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Evaluating problem solving in the mathematics curriculum: A case study

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EVALUATING PROBLEM SOLVING IN THE MATHEMATICS CURRICULUM: A CASE STUDY

by

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APPROVAL PAGE

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The purpose of this evaluation case study was to assess the current status of problem solving in a typical mathematics curriculum, and to examine the process involved in the implementation of the recommendations found in NCTM's Standard 1: Mathematics as Problems Solving.

During phase 1, preparing to evaluate, individual interviews and self-reporting by teachers indicated that the pre-existing mathematics curriculum was not providing problem solving activities for students on a regular basis. As a result, teachers began an implementation period for the recommendations of Standard 1, during which time students were to engage in problem solving activities at least once weekly, with increasing frequency as the study progressed until eventually, problem solving was used as part of the normal instructional process. In doing so, teachers attempted to provide activities for students which allowed them to view mathematics in a more useful and personal manner. The implementation period for Standard 1 required nine weeks.

The last phase of the study, a post-implementation period, consisted of a second set of individual interviews, an Attitude Assessment Survey administered to students and follow-up focus group discussions. Results were very

positive. Students reported that they enjoyed the opportunity to explore and think for themselves, and indicated a belief that they were learning more mathematics. Teachers indicated plans to continue problem solving activities on a regular basis and to present new material in this manner when possible. Overall, the implementation of the recommendations of Standard 1 was successful. In addition, teachers reported numerous factors which they believe will enhance/inhibit implementation of the NCTM Standards.

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And finally, I would like to dedicate this document to the memory of my parents. It is a result of their love, guidance, and support that I have been able to develop my own sense of direction and a love of learning which continues to influence my life today.

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CHAPTER I

INTRODUCTION

> MATHEMATICAL POWER. This term denotes an individual's abilities to explore, conjecture, and reason logically, as well as the ability to use a variety of mathematical methods effectively to solve nonroutine problems. This notion is based on recognition of mathematics as more than a collection of concepts and skills to be mastered; it includes methods of investigating and reasoning, means of communication, and notions of context. In addition, for each individual, mathematical power involves the development of personal self-confidence.
> The National Council of Teachers of Mathematics, 1989, page iii.

Never before has our nation's public school system been the object of such intense scrutiny. Never before has there been such public demand for accountability by schools and teachers. Particularly during the decade of the 1980s the business community, the general public, and many educators have realized the development of any country depends on the intellectual development of its people (Costa, 1985). An explosion of scientific and technological knowledge has increased public awareness of the importance of mathematics education in preparing young people to live and work in the society of the 1990s and beyond (Davis and Hersh, 1981; Paulos, 1988). The National Council of Teachers of Mathematics (1989) in their

Professional Standards for Teaching Mathematics has stated that:

> Pupil performance on standardized mathematics tests, comparative results on international studies of mathematics education, increasing attrition from the mathematics teaching ranks, and the reassignment of teachers not properly qualified to fill mathematics teaching positions have raised concern about the quality of the mathematics instruction being given our nation's youth (page 1).

These and other factors have caused many educators to examine the existing gap between the reality of mathematics education in schools and classrooms across the continent and the recommended standards of professional practice for high-quality mathematics education for American students.

In a document entitled Curriculum and Evaluation Standards for School Mathematics, NCTM (1989) has said:

> Historically, the purposes of secondary school mathematics have been to provide students with opportunities to acquire the mathematical knowledge, skill, and modes of thought needed for daily life and effective citizenship, to prepare students for occupations that do not require formal study after graduation, and to prepare students for postsecondary education, particularly college (page 123).

However, none of these goals are being achieved successfully. A new awareness of mathematics education is rapidly causing many professionals to conclude that all students need to learn more, and often different, mathematics and that the current mathematics curricula must be significantly revised. Research by the National

Research Council and others has shown that most students cannot learn mathematics effectively by only listening and imitating; yet most teachers continue to teach mathematics just this way. Most teachers teach as they were taught, not as they were taught to teach. Mathematics continues to be primarily a passive activity: teachers prescribe; students transcribe. Students simply do not retain for long what they learn by imitation from lectures, worksheets, or routine homework. Most students gradually construct a view of mathematics as a rigid system of externally dictated rules governed by standards of accuracy, speed, and memory. Practicing the skills of mathematics often becomes the goal of learning, rather than one of many strategies used by teachers to help students achieve mathematics understanding. Presentation and repetition help students do well on standardized tests and lower-order skills, but they are generally ineffective as teaching strategies for long-term learning, for higher-order thinking, and for versatile problem-solving (Everybody Counts, 1989). Because mathematics is one of the pillars of education, reform in education must include significant change in the way mathematics is taught and learned. As mathematics and society change continuously, so too must mathematics education.

The special role of mathematics in education today is appropriately summarized by the National Academy Press in

Everybody Counts, 1989, as a consequence of its universal applicability. Mathematics is a science of pattern and order. The process of "doing" mathematics is far more than just calculation or deduction; it involves observation of patterns, testing of conjectures, and estimation of results. More specifically, The National Academy Press states that:

> Mathematics offers distinctive modes of thought which are both versatile and powerful, including modeling, abstraction, optimization, logical analysis, inference from data, and use of symbols. Experience with mathematical modes of thought builds mathematical power -- a capacity of mind of increasing value in this technological age that enables one to read critically, to identify fallacies, to detect bias, to access risk, and to suggest alternatives. Mathematics empowers us to understand better the information-laden world in which we live (page 31-32).

According to the National Research Council, prior to the 1980s it had been widely accepted that the learning of mathematics required some special, innate ability, which most students, particularly females and minorities, did not possess (Everybody Counts, 1989). Parents often accepted and even expected their child's poor performance in mathematics. In addition, these parents tended to measure the mathematical needs of today's students by their own experiences and accomplishments. The fact that many adults who never learned mathematics had been able to survive and perhaps even succeed without it helped propagate an attitude of acceptance for poor mathematics performance. However, these attitudes are slowly changing.

The technological advances of the twentieth century have helped transform the field of mathematics from one of abstraction into a profound and powerful part of human culture. The ideas of mathematics influence the way we live and the way we work on many different levels. Mathematics can have a practical affect on our lives as we compare prices, calculate risks, make more informed consumer choices, and try to understand the effect of various rates of inflation -- all of which can help to improve individual living standards. Mathematics can impact our professional lives, in applications ranging from theoretical physics to business management, since it serves as a prerequisite for hundreds of careers. Mathematics can affect our civic choices as society debates over such policies as tax rates, nuclear deterrence, public health matters, projected population growth, and the many interactions among the various factors of economic growth. Mathematics can even affect our leisure activities as is readily evident by the popularity of lotteries, sports wagers, and various other games of logic, chance and strategy. Mathematics has become a corner-stone of our present society, applicable in almost every aspect of everyday life. Mathematical literacy for all students must become a national goal if we are to prepare today's students for the twenty-first century. Now more than ever, mathematics literacy, mathematical power, must become the educational goal for all students rather than the private domain of a select few.

OVERVIEW OF THE AREA OF CONCERN

> The skills and expertise of a country's workforce are the foundation of its economic success. Lately, in our country, this foundation appears too fragile to withstand the challenge of the 21st century.
> National Assessment of Educational Progress, ETS, 1990.

According to recent findings which have been made public by the National Assessment of Educational Progress in The Mathematics Report Card (1990), mathematics instruction consists almost exclusively of teacher explanation, reliance on textbook and chalkboard demonstrations, regular homework assignments, and routine testing. Their findings indicated that the only deviation from earlier patterns of instruction (documented in a 1986 study by the NAEP) were student reports of significant increases in homework assignments and testing. This recent shift may be the only noticeable response to demands for increased academic rigor in the field of mathematics. Even though the increased emphasis on skill development and testing is perhaps warranted, the lack of innovative instructional approaches and curriculum changes is cause for concern. The Mathematics Report Card also indicates that students say they rarely engage in any activities which would allow them to apply their mathematical skills in real world situations.

Excessive emphasis on the mechanics of mathematics not only inhibits learning, but also propagates the widespread misconception that the use of mathematical methods leads to a single correct answer (National Research Council). Mathematics instruction must not reinforce the common impression that mathematics is the product of authority, magic, or wizardry. The National Academy Press (1989) points out:

> Mathematics is a natural mode of human thought, better suited to certain types of problems than to others, yet always subject to confirmation and checking with other types of analyses. There is no place in a proper curriculum for mindless mimicry mathematics (page 44).

The ability of each individual to use mathematics wherever it arises in their later lives depends heavily upon the attitudes conveyed toward mathematics in our classrooms. If we expect students to make use of their mathematics ability as wage-earners, parents, or citizens, then steps must be taken to assure that the mathematics curricula in our schools leave a legacy of confidence, clarity, and empowerment, rather than one of misunderstanding, apprehension, and fear.

The irony of the current lack of mathematical understanding in our present society is that young children enjoy mathematics and are naturally good at discovering patterns and making conjectures (National Research Council). The natural curiosity of a young child is a powerful teacher of mathematics. Unfortunately, as children grow and become socialized by school, their perceptions of mathematics gradually shift from enthusiasm to apprehension, from confidence to fear. More than half of all students leave mathematics under duress, convinced that only the extremely intelligent can make sense of it. Later, as parents, they pass this same attitude on to their children. Even more tragic is that some teachers convey this attitude to their students.

Contained in the preface of Everybody Counts, The National Academy Press (1989) comments:

> Three of every four Americans stop studying mathematics before completing career or job prerequisites. Most students leave school without sufficient preparation in mathematics to cope with either on-the-job demands for problem-solving or college expectations for mathematical literacy. Industry, universities, and the armed forces are thus burdened by extensive and costly demands for remedial education. Our country cannot afford continuing generations of students limited by lack of mathematical power to second-class status in the society in which they live. It cannot afford to weaken its preeminent position in science and technology (page viii).

Even though there is no set educational policy for mathematics in the United States, it remains true, particularly in the field of mathematics, that teachers tend to teach what is in the textbook and students learn only what will be on the test (National Research Council, 1989). The National Academy Press (1989) states:

> In practice, although not in law, we have a national curriculum in mathematics education. It is an "underachieving" curriculum that follows a spiral of almost constant radius, reviewing each year so much of the past that little new learning takes place (page 45).

In the past, these standards for mathematics seemed sufficient, if somewhat limited. However, the most recent analyses of school mathematics have concluded that students are not acquiring the skills and understandings they will need for the technology of the future (National Assessment of Educational Progress, ETS). Data from the National Assessment of Educational Progress and from college entrance testing programs reveal a discouraging pattern of mathematics achievement, particularly in important problem-solving and higher-order thinking skills.

There is no shortage of advice on new directions for the K-12 mathematics curriculum. The challenge of defining new curriculum priorities and new standards for teacher performance and student achievement has attracted attention from a broad range of groups interested in school mathematics (National Research Council, National Assessment of Educational Progress, National Council of Teachers of Mathematics, The National Science Board, and others).

Their recommendations respond to two generally perceived problems in mathematics education in grades 7 - 12. In a recent article in Educational Leadership, Zalman Usiskin (1987) described those problems in the following manner:

> The first is that high school graduates are not learning enough mathematics. And second, the mathematics curriculum has not kept up with changes in mathematics and the ways mathematics is used in business, industry, and the marketplace (page 31).

A mathematics curriculum can no longer afford the luxury of a program which is prescribed for college-preparatory students. Students must prepare now for a world where the benefits and responsibilities of full citizenship will require a substantial measure of skill and understanding in the mathematics of science and technology. No longer can we settle for a mathematics curriculum that provides its students with only mindless training in mechanical skills.

In 1978 the National Council of Supervisors of Mathematics proposed a list of ten basic skills in mathematics. These skills -- problem solving; applying mathematics in everyday situations; alertness to the reasonableness of results; estimation and approximation; appropriate computational skills; basic geometric properties; measurement; use of tables, charts, and graphs; using mathematics to predict; and computer literacy -- reflect new goals for mathematics curricula. These goals are not simply a matter of style or approach; they constitute a fundamental change in the content of both the elementary and secondary mathematics curricula. The National Council of Teachers of Mathematics in its Curriculum and Evaluation Standards for School Mathematics (a copy of the NCTM Curriculum and Teaching Standards appears in Appendix A of this document) has endeavored to create a vision of mathematics education which can help produce those changes. NCTM stated within the mentioned document that:

> The fourteen standards developed by NCTM for grades 9 - 12 establish a framework for a core curriculum that reflects the needs of all students, explicitly recognizing that they will spend their adult lives in a society increasingly dominated by technology and quantitative methods (page 123).

At the very center of this core curriculum is the concept of mathematical problem solving, which should be the focus of school mathematics.

PURPOSE OF THE STUDY

The purpose of this case study, therefore, was to evaluate the current status of problem solving in a mathematics curriculum in a typical high school, and to examine the process involved in the implementation of the recommendations found in NCTM's Standard 1: Mathematics as

Problem Solving. More specifically, the following questions were used to guide this program evaluation:

1. To what extent are the recommendations of Standard 1 not being satisfied by the current mathematics curriculum in grades 9 -12 in a specified high school?

2. What are the changes perceived by teachers to be necessary before the curriculum recommendations found in Standard 1 can be implemented?

3. What are the aspects of current mathematics education which may inhibit or enhance the implementation of NCTM's vision for a more relevant and useful mathematics curriculum within a typical school?

The NCTM Curriculum Standard which was selected by this investigator to guide this program evaluation is:

Standard 1: Mathematics as Problem Solving

In grades 9 - 12, the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can --

--use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content;

--apply integrated mathematical problem-solving strategies to solve problems from within and outside mathematics;

--recognize and formulate problems from situations within and outside mathematics;

--apply the process of mathematical modeling to real-world problem situations.

During the evaluation of Standard 1: Mathematics as Problem Solving, this investigator utilized those indicators of quality for Standard 1 which were developed by the Center for Educational Research and Evaluation at UNC-G for the evaluation of mathematics programs. Those indicators are:

Standard 1: The curriculum provides students with the opportunity to engage in problem solving.

1.1 The curriculum provides students with the opportunity to solve problems on a regular basis.

1.2 The curriculum provides students with the opportunity to define problems from everyday life as well as mathematical situations.

1.3 The curriculum provides students with the opportunity to develop and carry out plans to solve a wide variety of nonroutine problems.

1.4 The curriculum provides students with the opportunity to look back at the original problems to verify and interpret their results.

