, s. N. & Clark, D. C. (1985, January). Staff Development at the Middle Level School. Paper presented at the annual conference of the National Association of Secondary School Principals, New Orleans, LA.

Coley, R. J. & Gant, J. V. (1991). Middle Grade Students' Attitudes about Mathematics and Their Math Classes. New York, NY: National Urban League, Inc.

Davis, R. B. (1984). Learning Mathematics: The cognitive science approach to mathematics education. Norwood, NJ: Ablex Publishing Corporation.

DeVault, M. V. (1981). Doing Mathematics Is Problem Solving. Arithmetic Teacher, 28, 40-43.

Dossey, J. A. (1993). Can Students Do Mathematical Problem Solving? Results from Constructed-Response Questions in NAEP's 1992 Mathematics Assessment. (Report No. ETS-R-23-FR01). Princeton, NJ: Educational Testing Service.

Dossey, J. A. (1997). Essential Skills in Mathematics: A Comparative Analysis of American and Japanese Assessments of Eighth-Graders. (Report No. NCES-97-885). Washingtion, DC: National Center for Education Statistics.

Epstein, J. L. & Salinas, K. C. (1990). Promising Practices in Major Academic Subjects in the Middle Grades. Report No. 4. Baltimore, MD: Center for Research on Effective Schooling for Disadvantaged Students. (ERIC Document Reproduction Service No. ED324121)

Epstein, J. L. & Salinas, K. C. (1992). Promising Programs in the Middle Grades. Reston, VA: National Association of Secondary School Principals.

Gilbert-Macmillan, K. & Leitz, S. J. (1986). Cooperative Small Groups: A Method for Teaching Problem Solving. Arithmetic Teacher, 33, 9-11.

Hawkins, V. J. (1987). The Problem-Solving Nemesis. The Clearing House, 60, 423-424.

Hill, S. A. (1980). National Council of Teachers of Mathematics. Arithmetic Teacher, 28, 49-54.

Jarvis, C. (1988, June). Shaping the Future: Teaching Our Youngest Students. Research Brief #2. An Office of Educational Assessment Bulletin Linking Research with Educational Practice, 2, 1-9.

Johnson, L. C. (1986). The Effects of the Groups of Four Cooperative Learning Model on Student Problem-Solving Achievement in Mathematics (Doctoral dissertation, University of Houston, 1985). Dissertation Abstracts International, 47, 403A.

Kohler, W. (1925). The Mentality of Apes. New York, NY: Harcourt Brace Jovanovich.

Lapointe, A. E. (1992). Learning Mathematics. (Report No. ETS-22-CAEP-01). Princeton, NJ: Educational Testing Service.

LeBlanc, J. F. (1982). Teaching Textbook Story Problems. Arithmetic Teacher, 29, 52-54.

MacIver, D. J. (1991). Helping Students Who Fall Behind: Remedial Activities in the Middle Grades. Report No. 22. Baltimore, MD: Center for Research on Effective Schooling for Disadvantaged Students. (ERIC Document Reproduction Service No. ED339545)

Mayer, R. E. (1983). Thinking, Problem Solving, Cognition. New York, NY: W. H. Freeman and Company.

Mayer, R. E. (1985). Implications of Cognitive Psychology for Instruction in Mathematical Problem Solving. In E. A. Silver (Ed.), Teaching and Learning Mathematical Problem Solving: Multiple Research Perspectives (pp. 123-138). Hillsdale, NJ: Lawrence Erlbaum Associates.

Mullis, I. V. (1994). NAEP Trends in Academic Progress. (Report No. NAEP-23-TR01). Princeton, NJ: National Assessment of Educational Progress.

National Council of Teachers of Mathematics. (1926). Second Yearbook. New York, NY: Bureau of Publications, Teachers College, Columbia University.

National Council of Teachers of Mathematics. (1928). Third Yearbook. New York, NY: Bureau of Publications, Teachers College, Columbia University.

National Council of Teachers of Mathematics. (1989). Curriculum and Evaluation Standards for School Mathematics. Reston, VA: National Council of Teachers of Mathematics.

New Jersey Mathematics Coalition. (1996). New Jersey Mathematics Curriculum Framework. Trenton, NJ: New Jersey State Department of Education.

Polya, G. (1957). How to Solve It. Garden City, NY: Doubleday Anchor.