1.5 The curriculum provides students with the opportunity to generalize solutions and strategies to other situations.

A comparison of the recommendations found in Standard 1 and the five indicators of quality which were used to evaluate problem solving in the mathematics curriculum show they parallel one another in all but one area. The first recommendation of Standard 1 states that the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can use with increasing confidence, problem solving approaches to investigate and understand mathematical content. The quality indicators do not address this recommendation. Therefore, this aspect of Standard 1 was assessed in the following manner: comments found in individual teacher journals, examples of student work from teacher portfolios, and the examination of the results of a problem solving attitude assessment survey for students. (See Appendix B for a copy of the survey.)

SCOPE OF THE STUDY

> Only from his actions, his fixed utterances, his effects upon others, can man learn about himself; thus he learns to know himself only by the round-about way of understanding. What we once were, how we developed and became what we are, we learn from the way in which we acted, the plans which we one adopted, the way in which we made ourselves felt in our vocation, from old dead letters, from judgements on which were spoken long ago....we understand ourselves and others only when we transfer our own lived experience into every kind of expression of our own and other people's lives.
>
> Wilhelm Dilthey (1910)

This investigation involved the use of techniques from qualitative or ethnographic research and has utilized them in varying degrees as befits an emergent study. Much of the scientific research which has been undertaken has failed to impact upon the realities of classroom teachers (Hitchcock & Hughes, 1989; Calkins, 1985; LaCompte & Goetz, 1984; McCutcheon, 1981; Paul, 1990; Patton, 1980; Rogers, 1984). Robert Stake (1986) has said:

> The quality of educational practice, particularly its teaching and administration, rests largely on intuitive and experiential processes. Some wish that educational practice would be more rational and technical -- but immediate improvement in practice continues to rely largely on experiential understandings (page 46).

If we are to improve mathematics curricula and instruction in schools today, we must endeavor to understand the particular situation, the particular program. Our past efforts to generalize the teaching and learning of mathematics is part of the existing problem. The intent of this investigation was to provide a comprehensive understanding of a particular situation through which the report readers can draw their own generalizations through the combination of previous experience with the new. This investigation was therefore a case study of the evaluation of problem solving in the existing mathematics curriculum and the attempt to implement NCTM's Standard 1: Mathematics as Problem Solving. The investigation attempted to focus upon the congruence of the current mathematics curriculum and the recommendations found in Standard 1, and examined the process involved in the implementation of the standard into the existing program. The period of investigation was set to cover a time span of less than one semester, and to cease when this investigator was able to conclude that Standard 1 had been implemented or that no additional progress could be made toward implementation of Standard 1. The intent of this investigation was not to determine whether implementation of NCTM's Standards will or can bring about the previously stated and much needed reforms in mathematics education. Unfortunately, verification of those types of results were beyond the scope of this study, and perhaps will not be known during this decade. However, if Standard 1 is never implemented within the present mathematics curriculum, the question of a resultant mathematics educational reform may never be addressed at all. Of special interest during this program evaluation was the analysis of problems which mathematics teachers believe will result due to the attempted implementation of Standard 1. An additional set of concerns revolved around whether the Standards could be implemented into the existing mathematics curriculum, and whether implementation of the standards is even possible given the present classroom conditions and expectations. The study includes comments from teachers concerning their perceptions of whether curriculum changes will occur as a result of the investigation. The investigation attempted to assess the congruence between the current curriculum goals for problem solving and those recommended by Standard 1 and will make recommendations based on those findings. The mathematics program at South Caldwell High School, located in Hudson, North Carolina, was selected for this case study by the investigator.

SIGNIFICANCE OF THE STUDY

Clearly, we know more today about teaching, learning and the development of relevant, useful mathematics curricula than we did twenty years ago, and yet many of today's students receive much the same mathematics instruction from exactly the same mathematics curricula as that which was being given in mathematics classrooms decades ago (National Research Council). The 1980s have been viewed as the decade which reported that schools were not succeeding in their jobs of educating students. It was the decade which demanded quality education in our public schools across the nation. As a result, we are now experiencing an era of educational reform. The public has issued a clear challenge to educators for the next decade: to improve student learning and achievement, particularly student learning and achievement of higher-order thinking skills, such as problem solving in mathematics. There is widespread agreement that major changes are required in mathematics curricula if mathematics programs are to prepare students for the world in which they will live and work. Considering the current atmosphere in which schools must function and the proliferation of so-called cures proposed by persons inside and outside the realm of education, it would seem advisable to look directly at the day to day curriculum practices within typical mathematics classrooms. If we can accurately determine the type of curriculum standards teachers are currently using inside their classrooms, how closely that curriculum matches the professional views of what a mathematics curricula should be, and the perceived problems which will be encountered if change is allowed to happen, perhaps then wise decisions can be made which will engage students more meaningfully in the study of mathematics. Although this study involves only one standard, this one standard provides the basic framework for all the other standards. The concept of problem solving is the basic foundation for the type of mathematics curriculum proposed by NCTM and others. The depth of this inquiry can be expected to yield insights which may serve mathematics educators in providing the kind of curriculum standards that support the goals and visions of the NCTM Curriculum and Evaluation Standards for School Mathematics.

CHAPTER II

LITERATURE REVIEW

> The most important purpose of evaluation is not to prove, but to improve....We cannot be sure that our goals are worthy unless we can match them to the needs of the people they are intended to serve.
>
> Daniel Stufflebeam, 1985.

There are many reasons for conducting mathematics program evaluation. In general, evaluations are needed for the following reasons: to determine effectiveness of existing programs, to determine whether changes are needed in existing programs, to set priorities and formulate program goals, to develop a program which is suited to a particular school, and to determine whether a program meets quality standards. The purpose of this case study dealing with the evaluation of problem solving is of course the latter. Today we stand on the threshold of the twenty-first century, realizing mathematics education is critical to the current generation of students. We also realize most students do not possess the mathematics proficiency needed to adapt to the technological society in which they must live and work. Improving mathematics performance among our nation's youth will require upgrades in the curriculum, corresponding modifications in classroom instruction, and the use of appropriate evaluation results.

The National Council of Teachers of Mathematics, in an effort to reform school mathematics, has developed a set of professional standards for the teaching of mathematics. For NCTM, the development of standards as statememts of criteria for excellence in order to produce change was the focus. Schools must reflect the consequences of the current reform movement if our students are to be adequately prepared to live in the twenty-first century. NCTM advocates that the standards should be viewed as facilitators of reform. The purpose of this inquiry was to assess current curriculum practices with reference to NCTM Standard 1: Mathematics as Problem Solving. The focus of this case study consisted of an evaluation of those specific parts of the mathematics curriculum which provide opportunities for students to engage in problem solving. During this review of literature relevant to educational evaluation, this investigator has attempted to define the structure of the evaluation techniques used in the program evaluation.

A portion of the scholarly literature relevant to this study has been reviewed to gain insight into seven major areas: (a) mathematics as problem solving, (b) defining the concept of evaluation, (c) planning and evaluation models, (d) assessing the problems of evaluation, (e) planning and conducting evaluation studies, (f) analyzing and interpreting evaluation information, and (g) the role of evaluation in mathematics classrooms.

Mathematics as Problem Solving

Problems and their solutions have always occupied a central place in any school mathematics curriculum, but problem solving has not. "Only recently have mathematics educators accepted the idea that the development of problem solving ability deserves special attention" (Charles & Silver, page 1). It has only been during the last decades that the focus of the teaching of problem solving has shifted from a philosophy that students should be presented with problems and the rules for solving those particular problems to one which advocates a more general approach to problem solving. Until this century, it was assumed that the study of mathematics would in some way improve an individual's intelligence or ability to think. Grube has quoted Plato as saying that:

> Those who are by nature good at calculation are, as one might say, naturally sharp in every other study, and...those who are slow at it, if they are educated and exercised in this study, nevertheless improve and become sharper than they were (page 18).

As such, solving problems in the curriculum was simply a ploy to get students to study mathematics. "Problems were a given element of the mathematics curriculum that contributed, like all the other elements, to the development of reasoning power" (Charles & Silver, page 10). Mental discipline theories during the nineteenth century provided the framework for the idea that mathematics provided a primary vehicle for the development of the reasoning faculty for an individual's mind.

Near the beginning of the twentieth century, the work of Edward L. Thorndike led to significant changes in how the study of mathematics was viewed and as a result, he is generally credited with refuting the basic notions of mental discipline theory. However, even Thorndike never completely rejected the idea of mental discipline. Consequently the early 1900s witnessed two very different ways of looking at people, education, and the school curriculum. The mental disciplinarians argued that mathematics was a crucial element of the curriculum and that all students could benefit from the same knowledge and methods of instruction. Thorndike, however, provided the foundation for the idea which advocated the need to expose different children to different subject matter. Critics of mathematics began to feel that most people needed to know no more than sixth grade arithmetic. The 1930s saw the place of mathematics in the school curriculum come under attack which led to a crisis in mathematics education. On the one hand, critics were calling for methods of making mathematics more relevant to real life, while mathematics educators were afraid of giving up the former role of mathematics for the sake of application. This crisis has yet to be resolved. According to Charles and Silver (1988):

> The events surrounding the decline of mental discipline theory may have set the stage for mathematics educators to begin to give more specific emphasis to the development of problem solving ability, but the clash of basic ideas about human intelligence, education, and the school curriculum still permeates discussions of problem solving (page 13).

The term problem solving is used in many different contexts and has many different meanings. The three most common interpretations of problem solving are: (1) problem solving as context, (2) problem solving as skill, and (3) problem solving as art.

Problem Solving as Context

Generally it is agreed that problems and the solving of problems are a means to achieve other valuable ends. Historically, problem solving has held an important place in the mathematics curriculum because it helped provide justification for the teaching of mathematics. If some problems in the curriculum related in some way to real-world experiences, then they served to convince students of the value of mathematics. Problem solving has also been used in an effort to gain student attention and to motivate them to learn new processes or algorithms. The use of puzzles and other problems without any real-world connections are used to allow students to have some fun with the mathematics they have already learned. Problem solving and discovery techniques can provide a vehicle for learning new concepts and skills. And finally, problem solving as practice has had the largest influence on the mathematics curriculum as it provides the necessary practice to reinforce skills and concepts.

Problem Solving as Skill

Problem solving is considered in some instances as one of a number of skills to be taught in the school curriculum, rather than as simply a means to achieve other ends. Placing problem solving in a hierarchy of skills to be acquired by students often leads to a distinction between solving routine and nonroutine problems. As such Charles and Silver (1988) state that nonroutine problem solving can be:

> Characterized as a higher level skill to be acquired after skill at solving routine problems (which, in turn, is to be acquired after students learn basic mathematical concepts and skills). This view postpones attention to nonroutine problem solving, and, as a result, only certain students, because they have accomplished the prerequisites, are ever exposed to such problems (page 15).

The lack of exposure to nonroutine problem solving for all students is a common characteristic of the mathematics school curriculum in classrooms today.

Problem Solving as Art

The work of George Polya and his view of problem solving as art provides a more comprehensive view of problem solving in the school mathematics curriculum. Polya's experience in learning and teaching mathematics led him to revive the idea of heuristics (the art of discovery.) Polya believed that students would understand mathematics much better if they could get some taste of mathematical discovery for themselves.

To Polya, problem solving was an art "like swimming, or skiing, or playing the piano," which must be learned through imitation and practice. Polya believed that simply solving problems did very little to improve performance, nor did he agree that the study of mathematics contributed by its very nature to one's general level of intelligence. Polya defined problem solving as the process of finding the unknown means to a distinctly conceived end. Charles and Silver (1988) state that Polya:

> Recognized that techniques of problem solving need to be illustrated by the teacher, discussed with the students, and practiced in an insightful, nonmechanical way....He observed that although routine problems can be used to teach students to follow a specific procedure or use a definition correctly, only through the judicious use of nonroutine problems can students develop their problem solving ability (page 16).

To Polya, the teacher is the key to providing the right kind of problem for a given class and the proper amount of help and guidance. Therefore Charles and Silver have said that Polya felt:

> No one can program the teaching of problem solving; it remains an activity that requires experience and judgement. In a sense, problem solving as art gets reduced to problem solving as skill when attempts are made to implement Polya's ideas by focusing on his steps and putting them into textbooks (page 17).

Certainly Polya did not provide a recipe for making all students into accomplished problem solvers. However, he did provide us with the basic issues of what problem solving is and why we should teach it.

Polya was one of the first mathematics educators to advocate the belief that mathematics in general and problem solving in particular are for all students. It is the aim of this inquiry to promote the notion that problem solving really is for every student. It is important to provide a curriculum which offers all students the opportunity to develop an ability to solve problems. In doing so this curriculum must provide a variety of situations and examples which can help students link the subject matter of mathematics to the experience of solving meaningful problems.

Defining the concept of evaluation

"Evaluation is one of the most widely discussed but little used processes in today's educational system" (Worthen & Sanders, page 1). Society has demanded that educational systems be held accountable and legislators have responded by allocating more and more funds for the evaluation of educational programs. However, "despite these trends toward accountability, only a tiny fraction of the educational programs operating at any level have been evaluated in any but the most cursory fashion, if indeed at all" (Worthen & Sanders, page 1). Evaluation is a complex process, indeed, even the process of finding an acceptable definition for evaluation seems not only complex, but controversial. At the most general level, evaluation has been defined as "the assessment of merit" (Popham, 1975). A somewhat more elaborate definition is provided by L. J. Cronbach who defines evaluation as "[the] collection and use of information to make decisions about an educational program" (Cronbach, 1963). Richard Wolf (1979) has said:

> This definition of evaluation, emphasizing the collection and use of information about learner performance, is a distinct improvement on the "assessment of merit" definition, but it still does not go far enough in saying what evaluation is (page 3).

A more extended definition, supplied by C. E. Beeby, describes evaluation as "the systematic collection and interpretation of evidence, leading, as part of the process, to a judgement of value with a view to action" (1975). Implicit in both the Beeby and Cronbach definitions is the distinction that evaluation is decision-oriented and that its intent is to lead to better policies and practices in education.

Ralph W. Tyler is generally considered the father of educational evaluation. "In general terms, Tyler considered that evaluation should determine the congruence between performance and objectives" (Stufflebeam & Shinkfield, page 70). Tyler saw the purpose of evaluation as providing a check as to whether the plans for learning experiences actually function to guide the teacher in producing the desired outcomes. The Tylerian approach suggested the utilizaton of feedback in educational improvement; however, it has been used almost exclusively to judge final success only. The Tylerian concept of relating outcomes to objectives, gave predominance to a terminal process that yielded information only after the full cycle of the program had occurred. This view has continued and is reflected in several current approaches to evaluation.