Stecher, B. M., & Mitchell, K. J. (1995, April). Vermont Teachers' Understanding of Mathematical Problem Solving and "Good" Math Problems. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Thorndike, E. L. (1911). Animal Intelligence. New York, NY: Macmillan.

Wertheimer, M. (1959). Productive Thinking. New York, NY: Harper & Row.

Wilderman, A. M. & Sharkey, V. (1980). Basic Math: More Than Just Computing. Instructor, 89, 34.

Appendix A

Pretest and Posttest Instruments

Sample GEPA Exam

Name: ______________________________ Date: ____________

Directions: Today you will be taking the multiple-choice section of a sample GEPA exam. Please read each question carefully, and then select the best answer from the four choices. You may use scratch paper and a calculator, but do not make any marks in the workbook. If you finish early you may go back over your answers in part 1, but do not go ahead in the workbook. Your results, along with the results of others in your grade, will be used to help assess mathematical growth due to a new program that will be implemented this year.

You will have 30 minutes to complete the seventeen multiple-choice problems. I will announce to you how much time is remaining as you complete the exam. Please circle the letter on this answer sheet which corresponds to each answer from the exam. Are there any questions?

Please open the workbook to page 291. You will only be completing Part 1 of the sample exam. Turn this sheet over and you may begin.
YOU SHOULD BE TAKING THE SAMPLE GEPA EXAM 2

Circle the best answer.

1.	A	B	C	D
2.	A	B	C	D
3.	A	B	C	D
4.	A	B	C	D
5.	A	B	C	D
6.	A	B	C	D
7.	A	B	C	D
8.	A	B	C	D
9.	A	B	C	D
10.	A	B	C	D
11.	A	B	C	D
12.	A	B	C	D
13.	A	B	C	D
14.	A	B	C	D
15.	A	B	C	D
16.	A	B	C	D
17.	A	B	C	D

SAMPLE GEPA EXAM 1

PART 1: Multiple Choice (MC)

Select the correct answer for each problem. Answers are worth 1 point each.

1. This year there were 216,000 sales of a particular car model. This figure represented 84% of last year's sales. Approximately how many of these cars were sold last year?

   A. 25,000 B. 100,000 C. 185,000 D. 260,000

2. Which of these numbers has the greatest number of *different* prime factors?

   A. 42 B. 45 C. 64 D. 99

3. Which of the numbers described below is the largest?

   A. The sum of 0.8 and 0.2
   B. The product of 0.8 and 0.2
   C. 0.8 divided by 0.2
   D. 0.8 raised to the second power

4. A plumber needs to drill a hole just slightly larger than $\frac{3}{4}$ inch in diameter. Which of these is the smallest, but still greater than $\frac{3}{4}$ inch?

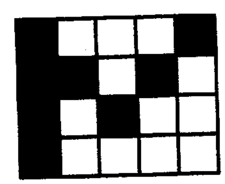
   A. $\frac{9}{16}$ inch B. $\frac{21}{32}$ inch C. $\frac{15}{16}$ inch D. $\frac{27}{32}$ inch

5. It takes Tina 25 minutes to make a cake before She wants the cake to come out of the oven $\frac{3}{4}$ of an hour before dessert. The recipe calls for baking 20 minutes at 450°, then 30 minutes at 350°. If dessert is served at 7:30, when should she begin making the cake?

   A. 5:30 B. 5:40 C. 5:50 D. 5:55

6. Which number does **NOT** represent the figure's unshaded portion?

   A. $\frac{3}{5}$ B. $\frac{6}{10}$ C. 60 D. 60%



7. If 5 out of 7 people in Garden City use CAVITY TOOTHPASTE, find the approximate number that use this product if there are 4326 people in the city.

   A. 2163 B. 3090 C. 3900 D. 6056

8. In a factory, 27,320 parts were produced. They were tested for quality. 5% were discovered to be defective. How many parts were good?

   A. 1366 B. 25,954 C. 27,315 D. 28,686

9. Suppose two parallelograms are similar. Which of the following is not necessarily true?

   A. Corresponding angles are right angles.
   B. Corresponding angles are congruent.
   C. Corresponding sides are proportional.
   D. Ratio of areas is same as square of ratio of corresponding sides.