Edward Suchman, however wrote in 1967 that evaluation should be viewed as a scientific process. He stated his beliefs that the same procedures which are used to discover knowledge could be utilized to evaluate the degree of success in the application of this knowledge (Stufflebeam & Shinkfield). Suchman advocated that program evaluation should consist essentially of the measurement of success in reaching the practical objectives of an educational program.

During the last few decades, new definitions of evaluation have emerged, among which are those of Robert Stake, 1967 and Daniel Stufflebeam, 1971. As an alternative to the Tylerian definition, Daniel Stufflebeam redefined evaluation as "the process of providing useful information for decision making" (Stufflebeam, 1966). Stufflebeam reported that evaluation in general was the victim of a great illness, recognizable by symptoms exhibited by evaluators at all levels of education and by the dismal quality of their evaluation work. Stufflebeam sees the role of evaluation as a means of sorting out the good from the bad, a method of pointing the way to needed improvements and of helping educators gain a better understanding of their field.

Robert Stake has "argued that evaluation's basic function in education should be to guide curriculum improvement, not to judge completed, packaged curriculums" (Stufflebeam, page 211). Stake defined evaluation as "an observed value compared to some standard." Stake advised the evaluator to make a comprehensive statement of what the program is observed to be and to reference the satisfaction and dissatisfaction that appropriately selected people feel toward the program. He views the evaluator as a "truth seeker" and has cautioned that many outcomes, rather than only those which are measurable, testify to the worth of an education program.

James Sanders and Blaine Worthen (1987) define evaluation as:

> The determination of the worth of a thing. It includes obtaining information for use in judging the worth of a program, product, procedure, or objective, or the potential utility of alternative approaches designed to attain specified objectives (page 19).

Thus it seems an unlimited number of definitions for evaluation exist, some of which have strong commonalities. Obviously, the way in which one defines evaluation has direct impact on the type of evaluation activities conducted. The ultimate role of evaluation must be the determination of merit or worth. According to Worthen and Sanders (1987):

> Evaluation can play many roles in an educational program: it can aid the developers by providing mastery test data, and it can provide data to facilitate administration of the program, to name only two. However, the goal of evaluation must always be to provide the answer to an all-important question: Does the phenomenon under observation have greater value than its competitors or sufficient value of itself that it should be maintained? (page 26).

The definition of evaluation which was used to guide this case study is a combination of those offered by Stufflebeam and Stake. The evaluation has endeavored to compare an observed value to a set of standards, then point the way toward needed improvement and a better understanding of the current mathematics curriculum. This investigator chose this combination of definitions since it implies evaluation should be concerned with process rather than simply with outcomes or products. However, the investigation also used Provus' Discrepancy Evaluation definition (1971) which states:

> Program evaluation is the process of (1) defining program standards; (2) determining whether a discrepancy exists between some aspect of program performance and the standards governing that aspect of the program; and (3) using the discrepancy information either to change performance or to change program standards (page 183).

This investigator used Provus' definition in the assessment of the congruence of the current mathematics curriculum at South Caldwell High School and the criteria of NCTM's Standard 1: Mathematics as Problem Solving.

This case study began as a program evaluation and as such compared current problem solving practices with those recommended by NCTM. However, it also focused upon the dynamics involved as change occurs in an existing program. Implementation of Standard 1 was expected to be gradual with problem solving activities being added in a systematic manner in the beginning, until eventually problem solving becomes an integral part of the mathematics curriculum.

Planning and Evaluation Models

Since there is more than one method of conducting a defensible educational evaluation, the skilled educational evaluator should be aware of the various alternative options for carrying out that task. There are different evaluation strategies for different educational situations. In choosing a particular evaluation design, the evaluator should consider not only its special features but also the conditions under which it will be used. Each design has certain strengths and weaknesses. Knowledge of each of them is important, and adequate provision for dealing with the weakness inherent in a particular design is critical to the success of an evaluation study.

Immediately following the enactment of the Elementary and Secondary Education Act of 1965, the development of evaluation models was clearly a fashionable activity. However, as is often true, some of the later evaluation models incorporated large portions of previously presented models. Each model was developed as a course of action which, if followed, would lead to more effective evaluation. As such none of the models are truly distinct. Popham (1988) in the book Educational Evaluation stated that:

> No matter what factors one chooses to employ in distinguishing among educational evaluation models, the resulting categories fail to satisfy those who would toss particular models into distinctive classification cells without overlap (page 22).

Popham has devised a five-category set of descriptors for the educational evaluation models currently available.

Popham describes these categories as neither flawless nor mutually exclusive. The five classes of educational evaluation models to be considered by this evaluator are as follows:

Goal-Attainment Models
Judgemental Models Emphasizing Inputs
Judgemental Models Emphasizing Outputs
Decision-Facilitation Models
Naturalistic Models

Goal-Attainment Models

"A goal-attainment approach to educational evaluation conceives of evaluation chiefly as the determination of the degree to which an instructional program's goals were achieved" (Popham, page 24). The goal-attainment concept of educational evaluation is generally associated with the efforts of Ralph W. Tyler. According to Popham (1988):

> Tyler's general approach involves the careful formulation of educational goals according to an analysis of three goal-sources (the student, the society, and the subject matter) and two goal-screens (a psychology of learning and a philosophy of education). The resulting goals are then transformed into measurable objectives. At the conclusion of an instructional program, measurements of pupils are taken in order to see the degree to which the previously established goals were achieved (page 25).

Educational goals and the degree to which they are achieved constitute the heart of Tyler's evaluation approach.

A more recent variation of the goal-attainment model was proposed by Hammond (1969) and includes: (1) isolating that aspect of the current educational program to be evaluated, (2) defining the relevant institutional and instructional variables, (3) specifying objectives in behavioral terms, (4) assessing the behavior described in the objectives, and (5) analyzing goal-attainment results. Hammond's model goes into greater depth in an effort to determine the factors which might be relevant in considering the degree to which expressed objectives are achieved.

Metfessel and Michael (1967) offered an eight step goal-attainment model which includes: (1) involvement of members of the total community, (2) construction of broad goals and specific objectives, (3) translation of specific objectives into forms that are communicable and that facilitate learning, (4) development of measurement instrumentation, (5) carrying out periodic measurement, (6) analyzing measurement data, (7) interpretation of analyzed data, and (8) formulation of recommendations for program change of modified goals and objectives. The main thrust of goal-attainment models is the degree to which prespecified instructional goals have been achieved.

Judgemental Models Emphasizing Inputs

Another class of evaluation models includes those in which major attention is given to professional judgement. The evaluator's judgement determines how favorable or unfavorable the evaluation turns out to be. Here the evaluator directs his attention toward inputs, or intrinsic criteria, which can be referred to as process criteria. The intrinsic features of a textbook might will be its design, illustration, and use of color. (How well the student can learn from the book would concern its outputs, its extrinsic criteria, also referred to as product criteria.) Judgemental approaches to educational evaluation in which the emphasis is on inputs are very common in education, however Popham views most of them as too haphazard to be properly classified as systematic evaluation. One exception is the accreditation model in which an accrediting agency visits a school and, on the basis of previously determined criteria, judges a school's program. In most cases, the interest of the accreditation team is directed toward intrinsic criteria, such as the number and quality of books in the library, the degree of training of the school's faculty and the physical plant.

Recently, there has been growing dissatisfaction among educators for this type of evaluation due to the lack of empirical evidence to confirm and support the final outcomes of the instructional sequence. Consequently, evaluation models that are dominated with a concern for inputs are not often recommended today.

Judgemental Models Emphasizing Outputs

There are several approaches to educational evaluation which can be described as judgemental processes in which the primary attention is given to outputs, or extrinsic criteria. The most significant of these models have been developed by Michael Scriven (1974) and Robert E. Stake (1967). Although Scriven's position has remained virtually the same, Stake's views have changed considerably (this will be discussed later) over the years.

Scriven's approach to educational evaluation calls for the evaluator to judge a program, attending chiefly to program outputs. He begins his model with the formative-summative distinction: an evaluator can formatively attempt to improve a still-under-development instructional sequence or he can summatively assess the merits of an already completed instructional sequence. Scriven views evaluation as an assessment of merit. Popham says this of Scriven:

> He is particularly dismayed with those who would equate evaluation merely with the degree to which goals are achieved. As he points out, "...it is obvious that if the goals aren't worth achieving, then it is uninteresting how well they are achieved" (page 28).

Scriven recommends that evaluators should never simply appraise a program relative to its goals; instead evaluators should appraise the goals themselves.

Scriven advocates a comparative orientation to evaluation, pointing out that decisions regarding educational evaluation typically involve choices from alternatives which in turn require comparisons of the competitors. It is the job of the educational researcher to determine which factors lead to a more effective program. Scriven has also proposed goal-free evaluation. Popham (1988) has said that Scriven believed:

> The goal-free evaluator is not concerned with the rhetoric of the instructional designers regarding what they want to accomplish, but rather attends to the results accomplished by the designers' programs (page 30).

The chief advantage of goal-free evaluation is that it encourages the evaluator to focus on a wider range of program outcomes than might be possible when the evaluator has been influenced to look for project results related to project aims. A well-designed evaluation, according to Scriven, would contain both goal-based and goal-free evaluation.

In 1967, Robert E. Stake proposed a system of evaluation often referred to as his Countenance Model. His 1967 conception of evaluation emphasized two activities: description and judgement. Stake distinguished between descriptive and judgemental acts of the evaluator according to three phases of an educational program: its antecedent, transaction, and outcome phases. Antecedents, according to Stake, are conditions which exist prior to instruction which may relate to outcomes; transactions constitute the process of instruction; and outcomes are the effects of the instructional programs. Stake divided descriptive acts through references to what was intended or what was actually observed; Judgemental acts either refer to the standards used in reaching judgements or to the actual judgements themselves. Popham's (1988) account of Stake's view indicated that:

> He pointed out that when we judge an educational program we engage either in relative comparison (one program versus another), absolute comparison (one program versus standards of excellence not associated with any particular program), or both relative and absolute comparison. The real payoff in the Countenance Model, of course, was the judged outputs of the program being evaluated (page 33).

<u>Decision-Facilitation Models</u>

Decision-Facilitation Models differ from judgemental models in that the evaluator is less willing to assess personally the worth of the educational program. They, in essence, collect and present information to someone else, who will then determine worth. One of the best known decision-facilitation evaluation models is the CIPP, an acronym representing the four types of evaluation this model identifies: content, input, process, and product evaluation. The CIPP Model was designed by Daniel Stufflebeam and Egon Guba (1971) and "is deeply rooted in its definition of evaluation: evaluation is the process of delineating, obtaining, and providing useful information for judging decision alternatives" (Popham, page 34). The three major steps in the CIPP model are: (1) delineating, or a focus on the information requirements of the decision maker, (2) obtaining or the collection, organization and analysis of information using measurement and statistics, and (3) providing a synthesis of the information. All three steps involve information and how it can best be isolated, gathered and presented to those individuals who will make decisions. The CIPP model provided the first guide for evaluators who believed that their primary goal was to aid those who make decisions.

A second decision-facilitation model, offered by Malcolm Provus (1971), is the Discrepancy Model, so called due to the particular attention paid to the discrepancies between posited standards and actual performance. The Discrepancy Model consists of five stages: (1) design, which focuses upon documenting the nature of the program, (2) installation, or a determination of whether an installed program is congruent with its installation plans, (3) process, or an assessment of whether enabling objectives are being achieved, (4) product, or an assessment of whether terminal objectives are being achieved, and (5) program comparison, or a cost-benefit analysis. After performance is compared to standards, the discrepancy information can lead to four alternatives: the program can be ended; the program can proceed unaltered; the program can be altered; or the program standards can be altered.

Naturalistic Models

The final category of educational evaluation models to be considered here is referred to as naturalistic or qualitative, an evaluation model which places few or no constraints upon potential outputs or those factors which are present in an evaluation at its outset (such as pupil aptitude).

In the 1970s, Robert Stake became somewhat disenchanted with his own highly structured Countenance Model and began to endorse a model he characterized as a responsive evaluation. Popham's (1988) account of Stake says:

> He argued that an educational evaluation would be responsive if it "orients more directly to program activities than to program intents, responds to audience requirements for information, and if the different value perspectives present are referred to in reporting the success and failure of the program." Whereas Stake considers most conventional evaluations to be formal, preplanned, objective, and based on prespecified intentions, he views responsive evaluation to be informal, flexible, subjective, and based on evolving audience concerns (page 42).

Eliot Eisner has also developed a model for naturalistic educational evaluation. Eisner's model relies upon the two concepts of educational connoisseurship and educational criticism. Connoisseurs are able to appreciate the subtle qualities of a complex educational phenomena, while the critic serves the role of disclosure. Popham (1988) has said Eisner believes:

> The educational critic strives not only to discern the qualities constituting an event or object, but also to render in verbal form what has been experienced, so that those who do not possess the critic's level of connoisseurship can understand what the critic has perceived (page 43).

There have been very few guidelines provided for the implementation of a connoisseurship model and as a result, this model has been employed mostly by Eisner, his co-workers, and his students.

An ethnography can be defined as a description of a situation in which the beliefs, knowledge, behaviors, and practices of those involved are depicted. Therefore ethnographic educational evaluations are thought to yield a more meaningful picture of the educational process. An ethnographic evaluation should be guided by: (1) phenomenology, or the viewpoints of those being studied, (2) holism, or the large picture rather than details and the interrelationship among those under analysis, (3) nonjudgementalism, where the evaluator avoids making judgements and where biases are made explicit, and (4) contextualization, in which the evaluator examines information in its own environment in order to provide an accurate representation.

There are of course other models of educational evaluation and those models could perhaps be classified by various other methods. However, the five categories discussed here serve to provide a useful set of descriptors for those models currently available for educational evaluation. The model selected by this investigator for use during this inquiry is a combination of several of the characteristics from Provus' Discrepancy Model and those qualities specific to an ethnographic study. The Discrepancy Model provides the necessary framework for a comparison of program performance (in this case, the current curriculum problem solving practices) to NCTM's Standard 1: Mathematics as Problem Solving. The discrepancy information (when found) was gathered and presented along with recommendations to those individuals responsible for program decisions. Through the use of various ethnographic techniques, this investigator has hopefully presented a more accurate description of many of those beliefs and behaviors which can affect the actual mathematics curriculum which is now being used when teaching students in grades 9 - 12.

Assessing the problems of evaluation

One of the fundamental goals of program evaluation is to determine whether a program is doing what it is intended to do, whether it is meeting its goals. In order to decide whether a goal is being met, one must know what that goal is. In other words, "program evaluation actually has two sets of goals: the goals of the evaluation process itself (the research goals) and the goals of the program being evaluated (the program goals)" (Moursund, page 9). It is generally agreed that one fundamental goal of evaluation is to determine whether the stated goals of a program are being met. A second and equally valid function of evaluation is to determine whether the stated goals are the actual goals on which the program is operating, and if these goals are appropriate. Traditionally, an evaluation begins with setting up, or ascertaining, the goals of the program one wishes to evaluate. C. H. Weiss (1972) has suggested there are four major problems in determining the real goals to be dealt with in evaluation.

> First, the goals of the program being evaluated may be quite hazy and ambiguous. Second, even when goals are stated, the list may not be exhaustive; the program often aims toward objectives not included among its "official" goals. Third, most programs are fairly complex, with different parts doing different things. It is difficult to decide how the subgoals of each program part interact to accomplish the overall goals of the program. Finally, good evaluative research must be as concerned with why things happen as with whether they happen. This qualitative aspect of evaluation is usually neglected in proportion to the difficulty of carrying it out, but it is a crucial part of evaluation (Moursund, page 12).

The mathematics curriculum goal which I attempted to evaluate during the course of this inquiry was:

Standard 1: Mathematics as Problem Solving

In grades 9 - 12, the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can --

--use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content;

--apply integrated mathematical problem-solving strategies to solve problems from within and outside mathematics;

--recognize and formulate problems from situations within and outside mathematics;

--apply the process of mathematical modeling to real-world problem situations.

Daniel Stufflebeam attributes the "sickness" of evaluation to five major problems. The first contributor is that of definition; evaluation can be defined in many essentially arbitrary ways, each of which affects the method of evaluation and perhaps the resulting judgements and conclusions. Three particular definitions have gained common acceptance: the measurement definition; the congruence definition; and, the judgement definition. Each definition has certain advantages and disadvantages. The second problem in evaluation is one of decision making. Evaluation is an action-related process in the sense that an action referent is implied in every evaluation activity. Stufflebeam believes evaluation is in difficulty because knowledge of the decision-making process and of the methodologies for relating evaluation to decision making is woefully inadequate. The third major problem area of evaluation concerns values and criteria. Data collection alone does not constitute evaluation; there is always a need to make judgements about the data in terms of some implicit or explicit value structure. Rather than asking only whether or not objectives are achieved, the question becomes how well they are achieved. The introduction of values creates a number of problems. A fourth major problem area is that of levels. The problem of levels stems from the fact that the evaluator's traditional point of focus has been the individual student, the classroom, the school building rather than the school district, the state system or the national network. Many evaluators today are faced with problems at higher, broader levels. The final major problem area is that of the research model. Perhaps the greatest challenge facing the evaluator is overcoming the idea that evaluation methodology is identical to research methodology. Equating the two makes it impossible to meet certain needs which are served by good evaluation (Stufflebeam, et al., 1971).

There are several simpler, more obvious problems in program evaluation. These include: cost, limited amounts of available time, lack of interest and commitment on the part of those involved in the evaluation, reluctance or inability to institute change, as well as a general tendency to fear or distrust evaluation results.

Planning and conducting evaluation studies

Before beginning the evaluation study, the evaluator should first consider a needs assessment. "The purpose of a needs assessment is to identify the goals for which a program should strive, goals that are important to society, not currently being achieved, and potentially feasible" (Kosecoff & Fink, page 27). After completing the needs assessment, the evaluator should begin work on the management of the evaluation studies. This activity should begin before the evaluation is implemented, and continue until the evaluation is completed. Every evaluator must learn to establish schedules which monitor the activities of the evaluation. Any evaluation, large or small, must provide information which will accurately describe what the evaluation program is, what it does, and how well it does it. Kosecoff and Fink (1982) offer a set of evaluation guidelines which can be used to design a new evaluation or to judge the credibility of an evaluation study done by others.

Guideline 1: An evaluation must ask specific questions or test hypotheses about a program.

Guideline 2: Limit evaluation questions to those that will provide useful information for the people who expect to act on it.

Guideline 3: Every evaluation should ask questions about outcomes.

Guideline 4: Evaluations of large-scale programs should always ask questions about costs and generalizability.

Guideline 5: Standards of program merit should be set for each evaluation question.

Guideline 6: Standards of merit must be set before any data collection begins.

Guideline 7: Evaluation standards must have scientific validity.

Guideline 8: Select a design suited to each evaluation question.

Guideline 9: For evaluation questions dealing with important issues or large-scale studies, use a design that establishes causality.

Guideline 10: For each question, select a sample representative of the population to which the findings will be applied.

Guideline 11: Sample size should be determined by the extent of the effect that is considered to be meaningful.

Guideline 12: Use instruments that are reliable, valid, and suited to the evaluation question.

Guideline 13: Use more than one method of collecting information when assessing important issues.

Guideline 14: Keep data collection as unobtrusive as possible.

Guideline 15: Use analysis techniques that are technically sound and suited to the quality of the data.

Guideline 16: Interpret analysis results in terms of the evaluation questions and standards.

Guideline 17: Report techniques and results so they are meaningful to both the layperson and the professional.

Guideline 18: An evaluation report should answer the evaluation questions and explain how each was arrived at.

Guideline 19: Offer recommendations only on those aspects of a program that the evaluation is specifically designed to study -- and then only if asked to do so.

(Kosecoff & Fink, page 49-64)

In the design of this inquiry, this investigator has endeavored to conform to each of these guidelines with the exception of guideline 4 and guideline 9 which do not seem appropriate for this study. Since Guidelines 16 - 19 deal with analysis, interpretation, and reporting the results of evaluation, they were used to guide the final stages of this program evaluation.

Analyzing and interpreting evaluation information

All evaluations accumulate data that need to be analyzed. Kosecoff and Fink have said:

> The difference between an efficient evaluation and an inefficient one is that the former collects and analyzes just what is needed to answer the evaluation questions, while the latter may not collect enough relevant data but instead, gathers information that is not really targeted to the program. One way of ensuring efficiency is to focus on the evaluation question (page 177).

The evaluation questions shape the entire evaluation, and the evaluator should choose analysis methods which will answer the questions directly.

The following questions were used to guide this inquiry:

1. To what extent is the criteria of Standard 1 being satisfied by the current mathematics curriculum in grades 9 - 12?

2. What are the changes perceived to be necessary before the curriculum recommendations found in Standard 1 can be fully implemented?

3. What are the factors which may inhibit or

enhance the implementation of NCTM's vision for a more relevant and useful mathematics curriculum within a typical school?

The first step in the analysis and interpretation of evaluation information is the organization and summarization of data. The aim is to give a reader not only the main results of an evaluation study but the full range of findings. There are several analytical techniques which give answers to commonly asked evaluation questions. Those techniques include descriptive statistics, correlations, and regression analysis. Once the analysis has been completed, the evaluator can begin to interpret the results. Some questions typically asked concern program merit, design strategy and sampling procedures, and validity of information collection and analysis.

Interpreting results also involves distinguishing between statistical and programmatic significance. Statistical significance tells you whether an outcome makes a difference in terms of program goals -- that is, whether the outcome justifies the time, and effort. According to Kosecoff and Fink (1982):

> Statistical significance and programmatic significance are analogous to reliability and validity. Like reliability, statistical significance is a measure of precision; like validity, programmatic significance is a measure of efficacy and cogency (page 187).

Finally, analytical results point to recommendations as to how to improve or certify the effectiveness of a program. The evaluator, however is not always expected to provide those recommendations while those being evaluated certainly have no obligation to comply with those recommendations.

THE ROLE OF EVALUATION IN MATHEMATICS CLASSROOMS

The National Council of Teachers of Mathematics in their 1961 Yearbook state:

> The evaluation of instruction has been called the quality control of the education program. It is a means by which the quality of our mathematics programs can be constantly improved. Through evaluation activities we chart the present achievement of our students and measure the progress they have made in the desired direction (page 1).

Evaluation is an essential part of the mathematics curriculum at every level and should guide the instruction and learning of all students. An effective evaluation can serve many purposes, among which are: to improve the instructional program in the school, to enhance the effectiveness of mathematics teachers, to aid the learning of mathematics, and to furnish valid data for research. The National Council of Teachers of Mathematics has stated that the evaluation of the instructional program in mathematics has become more important during the last two decades because of these recent developments and pressures:

--New mathematics curricula are being advocated and tested by experimentation and research.

--New mathematics content is available and is being proposed for inclusion at several levels of instruction.

--New devices and materials of instruction, such as computers and calculators, are now available to our schools.

--New principles of learning are being emphasized in the presentation of mathematical concepts.

--Society is demanding greater mathematical competence of all citizens than ever before.

--National survival may depend upon the development of new mathematical concepts.

Evaluation becomes even more indispensable when we commit ourselves to the task of having each pupil achieve his optimum potential in mathematics. It can serve to improve the effectiveness of instruction in many different ways. Evaluation can establish levels of learning and locate a student at a level suitable for his current status in mathematics. It can help to provide data which can be used in the selection of materials, modes of instruction, and the organization and content of curriculum goals. Evaluation can help students learn mathematics more effectively by providing insight into how students learn as well as what motivates them to learn.

The Association for Supervision and Curriculum Development stated in 1967 that:

> Accurate assessment of educational outcomes is essential for sound planning and effective stimulation of growth in our educational structure. Assessment has always been an integral aspect of curriculum development and is a major responsibility of curriculum workers. This responsibility is especially critical in a time of awakened public concern, massive federal commitment and widespread professional reappraisal of our educational endeavors (page v).

These comments are just as valid today. Evaluation, according to the ASCD is feedback -- feedback which conditions what happens next in a school, or classroom. Thus the test of a good evaluation depends upon whether it satisfies the following basic criteria: (1) Evaluation must facilitate self-evaluation; (2) Evaluation must encompass every objective of the school; (3) Evaluation must facilitate learning and teaching; (4) Evaluation must produce records appropriate to the purposes for which records are essential; and (5) Evaluation must provide continuing feedback into the larger questions of curriculum development and educational policy. It seems unlikely that any school system will ever devise a program of evaluation that will meet all five of these criteria. However, what we must realize is that evaluation involves much more than measurement. According to The Association for Supervision and Curriculum Development (1967):

> If the evaluation is of sufficient scope and if it is handled through an interactive process, it has this clarifying, renewing effect upon learners, teachers, higher educational officers, and public alike. It helps everybody who is involved to think more clearly about what he is after and how he is getting along. In the long run, then, a high-quality evaluation program is the surest guarantee a learner, a teacher, or a school system can have of the ability constantly to envision valid objectives, plan for their achievement, look successes and failures in the eye, and develop new plans as these are needed (page 9).

Thomas L. Good and Bruce J. Biddle (1988) argue that evaluation has the capacity for generating empirically-based insights concerning the causes, conduct, and consequences of teaching, and that those insights can be used by educators to inform the decisions they make when planning or evaluating innovations in schools. Those insights can help educators to resist the enthusiasms of vendors who are trying to sell an educational product. They can lead educators to understand why certain teaching strategies are effective with some groups of pupils and ineffective with others. And finally, they can provide information useful for anticipating, measuring, or interpreting the outcomes of innovations. In short, Good and Biddle argue that schools and educators make more sensible decisions, that resources are saved and mathematics education is possibly improved, when the normal processes of educational innovation are supplemented by the insights arising from evaluation (Grouws & Cooney, page 120).

During this examination of relevant evaluation literature, several program evaluations were reviewed. However none were found which matched exactly the type of program evaluation which this investigator planned to attempt. One mathematics program evaluation of interest was done in 1985, by the Anne Arundel County public schools, in Annapolis, Maryland. The model which was designed to evaluate curriculum programs, provided for the evaluation of three phases of a program: the curriculum; implementation of the curriculum; and students' performance, attitudes, and later success. The model provided a comprehensive view of a program which went beyond the scope of evaluation models previously used. Within each phase of the model, a series of broad research questions were generated to guide the evaluation design. The evaluation resulted in a set of specific program recommendations and significant program changes which are ongoing and are monitored annually. These are some of the questions which were asked concerning the mathematics curriculum:

--Does the mathematics curriculum reflect current trends in curriculum development and current research in learning and instruction?

--Does the mathematics curriculum match students' cognitive development at each grade and age level?

--Does the mathematics curriculum meet students' diverse needs and characteristics?

--Are the mathematics content, skills, and learning outcomes appropriately sequenced and balanced?

--Is the amount of time devoted to mathematics instruction, kindergarten through grade twelve, sufficient and balanced with other content areas?

--Are the inservice opportunities available to teachers sufficient to insure that the mathematics curriculum is implemented to the fullest?

The questions were answered by collecting information from seven sources; consultants, a survey of current students, survey of former students, survey of school staff, high school achievement data in mathematics, and other data previously collected which was available to the school system.

Another study was done by Eugene Muller at Columbia University and was an evaluation of a Science/Mathematics gifted education program for junior high students. The main focus of the study pertained to the math, science, and computer science performance of the 7th grade class, entering the fall of 1983. The evaluation was directed at determining the cognitive and affective changes that would indicate student growth and positive effects of the program, and determining what aspect of the program could be improved.

Of major interest to this investigator was a study done in 1980-82 by the International Association for the Evaluation of Educational Achievement. In the study, known as the Second International Mathematics Study or SIMS, detailed information was obtained on the content of the implemented mathematics curriculum, what mathematics was actually taught by the teachers, and how that mathematics was taught. Eleven countries participated in SIMS, and in the United States, students in approximately 500 mathematics classrooms in about 250 public and private schools randomly selected from across the country were tested at the end of the 1981-81 school year. The SIMS study is based on a model that views the curriculum as intended, as implemented, and as attained. Consequently, patterns of achievement may be examined against a background of detailed information on the content of the curriculum both as intended to be taught and as actually taught. Such detailed curricular data may be useful to curriculum supervisors and evaluators, for example, as they assess present curricula, plan new programs and seek to document the extent to which curricular innovation has taken place. The kinds of data which may be obtained from SIMS replications include: a.) background data of a great variety, including characteristics of schools, teachers and students; b.) curricular content data concerning what topics are in the curriculum for each target population;

and c.) teacher coverage data, concerning which students receive what course coverage.