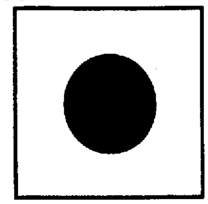
10. Which unit of measure would be most appropriate to measure the dimensions of a sheet of paper?

A. kilometer B. meter C. centimeter D. gram

11. Twenty pills weigh about 1 gram. What is the best estimate of the number of pills in a box weighing one kilogram?

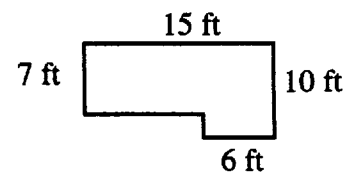
A. 50 B. 200 C. 1,000 D. 20,000

12. At the right is a diagram of a square dart board 20 in. on a side. The shaded portion is a circle with diameter 8 in. Players earn points for darts landing in the shaded circle. What is the best estimate of the portion of the dart board that is shaded?



A. 13% B. 32% C. 50% D. 80%

13. Find the minimum number of square yards of carpet needed to cover the rec room floor at right.



A. 12 B. 13 C. 14 D. 123

14. Jon draws a card from a standard deck of 52 cards and tosses a die. What is the probability of getting a red queen and a 4 on the die?

A. $\frac{1}{312}$ B. $\frac{1}{216}$ C. $\frac{1}{26}$ D. $\frac{1}{6}$

15. Nathan's test grades are 84, 90, 100, 70, 66, and 70. Which of the following describes how the mean, median, and mode are affected by an additional test grade of 80?

A. The mean, median, and mode all remain the same.

B. Only the mean remains the same.

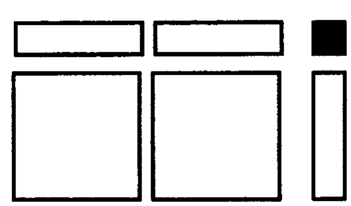
C. The mean and median remain the same, but the mode changes.

D. The mean and mode remain the same, but the median changes.

16. Suppose you are given 3 cents today, 6 cents tomorrow, 12 cents the third day, 24 cents the fourth day, and so on. How much would you get on the 8th day?

A. $3 \cdot 2^7$ B. $3 \cdot 2^8$ C. $3 \cdot 2^9$ D. 24

17. The tiles on your reference sheet were used to construct the diagram at the right. Which algebraic expression does this diagram represent?



A. $2x^2 + 2x$ B. $2x^2 + x$

C. $2x^2 + 3x + 1$ D. $2x^2 + 2x + 1$

SAMPLE GEPA EXAM 2

PART 1: Multiple Choice (MC)

Select the correct answer for each problem. Answers are worth 1 point each.

1. Rosa got an answer of about 8.5 when she entered 72 on her calculator and pressed the $\sqrt{\ }$ key. She always checks to see if her answer is reasonable. Which of the following is the most likely explanation for why her calculator answer is or is not reasonable?
   A. It is not reasonable, because the answer should be a whole number.
   B. It is reasonable, because 72 is an even number.
   C. It is not reasonable, because the answer should be only slightly more than 9.
   D. It is reasonable, because 8 squared is 64 while 9 squared is 81.

2. Every number is divisible by itself and 1. The number 24 is the smallest number divisible by six other positive integers, namely 2, 3, 4, 6, 8, and 12. What is the smallest positive integer that is divisible by itself, 1, and six other positive integers?
   A. 40 B. 45 C. 48 D. 60

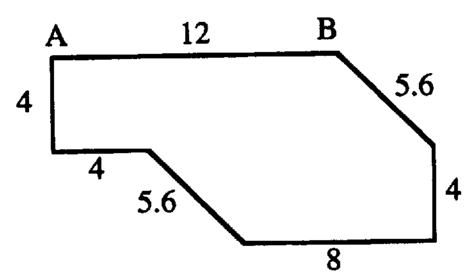
3. If these fractions were graphed on a number line, which of them would be closest to 1?
   A. $\frac{5}{9}$ B. $\frac{2}{3}$ C. $\frac{4}{5}$ D. $\frac{7}{5}$

4. Which of the numbers below is equivalent to 0.6?
   A. 6% B. $\sqrt{3.6}$ C. 0.63 - 3 D. $\frac{3}{5}$

5. The length of a square recreation field is a whole number of meters.
   The area of the field could possibly be which of the following?
   A. 160,000 square meters B. 25,000 square meters
   C. 16,000 square meters D. 90 square meters