Much of the evaluation in the United States involves testing of general intellectual development or aptitude which is often used as criteria for school achievement or effectiveness. SIMS, by contrast, focuses on the mathematical content of the curriculum, as found in the syllabus or textbook, as taught by the teacher and as learned by the student. SIMS, more that any other program evaluation reviewed by this investigator, most nearly approaches the type of educational evaluation which was performed during this inquiry.

Current mathematics instruction has become stagnant; the choices now being made by mathematics educators will affect an entire generation of students, not only in determining what mathematics they will learn, but also how they will learn and perhaps, more importantly, how much they will learn. Evaluation is the means we use to discover where we stand on the path between present experience and the desired objective. Effective evaluation can yield a better understanding of the learning of mathematics and can provide more adequate models for the improvement of its instruction. Only then can we hope to move forward in our attempts in mathematics education.

Evaluation is a complicated, sometimes painful process. However, it holds great promise for providing educators with badly needed information which can be used to improve the process of education. When used properly, evaluation can have a profound impact on the field of education. This case study began as a program evaluation and compared pre-existing problem solving practices for an existing curriculum with those recommended by NCTM. However, it also focused upon the dynamics involved as change occurred within an existing mathematics program.

> Evaluation research, not a new but nevertheless an increasingly robust enterprise, can have a major impact on social problems. While it would be foolish to argue that all the deficiencies of current programs or all the political and conceptual problems can be swept away by evaluation studies, the adequate assessment of existing and innovative programs can be a vital force in directing social change and improving the lives and the environments of community members.
>
> Francis Caro, 1971

CHAPTER III

METHODOLOGY

> Evaluation is not a search for cause and effect, an inventory of present status, or a prediction of future success. It is something of all of these but only as they contribute to understanding substance, function, and worth.
> Robert E. Stake & Terry Denny, 1969

In 1989 The National Council of Teachers of Mathematics wrote the following:

> The fourteen standards developed by NCTM for grades 9 through 12 establish a framework for a core curriculum that reflects the needs of all students, explicitly recognizing that they will spend their adult lives in a society increasingly dominated by technology and qualitative methods (page 123).

At the very center of this core curriculum is the concept of mathematical problem solving, which should be the focus of school mathematics.

Therefore, the purpose of this emergent case study was to evaluate the current status of problem solving in a typical mathematics curriculum, and to examine the process involved in the implementation of the recommendations found in NCTM's Standard 1: Mathematics as Problem Solving. The intent of this investigation was not to determine whether implementation of NCTM's Standards will or can bring about the desired reform in mathematics education.

Unfortunately, that type of conclusion is beyond the scope of this study, and perhaps will not be known during this decade. Rather, the main purpose of this investigation was to determine whether implementation can take place and how teachers react to perceived change within the mathematics curriculum. More specifically, the following questions were used to guide the inquiry:

1. To what extent are the recommendations of Standard 1 not being satisfied by the current mathematics curriculum in grades 9 - 12 in a specified high school?

2. What are the changes perceived by teachers to be necessary before the curriculum recommendations found in Standard 1 can be implemented?

3. What are the aspects of current mathematics education which may inhibit or enhance the implementation of NCTM's vision for a more relevant and useful mathematics curriculum within a typical school?

The NCTM Curriculum and Teaching Standard which has been selected by this investigator to guide this program evaluation is:

Standard 1: Mathematics as Problem Solving

In grades 9 - 12, the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can --

--use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content;

--apply integrated mathematical problem-solving strategies to solve problems from within and outside mathematics;

--recognize and formulate problems from situations within and outside mathematics;

--apply the process of mathematical modeling to real-world problem situations.

During the evaluation of Standard 1: Mathematics as Problem Solving, this investigator utilized those indicators of quality for Standard 1 which were developed by the Center for Educational Research and Evaluation at UNC-G for the evaluation of mathematics programs. Those indicators are:

Standard 1: The curriculum provides students with the opportunity to engage in problem solving.

1.1 The curriculum provides students with the opportunity to solve problems on a regular basis.

1.2 The curriculum provides students with the opportunity to define problems from everyday life as well as mathematical situations.

1.3 The curriculum provides students with the opportunity to develop and carry out plans to solve a wide variety of nonroutine problems.

1.4 The curriculum provides students with the opportunity to look back at the original problems to verify and interpret their results.

1.5 The curriculum provides students with the opportunity to generalize solutions and strategies to other situations.

An assessment of the ability of students to use with increasing confidence, problem solving approaches to investigate and understand mathematical content was completed in the following manner: comments found in individual teacher journals, examples of student work from the teacher portfolios, and the examination of the results of a problem solving attitude assessment survey for students.

The procedures for this study are discussed under three major headings: (1) evaluation setting, (2) evaluation plan, and (3) data analysis.

Evaluation Setting

This investigator has obtained permission from the administrative office of the Caldwell County Schools to conduct this study. South Caldwell High School (SCHS) is a rural high school, located in the southern part of Caldwell County. Built to accommodate the consolidation of two smaller community high schools, SCHS, a modern attractive facility, opened its doors in 1977. With a building capacity of 1100 and a current enrollment of 1141, South is experiencing overcrowding and all the inherent problems caused by too many students and not enough space.

The mathematics department at SCHS consists of nine faculty members, three males and six females, with seven of the nine each having more than fifteen years teaching experience. As one of the nine members of the South Caldwell mathematics faculty, this investigator was a participant-observer in this study. As such, this investigator not only participated in all activities involved with this study while observing the processes involved, but additionally when necessary, assumed the role of facilator. However, information from this investigator was not included in data collection, accumulated data results, or data analysis as a precautionary effort not to influence the outcome of the study. Therefore data was gathered from the remaining eight mathematics teachers only. The current mathematics enrollment at South Caldwell is 895 students, excluding those students in special education classes. The course selection in mathematics at South is quite diverse and ranges from General Math to College Calculus. Students at SCHS typically score twenty points above the state SAT average of 440, and compiled a 1990 average score of 462 on mathematics with 41% of all seniors participating. However, since the average SAT score in North Carolina is well below the National average, SAT scores have been targeted by the school's Senate Bill 2 committee as an area for needed improvement.

The eight members of the South Caldwell High School mathematics faculty were asked and all agreed to participate in the evaluation of the current mathematics curriculum with regards to the NCTM Curriculum and Teaching Standards of school mathematics in grades 9-12. They were made aware that the standard which was selected for curriculum assessment was Standard 1: Mathematics as Problem Solving.

Evaluation Plan

The evaluation phase consisted of four categories: (1) preparing to evaluate; (2) program evaluation, or the actual assessment of problem solving opportunities within the present curriculum, including recommendations for change; (3) implementation of Standard 1; and, (4) post implementation. Procedures for gathering data are based on several sources which discuss ethnographic research (LeCompte & Goetz, 1980; Bogdan & Bilken, 1982; Fetterman, 1988; Patton, 1980). Data sources consisted of a qualitative/quantitative mix as this program evaluation endeavored to document both quantitative and qualitative program outcomes.

1. Preparing to Evaluate

Change is not only difficult, but often impossible. If change is to occur in mathematics education today, then we must understand those factors which could enhance or inhibit such innovation. Therefore, I began my investigation using qualitative data to construct an accurate picture of the South Caldwell mathematics teachers and their impressions of both the present mathematics curriculum and those recommendations presented by the NCTM Standards. This investigator utilized a questionnaire to collect background information from each teacher (such as: years of experience, educational background, personal definition of curriculum, etc.) , while teacher impressions and opinions toward the NCTM Standards were obtained through an open-ended interview. The focus of these questions was to determine teacher attitudes toward the process of change. These are the questions which were answered:

1. What are your personal feelings regarding the teaching profession?

2. What are your personal opinions concerning the status of mathematics education today?

3. How do you respond to outside demands for change?

4. How do you determine the individual course curriculum for each of your classes?

5. What is your initial response to the NCTM Curriculum and Teaching Standards?

6. What factors do you personally feel will enhance/ inhibit the implementation of the NCTM Curriculum and Teaching Standards?

I believe this qualitative data collection helped create a complete picture of the views and attitudes of the participants. (A follow-up interview was used to determine teacher impressions after the implementation of Standard 1.)

Since the purpose of this case study was to evaluate the current status of problem solving in the South Caldwell High School curriculum and to examine the degree of congruence between this curriculum and the recommendations for problem solving found in NCTM's Standard 1, it was necessary for the teachers involved in the study be familiar with those Curriculum and Teaching Standards and the method which were scheduled to be used to evaluate those recommendations of Standard 1. Since seven of the eight teachers were not familiar with the NCTM Standards, this investigator held a focus group work session of all eight mathematics teachers involved, during which each of the fourteen Standards were discussed in the following manner: perceived importance within the present mathematics curriculum; methods which individual teachers could use for implementation; and, changes perceived to be necessary before complete implementation might be achieved. This meeting served to familiarize teachers with the Standards and to generate an informal comparison of the pre-existing curriculum and the type of instruction advocated by the Standards. A complete explanation of the results of the focus group discussion summarizing teacher comments concerning all fourteen Standards can be found in Appendix C.

Since several terms found in the quality indicators which were being used during the evaluation have various interpretations, a second focus group was held for the purpose of determining consensus definitions for the following terms: curriculum, problem solving, on a regular basis, mathematics in everyday life, and nonroutine problems. These definitions were used for the duration of the case study. Following the formulation of the definitions, each individual teacher was asked to keep a journal for the duration of the evaluation period, in which they were asked to document their impressions of Standard implementation, and their corresponding views toward the NCTM Standards and the evaluation in general. The journal should have begun with their initial reaction to the Standards and should have concluded with their reflections of the Standards and the evaluation, once the evaluation was completed.

2. Program Evaluation

The assessment of the congruence of the pre-existing curriculum and NCTM Standard 1: Mathematics as Problem Solving, was done in the following manner:

Individual teachers were asked to complete a checklist (see table 1), which consisted of detailed self-reporting of whether the pre-existing curriculum allowed students the opportunity to engage in solving a variety of routine and nonroutine problems on a regular basis, whether the problems define everyday life, whether the students verify and interpret their results, and whether students generalize strategies to other situations. On this initial checklist, individual teachers responded on a likert scale from 1 to 5, where: 1 = never, 2 = seldom, 3 = occasionally, 4 = frequently, and 5 = on a regular basis.

TABLE 1

Individual Curriculum Inventory Checklist

To be completed at the beginning and at the end of this program evaluation.

Teacher: #____________________

Standard 1: The curriculum provides students with the opportunity to engage in problem solving.

Use a scale from 1 to 5

Where: 1 = never, 2 = seldom, 3 = occasionally, 4 = frequently, and 5 = on a regular basis.

	TEACHER CHECKLIST				
Standard Indicators: The curriculum provides opportunities for students to:	Scale				
	1	2	3	4	5
Solve problems on a regular basis.					
Define problem from every day life as well as from mathematical situations.					
Define & carry out plans to solve a variety of nonroutine problems.					
Verify & interpret their results.					
Generalize solutions and strategies to other situations.					

Individual checklists were returned to the evaluator, who used the data to compile a group profile (see table 2) which indicated by an average of those responses to each of the individual questions on the checklist the degree to which the mathematics curriculum was used to provide problem solving activities for students. The group profile sheet was used to indicated the congruence of the original mathematics curriculum and Standard 1.

Following the completion of the curriculum inventory and the group profile, the evaluator conducted a third focus group with the eight members of the mathematics faculty. The group discussed existing problem solving practices, recommendations for change, and began working together to develop the necessary strategies which might guide them toward congruence with the recommendations of Standard 1. The discussions of the focus group were taped and transcribed. The following questions were answered:

1. Does the current curriculum provide students with the opportunity to engage in problem solving?

2. How often do students engage in problem solving? --Is it on a weekly basis? daily basis? etc.

3. Is there a variety of nonroutine problems?

4. Do students generalize solutions and strategies?

5. What recommendations were made as a result of the

TABLE 2

Group Profile For Curriculum Inventory

Scale: 1 to 5

Where: 1 = never, 2 = seldom, 3 = occasionally,
4 = frequently, and 5 = on a regular basis.

STANDARD 1: The curriculum provides students with the opportunity to engage in problem solving.

Standard Indicator: The curriculum provides students opportunity to:	Scale indicated by each: Teacher One	Two	Three	Four	Five	Six	Seven	Eight	Analysis: Average of all scores for this indicator
Solve problems on a regular basis									
Define problems from everyday life as well as mathematical situations									
Define and carry out plans to solve a variety of nonroutine problems									
Verify and interpret their results									
Generalize solutions and strategies to other situations									
Average of scores for all indicators of Standard 1:									

Group Profile for Curriculum Inventory?

3. Implementation of Standard 1

This phase of the program evaluation consisted of the attempt to implement Standard 1. When the group profile checklist indicated that problem solving was not being done in the current curriculum on a regular basis, recommendations for change were made. As soon as recommendations were made, teachers were asked to provide students in each of their classes with problem solving activities. All eight teachers began an implementation period, during which time they were asked to complete weekly checklists, detailing problem solving activities which were completed each week, to maintain individual journals, detailing reaction to each problem solving activity, and to maintain a portfolio of student work, containing one dated example of each problem solving exercise. (A copy of the weekly checklist for teachers can be found in Table 3.) Teachers were asked to answer 'yes' or 'no' to each indicator on the weekly checklist since for the short time interval involved during any specific week, they either satisfied each individual indicator or they did not.

At the end of each week, teachers met with the evaluator in weekly focus groups in order to determine the amount of progress being made toward the implementation of

TABLE 3

Weekly Individual Checklist

Teacher: #________________

Standard 1: The curriculum provides students with the opportunity to engage in problem solving.

	Teacher Checklist	
Standard Indicator:		
The curriculum provides students opportunities to:	YES	NO
Solve problems on a regular basis.		
Define problems from everyday life as well as mathematical situations.		
Define and carry out plans to solve a a variety of nonroutine problems.		
Verify and interpret their results		
Generalize solutions and strategies to other situations.		
Number of positive responses:		

Standard 1. The evaluator charted progress on graphs with a horizontal axis variable of 'time,' given in weeks and a vertical axis variable of 'number of positive responses' given on the weekly individual checklists during the week in question. The evaluator used the examples of student work found in the portfolio to verify the data found on the weekly individual checklist. This phase of the program evaluation was set to continue for an indefinite period of time (not to exceed one semester) and to cease when this evaluator was able to conclude that no additional progress could be made toward the implementation of Standard 1: Mathematics as Problem Solving. The criteria available for use in making such a determination were:

1. Standard 1 has been implemented and has become a continuing aspect of the mathematics curriculum at SCHS.

2. Standard 1 has been implemented as completely as is possible under existing conditions and curriculum expectations at SCHS.

3. Weekly graphs indicate the number of indicators with positive responses for problem solving activities have ceased to increase, or have actually begun to decrease.

4. Teacher journals and weekly graphs indicate

implementation of Standard 1 is not possible.

An assessment of the ability of students to use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content was done using the following information: data from the individual teacher journals, examples of problems from the portfolios containing student work, and the results from a survey used to assess student attitudes toward problem solving.

4. Post Implementation

The last phase of data collection began with another series of individual interviews. These are the questions which were asked:

1. What are you present perceptions of the NCTM Standards in general, and Standard 1 in particular?

2. Have your perceptions of problem solving changed during this study?

3. Can mathematics education be improved by implementation of the NCTM Standards?

4. What factors will inhibit the implementation of the type of mathematics curriculum advocated by the NCTM Standards?

5. Can the NCTM Standards be implemented into the

present mathematics curriculum?

6. What were the benefits / liabilities of this program evaluation?

7. Will this program evaluation impact the mathematics curriculum at SCHS?

Teachers were asked to complete the individual journals, detailing their impressions of the evaluation period, the frequency of problem-solving activities, student reaction to each activity, along with recommendations and planning strategies.

The post implementation period concluded with a final focus group of all participating teachers held for the purpose of discussing the perceived success of the attempt to implement Standard 1 into the existing curriculum. The following questions were answered:

1. Was the implementation of Standard 1 successful and complete?

2. If the implementation of Standard 1 was not complete, what were the inhibiting factors?

3. How did students react to the change in curriculum?

4. What problems were encountered during the attempt to implement Standard 1?

5. Did teacher perception of Standard 1 change during

the course of this study?

This program evaluation was set to adhere to the proposed evaluation activity time-table found in Table 4 and Table 5. As indicated in the tables, the first four weeks of the evaluation were used for individual interviews, formulation of definitions to guide the study, and assimilation of data collected during the interviews. Implementation of Standard 1 began during week five and was set to continue for an indefinite period, not to exceed one semester. The last phase of the program evaluation lasted four additional weeks and was used to perform the second individual interviews, to hold one last focus group, and to analyze all data which had been collected.

Data Analysis

The purpose of this case study was to evaluate the current status of problem solving in a mathematics curriculum in a typical high school, and to examine the process involved in the implementation of the recommendations found in NCTM's Standard 1: Mathematics as Problem Solving. The following questions were used to guide this program evaluation:

1. To what extent are the recommendations of Standard 1 not being satisfied by the current mathematics curriculum in grades 9 - 12 in a specified high school?

TABLE 4

Proposed Evaluation Activity Time-Table #1

Preparing to evaluate:

WEEK ONE - FOUR:	Individual interviews. Focus Group, formulation of definitions. Assimilation of information from interviews. Focus Group, discussion of NCTM Standards.
WEEK FOUR:	Curriculum assessment through individual checklists. Teachers maintain individual journal. First group profile for curriculum inventory. Focus Group, discussion of Curriculum Inventory Profile, including recommendations for change.

Implementation of Standard 1:

WEEK FIVE:	Teachers begin implementation period. Teachers maintain individual journal. Teachers maintain portfolio of student work. Teachers complete weekly checklist. Evaluator completes problem solving progress graph. Weekly Focus Group.
WEEK SIX:	Implementation period continues. Teachers maintain individual journal. Teachers maintain portfolio of student work. Teachers complete weekly checklist. Evaluator completes problem solving progress graph. Weekly Focus Group.
WEEK...X:	Implementation period ends. Teachers maintain individual journal. Teachers complete second curriculum inventory checklist. Return checklist and portfolio of student work to evaluator. Second group profile for curriculum inventory. Evaluator completes problem solving progress graph. Teachers administer Problem Solving Student Attitude Assessment Survey. Weekly Focus Group.

Post Implementation:

LAST FOUR-WEEKS:	Second individual interview. Final Focus group. Examination of completed journals and portfolios of student work.

TABLE 5

Proposed Evaluation Activity Time-Table #2

ACTIVITY	Preparing To evaluate WEEK 1-4	Implementation period WEEK 5	WEEK 6	WEEK... 7	WEEK X	Post Implementation LAST 4 WEEKS
Individual interviews:	X					
Focus groups (2):	X					
First Curriculum Inventory:	X					
Group profile for curriculum inventory:	X					
Individual journals:	X	X	X	X	X	X
Standard implementation:		X	X	X	X	
Weekly checklists:		X	X	X	X	
Portfolio of student work:		X	X	X	X	
Weekly graphs:		X	X	X	X	
Second curriculum inventory checklist:					X	
Second group profile for curriculum inventory checklist:					X	
Second individual interview:						X
Final focus group:						X
Student Attitude Assessment Survey:						X
Examination of data :						X

2. What are the changes perceived by teachers to be necessary before the curriculum recommendations found in Standard 1 can be implemented?

3. What are the aspects of current mathematics education which may inhibit or enhance the implementation of NCTM's vision for a more relevant and useful mathematics curriculum in a typical school?

This investigator attempted to determine the inherent reasons for or against, as well as the types of changes necessary for, the implementation of a revised curriculum through individual teacher interviews, before and after the attempted implementation of Standard 1, and through weekly focus groups of all teachers involved in this study. All individual interviews and focus group discussions were taped and transcribed, while all tapes, notes and documentation from participant observation, interviews and focus groups were reviewed for common attitudes, biases, or interpretations concerning NCTM's Standard 1 and its implementation. Each individual journal was reviewed for commonalities as well.

The first group profile checklist (see Table 2) for curriculum inventory was used to indicate the degree to which the pre-existing curriculum satisfied the recommendations of Standard 1. Since 5 = on a regular basis, if the group average from all eight teachers for each of the five indicators for problem solving was found to be at least 4.5, this evaluator will have concluded that the mathematics curriculum under study satisfied the recommendations of Standard 1. (A discrepancy between the pre-existing curriculum and the recommendations of Standard 1 would have been indicated by any group average less than 4.5.) If the recommendations of Standard 1 were not being satisfied, the evaluator will have assessed the amount of discrepancy using the average of all eight responses for each indicator, and will have endeavored to direct appropriate curriculum changes according to the recommendations made by the focus group.

During the implementation period, weekly individual checklists (see Table 3) were used to assess the amount of progress being made toward implementation of Standard 1. Individual journals and portfolios containing student work were used to verify the self-reporting by teachers on each weekly checklist. Implementation of Standard 1 progress was indicated on weekly graphs and on a cumulative weekly progress graph.

Following the implementation period, a second group profile checklist (the same checklist was used for the first and second group profile for curriculum inventory, see Table 2) was used to assess the success of the attempt to implement the recommendations of Standard 1 into the existing mathematics curriculum. If the group average from all eight teachers for each of the five indicators for problem solving was found to be at least 4.5, this evaluator will have concluded that the attempted implementation of Standard 1 into the existing curriculum was successful. A focus group will have been held to discuss the successful or failed attempt to implement Standard 1.

Triangulation procedures were used in both the qualitative and quantitative data (Fetterman, 1989; Worthen & Sanders, 1987; Lincoln & Guba, 1985; Bogdan & Bilken, 1982), as there are at least three sources of information for each type of data collected as indicated in Table 6. At the end of each week, this investigator examined each teacher checklist in order to determine which indicators were being satisfied. When any teacher responded 'yes' to an indicator, verification and triangulation was done through the examination of dated examples of student work, combined with entries from individual teacher journals for evidence which supported each response. Findings from the triangulation procedures were discussed during the weekly focus groups.

SUMMARY

The ability to use mathematics skills in general and mathematical problem solving, mathematical reasoning and

TABLE 6

Triangulation of Data

DATA COLLECTION	EVIDENCE
Curriculum assessment for problem solving.	Self-reporting by teachers. Dated examples of student work. Individual journals.
Teachers impressions, views and attitudes toward Standard 1.	Individual interviews. Individual journals. Follow-up interviews.
Increased student confidence in using problem solving.	Portfolio of student work. Individual journals. Survey for the assessment of student attitudes toward problem solving.

decision making in particular, are creating a new vision for mathematics instruction and learning in today's classrooms. New ways of instruction and new curriculum concepts must be explored which will provide solutions to persistent problems and which will ultimately allow all students to become mathematically powerful. Although the field of mathematics has changed dramatically during the last three decades, the mathematics curriculum of today does not reflect those changes. School mathematics has become an entity which has very little to do with what is important in mathematics today. For students, mathematics can open doors to careers; however today, more than any other subject, mathematics filters students from hundreds of professional careers. There are many possible steps to improving mathematics teaching and learning in today's schools. Mathematics educators at all levels have a responsibility to invest the time and energy necessary to find ways to communicate the excitement and usefulness of mathematics to young people, and to devise programs which will help all students persevere in the learning of mathematics. We need experimentation and carefully done follow-up evaluations of new and innovative curricula for mathematics. Perhaps then we will be prepared to choose the appropriate path to reform in mathematics education for the future.

CHAPTER IV

RESULTS

> In education, we do not march steadily and unhesitatingly forward. We repeat not only errors of the past, but also the successes--usually without knowing we are repeating ourselves. But worse, we regularly find that the procedures that failed at some time in the past are successful at a later date, and the procedures that were successful no longer succeed.
>
> Stephen S. Willoughby, 1990

The focus of this inquiry was to assess the current status of problem solving in a mathematics curriculum in a typical high school, and to examine the process involved in the implementation of the recommendations found in Standard 1: Mathematics as Problem Solving, developed by the National Council of Teachers of Mathematics in their Teaching and Curriculum Standards for High School Mathematics. The procedures for this study are discussed under three major headings: (1) the evaluation setting, which will describe the school, the students who attend this school, and the individual mathematics teachers which were selected for participation in this case study, (2) the evaluation plan, which will detail the methods of data collection used to document teacher reaction to Standard 1, the degree of congruence between the pre-existing curriculum problem solving opportunities and those recommendations found in Standard 1, and the actual implementation of Standard 1 into that existing curriculum, and (3) post implementation, which will assess the attempt to implement Standard 1.

The Evaluation Setting

The elements of the evaluation setting will be discussed in the following manner: the school, the teachers, and the students.

The School

South Caldwell High School was selected by the investigator as the site for this emergent case study and permission was obtained from the administrative office of the Caldwell County Schools to examine the current status of problem solving in the Caldwell County High School curriculum. One of three county high schools, South Caldwell lies nestled among the rolling hills of the southern end of Caldwell County. The building itself, located six miles from Lenoir off Highway 321, was designed to blend with and reflect the mountainous terrain visible to the north. Situated on one hundred acres of beautiful country, the facility boasts of 186,700 square feet, and is the largest educational complex within the county. South Caldwell is a one-building, three level complex, with the academic center of the school located on the upper level.

On the east side, the math-science loft contains classroom centers, Biology labs, a computer lab and separate quiet and project labs. Language and Social Studies occupy the west loft. Teacher's offices and work spaces are clustered within these lofts offering separate space for small group discussions and private interviews. Students may be involved in activities outside the loft areas without interference with classes which are in progress around the perimeter. The Media Center and theater are located at opposite ends of the third floor.

The second floor houses each of the vocational areas, while facilities for the performing arts occupy the first floor. Both academic and vocational areas feature the semi-open classroom concept designed around the central gymnasium and combination commons-cafeteria area. Carpet and air-conditioning add to the beauty and comfort of the complex. (A floor plan of SCHS is included in Appendix D of this manuscript.)

Built to accommodate the consolidation of two smaller community high schools, South Caldwell opened its doors in August of 1977 to a student body of grades 10 - 12. Uniting two communities and bonding two student populations, South became a cinderella school, rising up quickly to achieve academic and athletic honors and awards during its first year of existence. Settling down to the business of schooling, South Caldwell spent the next twelve years improving and refining its academic programs while expanding and supplementing the existing athletic programs and facilities. However, 1989 would mean drastic changes for students and faculty, as the local school board voted to include the ninth grade at South. With a building capacity of 1100 students and a current enrollment of 1141, South Caldwell is literally bursting at its seams, and is currently experiencing all the inherent problems caused by too many students and not enough space.

The Teachers

The mathematics department at SCHS consists of nine faculty members, three males and six females. As indicated earlier, this investigator is one of the nine mathematics teachers. As a participant observer, this investigator took part in all activities involved with this study. However, information from this investigator was not included in either data collection , data results, or data analysis. Therefore, data was gathered and compiled from the remaining eight teachers only. Identified in this study as Teacher # 1, Teacher # 2, etc., the following interview account for each teacher will help provide insight into the background of each in areas such education, experience, and teaching attitudes. The following questions were used to guide and direct each individual interview:

1. What are your personal feelings regarding the teaching profession?

2. What are your personal opinions concerning the the status of mathematics education today?

3. How do you respond to outside demands for change?

4. How do you determine the individual course curriculum for each of your classes?

5. What is your initial response to the NCTM Curriculum and Teaching Standards?

6. What factors do you personally feel will enhance/ inhibit the implementation of the NCTM Curriculum and Teaching Standards?

An account of each individual interview is provided for each of the eight teachers followed by a summary of their combined responses to the six questions.