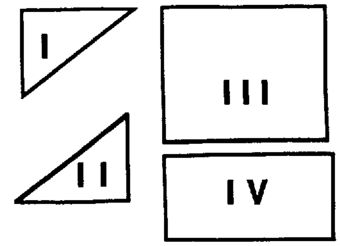
6. A television was listed at a price of $600. It was then advertised at a discount of $150. Find the percent discount applied to the listed price to produce the advertised price.
   A. 4 B. 15 C. 25 D. 40

7. Tony is enlarging the figure at the right so that the side corresponding to $\overline{AB}$ will be 30 units long. What will be the perimeter of the enlargement?



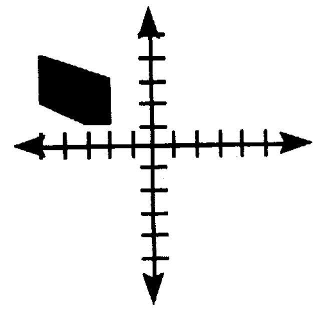
   A. 54 B. 94
   C. 108 D. 172.8

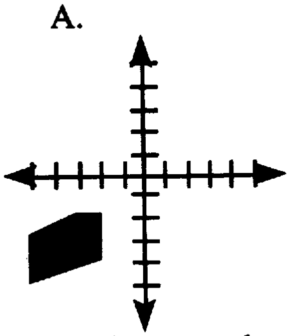
8. The figures at right are either right triangles or rectangles. Which shapes can be placed together, without overlap, to form a trapezoid? Each figure may be used only once.

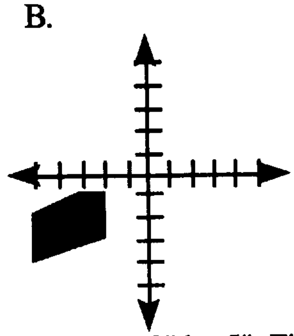


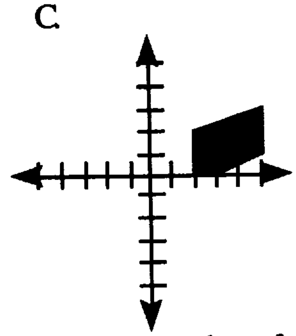
A. I, II, and III B. I, II, and IV
C. II and III D. II and IV

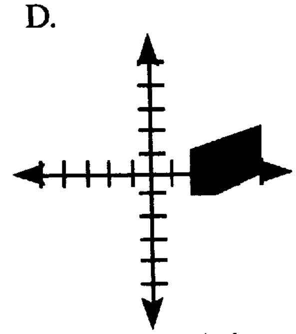
9. If the shaded figure the right is reflected in the x-axis and then translated 1 unit down, which figure below represents the resulting image?



A.


B.


C.


D.


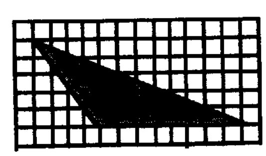
10. A rectangular tile measures 3" by 5". Find the fewest number of tiles that are needed to completely cover a square region that measures 5 ft on each side.

A. 32 B. 64 C. 240 D. 300

11. Two storage sheds are each shaped like a cube. Each edge of the smaller shed is $\frac{1}{3}$ the length of the corresponding edge of the larger shed. The larger shed will hold how many times as much volume as the smaller shed?

A. 3 times as much B. 9 times as much
C. 12 times as much D. 27 times as much

12. A triangle is drawn on the unit grid at the right. Find the area of the triangle.



A. 15 B. 20 C. 40 D. 80

13. The pentagon in figure (a) is 3 in. on a side and is rolled to the right along the line. Which of the following distances could it have rolled so that the shaded circle is in the position shown in figure (b)?

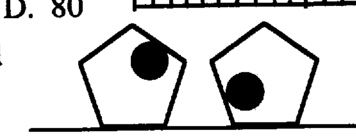


figure (a) figure (b)

A. 15 in. B. 21 in. C. 24 in. D. 27 in.

14. Using the table at the right, what is the wind-chill factor in degrees Fahrenheit when the air temperature is 20° F and the windspeed is 40 miles per hour?