Teacher # 1:

Years of teaching experience: 19

Highest educational degree: BS+

Certification: Mathematics

Current Teaching Assignment: Geometry; Alg I, Part 2;
Consumer Math

Teaching attitudes: "I like teaching and would select it as my career choice again today. I enjoy my job, yet I feel overwhelmed and overworked by too much paper shuffling. Wouldn't it be great to have an aide! I spend very little time worrying about all the societal demands for reform in mathematics education. I resent those people outside the classroom who think they have all the answers to all the problems in the classroom today. I try to gear my teaching methods to demand my students strive to excel in all areas of math. I believe the current mathematics program needs enhancement, perhaps requiring three years of math before graduation. Inadequate teachers need to be replaced. The curriculum which I teach each day is determined by end-of-course tests and the textbook. I believe Senate Bill 2, end-of-course testing and scholarships for math teachers are all efforts to improve mathematics education, and I agree with the reasoning behind all three; they just don't seem to be working. I'm only slightly familiar with the NCTM Standards. But I do not believe they can be implemented into the present curriculum; they need explanation and simplification before teachers attempt to implement them. It's difficult to know exactly what some of the Standards really mean. Besides, words won't cure the lack of mathematics knowledge; good teachers will. Teachers should work together and be involved in the development of new teaching techniques. I would change the way I teach if it would improve education, but not just to raise test scores. But first I'd need to know how to change. Teachers are not magicians; change has to be a cooperative effort, with everyone involved and willing to go the extra mile."

Teacher # 2:

Years of teaching experience: 8

Highest educational degree: BS

Certification: Mathematics and Biology

Current Teaching Assignment: Algebra I; Geometry; Business Math

Teaching attitudes: "I like helping students succeed. I really love math -- it's the only subject I would ever teach. However, due to the pressure teachers receive from the public and the lack of respect from students I would make a different career choice today. I agree that reform is needed in mathematics education, but we can't do it all in high school. Change will have to occur slowly and will need to begin in the first grade. Students should not be passed on to the next grade until they can demonstrate a mastery of basic skills. Right now I spend so much time reviewing concepts students should already know that I barely have time to teach the basics. Extra material is out of the question. My major focus each year is to finish the textbook; end-of-course testing requires it to be. I simply don't have time for extra topics which could benefit my students. I have no objection to end-of-course testing, as long as it isn't used to reflect the quality of teaching a student receives. Longer school days and school years simply are not the answer. Students and teachers would only get discouraged. Parents, students, the public and teachers must all work together in order to have good education. I'm willing to try almost anything to help my students learn more. But a radical change in teaching styles would probably cause confusion. The present public opinion of teachers is hard for me to handle. Educators are criticized by people who have no idea what the public school system is like. Students have not been taught to value learning; they just want to make good grades. There are no quick-fix solutions for the problems in today's schools, including the NCTM Standards. Basically, I resent outsiders who want to change the way I teach without knowing anything about it. Teachers know what problems exist and their input should be part of the solution. The NCTM standards look good on paper, but implementation is another matter."

Teacher # 3:

Years of teaching experience: 12

Highest educational degree: BS

Certification: Mathematics

Current Teaching Assignment: Algebra I; Computer Prog; General Math

Teaching attitudes: "I truly enjoy the variety of teaching since no two days are ever exactly alike. I like teaching math and I like having the freedom to control, for the most part, what I do in the classroom. I wish there was less paper work involved so teachers could spend more time teaching. I get upset when I think about the way the teaching profession is perceived by the general public. I agree that some change in mathematics education is necessary, but I believe much of the reform should occur in early grades, with more time spent on the basics. At present, mathematics education seems adequate for the higher level and lower level students, but average students are being totally left out; they're the forgotten majority. When I plan the curriculum which I teach inside my classroom, I depend on three things: end-of-course tests, sequencing presented in the textbook, and my own experience. I think end-of-course testing is of no value and in some ways seems to hurt the overall math program. I often feel that I need to rush through certain topics just to get to the end of the book. I don't really see a longer school day or year as a solution, because students and teachers tend to burnout. I think part of "what's wrong" with mathematics education today has more to do with attitude than actual education. Students simply do not value knowledge. The NCTM Standards don't address that problem. I had never heard of the Standards before this study began. I believe the Standards probably could be implemented into the present curriculum, but not without teachers who are willing to make the effort and textbooks that parallel the type of instruction implied by the Standards. I have no faith in those persons outside education who always seem to know just how to fix every problem. I would gladly make changes in the way I teach if I could be assured the students would benefit, but not to improve test scores alone. Overall, I believe the NCTM Standards are very idealistic and as such, it would be difficult to include them in the current curriculum. Before teachers can use these Standards as curriculum guides by which to teach, they first have to understand them. That in itself may be a huge task."

Teacher # 4:

Years of teaching experience: 19

Highest educational degree: BS

Certification: Mathematics

Current Teaching Assignment: Geometry, AG; Algebra I, AG; Alg I, Part 1; Alg III/Trig

Teaching attitudes: "I like working with students and being able to watch them grow-up, mature and develop their own personalities. I enjoy working in the field of mathematics and teaching it most of the time, even though it can be a difficult subject to teach. I get angry when teachers are given the blame for all the things wrong in education. Overall I agree that the mathematics education currently being received by most students is minimal. I believe lack of knowledge in mathematics can be traced back to the early grades where students were either unsuccessful or became unconcerned. Students in high school not only do not know the basics, they also do not know how to <u>think</u>. The curriculum I use in my classroom is determined for the most part by state guidelines and end-of-course tests. We should be using end-of-course testing to insure that minimum requirements are being satisfied at each level of mathematics; however, currently they seem to serve no purpose. There is no quick-fix for today's educational problems; most of the problems in schools are simply a reflection of the problems in society. I think it's time the public realized that the schools can't solve every problem, that most teachers are dedicated and handle a difficult job quite well, in spite of outside interference. I wouldn't make radical changes in the way I teach; I feel more comfortable with the idea of slow, gradual change. I really had no knowledge of the NCTM Standards before this study and I'm not really that comfortable with them. If I thought I had to implement all those standards into the present curriculum, first I'd panic. Then I'd ask <u>how</u> to do it, because I wouldn't know where to start."

Teacher # 5:

Years of teaching experience: 26

Highest educational degree: BS

Certification: Mathematics and Chemistry

Current Teaching Assignment: Tech Math; Alg I, Part 2; Algebra I

Teaching attitudes: "I like associating with young people and the variety of teaching five different groups of students each day. There seems to be a lot of pressure being placed on math teachers for students to perform well on SAT and college placement tests. It's hard to keep motivating yourself to do a good job when there are so few signs of appreciation from administrators, parents, and community members. I wish more parents cared about and understood what was best for their child in the long run. I believe some of the demands for reform in mathematics education are justified, mostly in the classes for average students. I believe we have to begin in the lower grades with more emphasis on basic skills and problem solving. I think math teachers have to start giving more examples of problems which require deductive thinking skills. The curriculum I use to teach my classes however is determined by the state guidelines, end-of-course tests, and the book. End-of-course testing in theory should improve mathematics education, but in reality it hasn't. I'm not really that familiar with the NCTM Standards, but I believe they probably could be phased into the present curriculum over a long period of time. However, I don't believe the Standards alone can cure the present lack of mathematics knowledge among our youths. There are many factors other than curriculum that affect a student's success or lack of it. There are no quick-fix programs, and I won't change the way I teach unless I'm convinced it will help the students."

Teacher # 6:

Years of teaching experience: 27

Highest educational degree: BS+

Certification: Mathematics, Dept Chairman

Current Teaching Assignment: Alg II/ Trig; Consumer Math

Teaching attitudes: "I enjoy working with young people who are motivated and enthusiastic. I like the concreteness of mathematics and believe it is the best subject to teach. We could improve education 100% if we were able to get rid of about 80% of all administrators and support personnel -- these people spend all day thinking up more busy work for teachers to do, rather than the one thing they need to do -- teach! I do not respond to public demands for educational reform. Inside my classroom, I do what I feel should be done. Most schools have an outdated mathematics curriculum and low standards of expectation for achievement. I believe we do need to make mathematics more relevant to the needs of all students through periodic updates and the reassessment of needs. Higher performance standards must be established and enforced at all grade levels. The curriculum I teach in my classes is determined by course objectives and the sequencing determined by the textbook. End-of-course testing is a good concept, but right now the standards are too low. Most of the other attempts presently being made by the state to upgrade mathematics education are a waste of time and money. I'm not familiar with all the NCTM Standards, but I believe a few of the Standards could be implemented by individual teachers under present conditions by just doing it. However most of the Standards would require further teacher training and the development of appropriate materials. Some of the Standards are good and certainly some might improve mathematics education, but they certainly are not a total cure for all the mathematical educational 'ills.' Teachers working alone will never be able to implement all the Standards. Full implementation would require a total commitment from all levels of education. Teachers would require further educational training, new materials and textbooks would need to be adopted, greater parental and public support would be needed; all of which require time and money. People who think they know how to provide quick solutions to the problems in education are not realistic and are just a pain to contend with. A goal of higher test scores would never be enough to make me change the way I teach. Under the present conditions of mass education, I would greatly question the wisdom of any decision to alter the present curriculum and methods of instruction."

Teacher # 7:

Years of teaching experience: 20

Highest educational degree: Ed. S.

Certification: Mathematics, AG

Current Teaching Assignment: Alg II, AG; Computer Prog; Adv. Math; Alg I, Part 1

Teaching attitudes: "I enjoy watching students grow academically and seeing their faces 'light-up' when they finally understand a difficult concept. I enjoy the order and structure of mathematics. I wish the public would realize that teaching is a demanding job and that there are no short-cuts in education. I find it difficult to deal with the public's attitude toward education and with students who don't want to learn. I agree that some reform is needed in mathematics education, but not for the sake of improved SAT scores. State Department officials and other professionals may have some sound ideas about how to improve the mathematics education of our students, but these ideas never reach the individual teacher. Most mathematics teachers have never even seen a copy of the NCTM Standards. Education is hard work and requires commitment from teachers, students, and parents. Inside my classroom, curriculum is determined by the Basic Education program, the textbook, and my own personal experience. Right now, end-of-course testing represents nothing more than minimum competency. I feel only slightly familiar with the NCTM Standards. Certainly not all standards can be reached by all high school students. It seems to me that the Standards are directed more toward college-bound students rather than toward all students. The implementation of the Standards could possibly improve mathematics education, but certainly not solve all the problems. There are many things that would add interest to the classroom so that students could see how mathematics is used, but taking the time to do these things takes time away from covering the book and course objectives. Also before most teachers, including myself, could explore many of the Standards with students, more education and training would be required. I'm sick and tired of all the talk about what's wrong with education. I believe those involved in education at all levels need to work together to decide the best strategies for improvement. I will not respond to demands for higher test scores and will not change the way I teach unless I know it will improve education. I agree with the idea of spending less time drilling concepts that calculators can handle and more time on problem solving, but I would panic if I thought I had to implement all those Standards without any training or material."

Teacher # 8:

Years of teaching experience: 16

Highest educational degree: BS+

Certification: Mathematics and Middle School Science

Current Teaching Assignment: Alg I; Consumer Math; Geometry

Teaching attitudes: "I enjoy getting involved with students and the thrill of seeing that 'light bulb' go off when they understand something for the first time. I find mathematics difficult to teach for two reasons: most students are afraid of math and public perception of mathematics is very negative. Most students have to overcome their 'fear' before they can learn, which is not easy when their parents and the media relay a message that it's okay to be dumb in math class -- since no one understands it anyway. I'm all for reform in mathematics education, but it must begin in the early grades. The type of instruction presently used in mathematics classes lends itself to memorization rather than understanding; quantity as opposed to quality is stressed. Mathematics education in high school has, in theory, developed into a series of classes for a select few where the average student is discouraged from taking math. Geometry has been labeled as too theoretical for most students. The mathematics curriculum of today is almost completely determined by end-of-course tests and by state adopted textbooks. Teaching for end-of-course testing leaves no time for equally important 'extra' material. I was familiar with the NCTM Standards prior to this study and believe that implementation will be slow and difficult. Right now, educators need a time interval devoted to improvement, without being pressured about test scores. We need to concentrate on critical thinking skills; of course some of the other aspects of the curriculum would suffer, and test scores might even decline. I won't change the way I teach just for the sake of test scores. However, if we can find a way to better prepare the students for the future, then, yes I'll do whatever it takes. Right now there's so much to do and so much pressure from the outside that teachers have no time to plan or explore new methods of teaching. I believe it was the quick-fix people in education who put us where we are today, in quick sand. If you want me to implement the NCTM Standards, then give me suggestions and methods, then the time necessary to plan and do it."

Teacher response to each of the questions asked can be summarized as follows:

Q 1. What are your personal feelings regarding the teaching profession?

A 1. The greatest pleasure of the teaching profession is the opportunity to work with young, motivated, interested students. One of the biggest thrills in life is seeing a young person grow and develop before your very eyes, or being able to make a difference in someone's life. The teaching profession is difficult, and most of the general public have no ideal of the pressure involved in being a dedicated, caring teacher. But despite those huge negatives, the actual 'teaching' aspect of the profession is very enjoyable.

Q 2. What are your personal opinions concerning the status of mathematics education today?

A 2. The majority of students are leaving high school with minimal skills in mathematics. Students know the requirements for graduation and are encouraged by counselors, parents, and friends to stop taking math as soon as they meet those requirements; many students have 'math avoidance.' The curriculum is outdated and neither relevant nor interesting to students of today who are accustomed to the instant results and gratification of calculators and computers. Standards of expectation are low. Mathematics is still being taught as a memorization-type skill, with drill and practice as a common instructional process.

Q 3. How do you respond to outside demands for change?

A 3. Some reforms in mathematics are warranted. However, until the individual teacher is seen as a part of the solution, rather than a part of the problem, outside demands will produce very little change and no lasting results. Teachers resent people outside education (the classroom) who are quick to point out existing deficiencies without providing solutions and the appropriate tools necessary to achieve them.

Q 4. How do you determine the individual course curriculum for each of your classes?

A 4. Teachers tend to use the textbook, and personal experience almost exclusively to determine the curriculum in any individual course. End of Course testing has also come to play a major role in determining course curriculum, followed by sequenced courses which require a certain amount of material to be covered. Teachers sometimes use the outlines which are provided by the Basic Education program. However, in reality, nothing influences what a teacher teaches as much as the 'next section in the textbook.'

Q 5. What is your initial reaction to the NCTM Curriculum and Teaching Standards?

A 5. The NCTM Standards alone will not change mathematics instruction; dedicated, educated, willing and informed teachers will.

Q 6. What factors do you personally believe will enhance/inhibit the implementation of the NCTM Curriculum and Teaching Standards?

A 6. Those factors which might enhance NCTM Standard implementation:

--Students take more responsibility for their own learning.

--Learning mathematics is more relevant to the individual student.

--The study of mathematics becomes less stressful for students and teachers.

--Students gain strength as problem solvers and independent thinkers.

Those factors which might inhibit NCTM Standard implementation:

--Time.

--Class size.