A. -21 B. -18

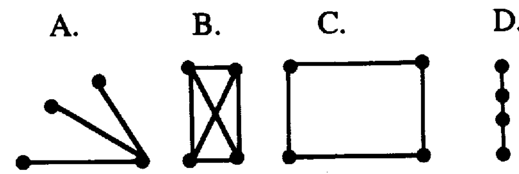
C. -6 D. 10

Wind-Chill Factors

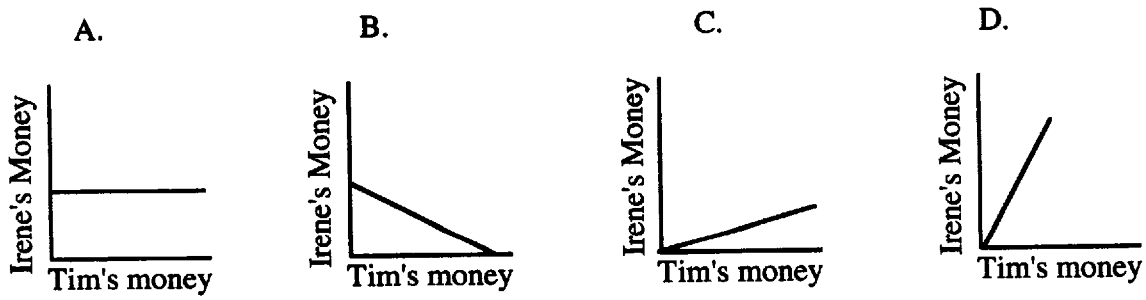
Wind Speed in Miles Per Hour

Air Temperature	10 mph	20 mph	30 mph	40 mph
40°F	28	18	13	10
30°F	16	4	-2	-6
20°F	4	-10	-18	-21

15. Which diagram best represents the following: Engineers are planning to connect highways so that people can drive between any two towns without going through another town.



16. Irene and Tim earn money by cleaning Mr. Tomlinson's house every week. They share the $60 they are paid weekly. Each person's amount depends upon who does the most work. Which graph below best represents the different ways the money can be shared?



17. Which of the following problems can be solved by using the equation $x - 6 = 24$?

A. Mary had a collection of 24 tapes. She gave 6 away. How many does she now have?

B. Martin had $24 in his savings account. He withdrew $6. How much did he then have?

C. A team lost 6 games. There were no ties. There were 24 wins. How many were played?

D. Tina jogged 24 laps on a circular track in 6 minutes. How many laps did she jog in 1 minute?

Appendix B

Field Notes

Math Program Syllabus

September 22	**Pretest**	
September 29	**Object Manipulation**	(blue cards 1-10)
October 6	**Creative Insight**	(green cards 11-20)
October 13	**Just For Fun**	(yellow cards 21-25)
October 20	**Logical Analysis**	(purple cards 26-35)
October 27	**Quantitative Thinking**	(orange cards 36-45)
November 3	**Brainstorming**	(red cards 146-152)
November 17	**Object Manipulation**	(blue cards 51-60)
December 1	**Creative Insight**	(green cards 61-70)
December 15	**Just For Fun**	(yellow cards 71-75)
December 22	**Logical Analysis**	(purple cards 76-85)
January 5	**Quantitative Thinking**	(orange cards 86-95)
January 5	**Just For Fun**	(yellow cards 96-100)
January 12	**Object Manipulation**	(blue cards 101-110)
January 12	**Creative Insight**	(green cards 111-120)
January 19	**Posttest**	

NOTES ON MATH PROGRAM

Wednesday September 1

I met with Valerie Hart regarding the selection of the experimental and control groups for the math program. We decided to use the Wednesday classes because she teaches both first and third periods of accelerated reader that day. It will be simpler to organize this project if I only have to work directly with one teacher throughout the project. First period will be the control group that will take the pretest and posttest. Third period will be the experimental group that will take the pretest and posttest, as well as complete the math program each week during the study.

Wednesday September 15

Both the control and experimental groups were given the pretest today. Each group was given the instructions for the test and the necessary supplies. Thirty minutes was allotted for the pretest. All students were cooperative and worked quietly. The test was given in the media center. This location was found to be a problem because disruptions occurred from teachers entering the room while the students were working. Workers entered with bookshelves during each testing period. Although I could have scheduled the test in a different room for the second group, I decided to keep the conditions as consistent as possible between the two groups. Most students used the entire thirty minutes to complete the pretest.

Wednesday September 29

The experimental group began the math program today. I allowed the students to select a partner. Object manipulation problems were completed. The students enjoyed using the manipulatives to find solutions. Motivation and interest was high and the students worked until the end of the period. I used the student progress cards to monitor completed problems.

Wednesday October 6

The experimental group worked on creative insight activities today. They continued to work in pairs. Initially some students were disappointed that they would not be using the manipulatives, but they quickly became involved in today's problems. Interest and motivation continues to be high. Students did not get disinterested and worked until the end of the period. I feel that some of the lower ability students have difficulty with the activities.

Wednesday October 13

The experimental group worked on Just For Fun activities today. The problems are mathematical games and puzzles that are less challenging in content but are used to encourage motivation and enjoyment. They required pairs of students to work together. The students liked the activities, but I found them to be too simple for most of the participants. In addition, the problems did not take the entire period to complete so we had extra time that I felt was wasted today. Next time we use Just For Fun activities, I will need to have additional problems prepared or plan to use them during an abbreviated class period.

Wednesday October 20

The students worked on Logical Analysis problems today. The students could not correctly discover some of the solutions. I had to offer some hints to keep their interest on some of the questions. They did work the entire period of the activities. The students did appear to be actively involved in the exercises.

Wednesday October 27

The students completed Quantitative Thinking exercises today. Some of the problems were rather difficult for the majority of the students. Interest and effort was lower today. I feel this was due to the difficulty of the problems as well as a need to redefine my expectations to the students.

Wednesday November 3

Today the students completed both Brainstorming and Just For Fun problems. Neither type is appropriate for an entire period; therefore it worked well using both during one session. I am assigning each student an attitude/participation score that will be averaged into their marking period grade for accelerated reader, and I hope that this will encourage their continued cooperation. All but one of the students worked very well today, and I will keep a close eye on that particular student to keep him on task.

Wednesday November 10

No class today. The students have an abbreviated school day.

Wednesday November 17

The students completed Object Manipulation problems again today. They all really enjoy these exercises and have fun using the manipulatives. The entire period was used productively. Some advance setup for the class was helpful. Interest was high again today. One student asked if they would continue this program throughout the year because it is the best class he has.

Wednesday November 24

No class today. The students have an abbreviated school day.

Wednesday December 1

The students did Creative Insight problems today. Their behavior was okay, but some of the students seem to be getting bored. I also think that some of these problems are more difficult, which causes the students to become frustrated and give up.

Wednesday December 8

I could not monitor the math program today because I was part of a curriculum meeting all morning. The students were disappointed.

Wednesday December 15

We had a shortened period today due to an assembly, so the students only completed the Just For Fun activities. They all worked well and appeared to enjoy themselves. I think that they were glad to work on the math problems since they missed the opportunity last week and also because they just got excused from the morning assembly. The problems are fun and can be used to focus the students on their schoolwork.

Wednesday January 5

This was our first meeting since the winter break. The students completed two types of problems today: Quantitative Thinking and Just For Fun activities. I eliminated a few of the Quantitative Thinking problems because I judged them to be too difficult or simply confusing. All the students were enthusiastic and willing to work the entire period. I found that the combination of the more difficult quantitative problems with the simpler fun problems created a worthwhile problem-solving session.

Wednesday January 12

This was our last class period to be used working on the mathematics problems. The students did Object Manipulation exercises today. They really enjoy working with the manipulatives. Many of the students find unique solutions to the same problem. They worked the entire period, and all students were actively involved in the activity.

Wednesday January 19

Today was the posttest for both the control and the experimental groups. Fortunately, no students were absent so I was able to test all the students from the pretest groups. The students worked extremely well and were very cooperative. There was no talking or interruptions during either posttest administration. Both groups took the test in one corner of the media center, and although there was another class working in the other half of the room there really were no disruptions. A few students in the experimental group completed the test with some time to spare; otherwise all the students used the entire thirty-minute time allowance.

Biographical Data

Name	Audrey Becker
High School	Downingtown Senior High School Downingtown, PA
Undergraduate	Bachelor of Science Mathematics Ursinus College Collegeville, PA
Graduate	Master of Arts Supervision and Curriculum Rowan University Glassboro, NJ
Present Occupation	Middle School Teacher Eugene A. Tighe School Margate, NJ