--Lack of appropriate teacher training.

--Lack of appropriate materials.

--Money.

--Lack of general agreement on how to 'fix' mathematics education.

--Lack of planning time.

--Parents and students who are not ready to accept change or new trends in education.

--Inability of observers to evaluate teachers who act as facilitators of learning.

--Teachers who cannot or will not change their ideas and methods of teaching.

Table 7 provides a summary of selected data for the eight South Caldwell math teachers.

Following the first set of individual interviews, a large amount of personal data had been collected for the eight mathematics teachers who were participants in this case study. From the number of years of teaching experience, it was evident that this mathematics faculty was well established, with all but two members having at least fifteen years of teaching experience. These teachers had long since developed their own individual teaching styles and were reluctant to make drastic program changes at the suggestion of outside influences. Specifically, only the teacher with the fewest years of experience (eight years) indicated a willingness to change, with seven of the eight teachers stating they would not change their teaching methods for the sake of improving test scores alone. However, all eight teachers indicated they were willing to change if they had some ideal that students would benefit. All eight of these teachers indicated they enjoyed being around young people, that they liked their jobs, and that their greatest pleasures came from seeing students learn

TABLE 7

Summary of Selected Data for the SCHS Mathematics Faculty

SEX

# of male math faculty	3
# of female math faculty	5

Years of teaching experience

5 - 10	1
11 - 15	1
16 - 20	4
26 - 30	2

Highest educational degree

BS - Teaching	7
Ed. Specialist	1

Career selection

Would choose teaching as career today	5
Would not choose teaching as career today	3

Would make radical changes in their teaching methods for the sake of improving test scores

willing	1
unwilling	7

Prior knowledge of NCTM Standards

Had prior knowledge	1
Had slight knowledge	2
Had no knowledge	5

Believed the NCTM Standards (or some other method) would provide a 'quick-fix' for the present lack of mathematics knowledge among today's youth.

Yes	0
No	8

TABLE 7 (Continued)

Membership in Professional Organizations

Organization	Membership	
NCAE	Yes	6
	No	2
NCTM	Yes	1
	No	7
NCCTM	Yes	3
	No	5
Other	Yes	0
	No	8

and achieve. This faculty was truly concerned about the quality of education their students receive, but were discouraged because of public opinion and lack of respect for their profession. Seven of the eight teachers did not believe that the implementation of the NCTM Standards alone can 'cure' or improve the present lack of mathematics knowledge among today's youth. They stated a belief that only dedicated, educated, willing and informed teachers will improve mathematics education. These teachers all expressed a degree of resentment for those individuals outside education who spend a lot of time talking about all the things wrong with education without supplying the methods and materials necessary to improve them. Only one of the eight teachers indicated having knowledge of the NCTM Curriculum and Teaching Standards and recommendations prior to the onset of this study, and then only as a result of information received during continuing college course work. They believe education is not likely to improve until teachers understand what they should do to make those improvements.

The eight members of the South Caldwell High School mathematics faculty all agreed to participate in the evaluation of the current mathematics curriculum with regards to the NCTM Curriculum and Teaching Standards of school mathematics in grades 9-12. This investigator has found them all to be extremely cooperative and receptive to any suggestion which might improve mathematics instruction and education at SCHS.

The Students

The students who attend South Caldwell are typically from middle to upper-income families. On the average, less than 1% of the student body is composed of students from minority groups. Students typically score at least twenty points above the state mathematics SAT average of 440, and compiled an average mathematics score in 1990 of 462 with 41% of all senior students participating. More than 65% of all graduating seniors continue their education, either in four year colleges, two year community colleges, or in vocational training. Students at SCHS average 10-15 points above the state average on the mathematics competency test. One of every three students do not reside with both natural parents.

The current mathematics enrollment at South Caldwell is 895 in regular classes and 29 in special education, for a total of 924 of the 1141 students who attend. The course selection in mathematics is quite diverse and ranges from General Math to College Calculus. Tables 8 and 9 offer detailed information concerning the course offerings and student enrollments in the various mathematics classes for the 1990-91 school year.

TABLE 8

Mathematics Course Enrollment for 1990-91

Course Title	# of students enrolled
General Math	77
Consumer Math	88
Algebra I, Part I	103
Algebra I, Part II	56
Algebra I	174
Algebra I - AG	11
Algebra II	50
Tech Math	64
Geometry	109
Explo Geometry - AG	12
Algebra II & Trig	63
Exp Algebra II - AG	26
Algebra III & Trig	10
Advanced Math	15
Computer Programming	22
Precalculus-Calculus	15
Math 1 - E	7
Math 2 - E	1
Math 3 - E	4
Math 1 - L	11
Math 2 - L	6

TABLE 9

Mathematics Course Enrollment Percentages for 1990-91

CLASS LEVEL	# STUDENTS ENROLLED IN MATH CLASSES	# STUDENTS IN CLASS LEVEL	% OF STUDENTS ENROLLED
9 TH GRADE	342	349	97.99%
10 TH GRADE	261	278	93.9%
11 TH GRADE	208	273	75.4%
12 TH GRADE	113	241	46.9%
TOTALS	924	1141	80.9%

Evaluation Plan

The evaluation and case study consisted of three phases: (1) preparing to evaluate; (2) a program evaluation, which included the assessment of problem solving opportunities within the pre-existing curriculum, recommendations for change required to satisfy Standard 1; and the attempted implementation of those recommendations; and, (3) post implementation period, including the assessment of the attempt to implement Standard 1. For the convenience of the reader, the actual time period for the evaluation plan is shown in Tables 10 and 11.

Preparing to evaluate

Since the purpose of this inquiry was to assess the current status of problem solving in the SCHS curriculum and to examine the degree of congruence between this curriculum and the recommendations for problem solving found in NCTM's Standard 1, teachers had to be familiar with those Curriculum and Teaching Standards and the method which were to be used to assess those recommendations of Standard 1. Since seven of the eight teachers were not familiar with the NCTM Standards, this investigator held a focus group of all eight mathematics teachers, during which each of the fourteen Standards were discussed in the following manner: perceived degree of importance within the present mathematics curriculum; suggested methods which

TABLE 10

Evaluation Activity Time-Table #1

Preparing to evaluate:

WEEK ONE - FOUR:	Individual interviews. Focus Group, formulation of definitions. Assimilation of information from interviews. Focus Group, discussion of NCTM Standards.
WEEK FOUR:	Curriculum assessment through individual checklists. Teachers maintain individual journal. First group profile for curriculum inventory. Focus Group, discussion of Curriculum Inventory Profile, including recommendations for change.

Implementation of Standard 1:

WEEK FIVE:	Teachers begin implementation period. Teachers maintain individual journal. Teachers maintain portfolio of student work. Teachers complete weekly checklist. Evaluator completes problem solving progress graph. Weekly Focus Group.
WEEK SIX:	Implementation period continues. Teachers maintain individual journal. Teachers maintain portfolio of student work. Teachers complete weekly checklist. Evaluator completes problem solving progress graph. Weekly Focus Group.
WEEK... : THIRTEEN	Implementation period ends. Teachers maintain individual journal. Teachers complete second curriculum inventory checklist. Return checklist and portfolio of student work to evaluator. Second group profile for curriculum inventory. Evaluator completes problem solving progress graph. Teachers administer Problem Solving Student Attitude Assessment Survey. Weekly Focus Group.

Post Implementation:

WEEKS ... : FOURTEEN -- SEVENTEEN	Second individual interview. Final Focus group. Examination of completed journals and portfolios of student work.

TABLE 11

Evaluation Activity Time-Table #2

ACTIVITY	Preparing To evaluate WEEK 1-4	Implementation period WEEK 5	WEEK 6	WEEK... 7	WEEK 13	Post Implementation WEEK 14-17
Individual interviews:	X					
Focus groups (2):	X					
First Curriculum Inventory:	X					
Group profile for curriculum inventory:	X					
Individual journals:	X	X	X	X	X	X
Standard implementation:		X	X	X	X	
Weekly checklists:		X	X	X	X	
Portfolio of student work:		X	X	X	X	
Weekly graphs:		X	X	X	X	
Second curriculum inventory checklist:					X	
Second group profile for curriculum inventory checklist:					X	
Second individual interview:						X
Final focus group:						X
Student Attitude Assessment Survey:						X
Examination of data :						X

individual teachers might use for implementation; and, changes perceived to be necessary before complete implementation would be achieved. (See Appendix C for a complete discussion of all fourteen Standards.) This meeting served to familiarize teachers with the Standards and to generate an informal comparison of the pre-existing curriculum and the type of instruction advocated by the Standards. The results of the discussion for Standard 1 are as follows:

Standard 1: Mathematics as Problem Solving

a. Importance in curriculum: vitally important. Mathematics is problem solving, therefore if students are not learning problem solving, they are not learning mathematics.

b. How to implement: Teachers can begin implementation through a series of exercises, where students are introduced to a variety of problems, including both routine and nonroutine problems with routine and nonroutine methods for finding solutions. Students should be taught to view mathematics in a more personal and relevant manner, and to learn to generalize solutions to different problems in mathematics and in everyday life. Teachers should gradually increase the frequency for problem solving activities and make every effort to incorporate problem solving strategies into appropriate teaching methods.

c. Changes required for full implementation (where problem solving is part of the mathematics curriculum): Teachers must realize the importance of problem solving in the mathematics curriculum. Second, teachers believed that before they could teach most topics from a problem solving approach, they would require extensive re-training. There should be less emphasis placed on end-of-course testing and less pressure to cover all the pages in the text. Finally, and perhaps most important, there must be development and provision of new textbooks with appropriate materials which emphasize mathematics through a problem solving approach, since most textbooks currently emphasize drill and practice.

During this focus group where each of the fourteen curriculum and teaching standards were discussed, it was apparent that a list of standards alone is not very helpful to teachers. Several of the standards set forth clear, important goals, yet a method of implementation and subsequent assessment of that implementation were difficult for these teachers to formulate. Without exception, upon discussion of each of the fourteen standards, teachers stated that implementation could only occur when teachers were retrained and were provided with the new textbooks and materials necessary to supplement instruction. Time, money, materials, training and resistance to change were cited as inhibitors to the implementation of the NCTM Standards.

Teachers were then given the five indicators of quality which were developed for the evaluation of problem solving within the mathematics curriculum. Since several terms used within these indicators can be interpreted in various ways, a second focus group was held for the purpose of defining for use in this study the following terms:

curriculum
problem solving
regular basis
nonroutine problems
mathematics from everyday life

Table 12 lists the definitions which were used for the duration of this study.

At first, teachers were eager to formulate their own definitions for the terms being used during the study. The investigator had elected to use a focus group for the development of these definitions in order to allow those teachers involved to gain ownership of and involvement in the study and this seemed to work well. However, later during this study, it was evident that some of those definitions created problems for the teachers who were attempting to use them. At that time, the teachers indicated they felt inadequate to interpret and define those terms used by NCTM and stated a belief that this

TABLE 12

Definitions Which Were Used During The Study

1. CURRICULUM -- any activity which occurs as a result of attending a particular school.

   In a classroom -- the curriculum is an operational plan for instruction and includes what students need to know, how they will learn and what the teacher will do to help students to develop their knowledge.

2. PROBLEM SOLVING -- any attempt, as well as the process involved, to find an unknown solution for an existing question.

   Problem solving includes the ability to :
   1. define the problem
   2. formulate a plan
   3. use various techniques appropriate for the problem
   4. verify results

3. REGULAR BASIS -- at least once weekly, in the beginning with increasing frequency as the study continues.

4. NONROUTINE PROBLEM -- any problem not normally found in a particular course; problems for which the students are not taught specific solution methods; problems which require investigation and organization, rather than the use of a particular math skill. (See Appendix E for examples of nonroutine problems.)

5. MATHEMATICS IN EVERYDAY LIFE -- any mathematics which encourages the development of independent and organized thinking ability. (See Appendix F for examples of mathematics problems from everyday life.)

should have been done by professionals (NCTM) in order to assure the widespread use by all teachers of one definition for each of those terms. A review of teacher comments and the study in general has caused this investigator to believe those definitions should have been provided for teachers rather than allowing them to be developed.

Following the formulation of definitions, this investigator determined that the "preparing to evaluate" stage was complete. The program evaluation began at this time.

Program evaluation

The assessment of the congruence of problem solving in the current curriculum and the recommendations of NCTM's Standard 1: Mathematics as Problem Solving was done in the following manner. Each of the eight mathematics teachers were asked to complete a curriculum inventory checklist. The checklist allowed teachers to give detailed self-reporting of whether the pre-existing curriculum allowed students the opportunity to engage in solving a variety of routine problems and nonroutine problems on a regular basis (at least once weekly), whether the problems define everyday life, whether the students verify and interpret their results, and whether students generalize strategies to other situations. The eight teachers responded, using a likert scale from 1 to 5, where: 1 = never, 2 = seldom, 3 = occasionally, 4 = frequently, and

5 = on a regular basis. Individual checklists were returned to the investigator, who used the data to compile a group profile for curriculum inventory (see Table 13), indicating by an average the degree to which the mathematics curriculum was used to provide problem solving activities for students. The group profile sheet was used to determine the congruence of the original mathematics curriculum and Standard 1 recommendations.

Using the information from the group profile for curriculum inventory (see table 13), this investigator conducted a focus group with the members of the mathematics faculty. (Throughout the course of this study, the focus group meetings evolved into a very helpful and powerful activity. For it was during the focus groups that the teachers involved were given first time opportunities to examine and think about concepts in new and different ways. Teachers used the other members of the group to clarify and redefine their own ideas and suggestions. When problems came up, teachers found solutions together, causing them to form a strong sense of sharing and comradeship. This bonding among teachers was a very unexpected, yet very positive and pleasant aspect of the implementation period.) The group discussed the findings for the initial problem solving practices, which indicated the opportunity to solve problems in the existing curriculum was between 1 and 2 with 1 = never and 2 = seldom. All teachers agreed that

TABLE 13

First Group Profile for Curriculum Inventory Results

STANDARD 1: The curriculum provides students with the opportunity to engage in problem solving.

Scale: 1 to 5 where:
1 = never; 2 = seldom; 3 = occasionally;
4 = frequently; and 5 = on a regular basis

Standard Indicator: The curriculum provides students opportunity to:	Scale indicated by each: Teacher One	Two	Three	Four	Five	Six	Seven	Eight	Analysis: Average of all scores for this indicator
Solve problems on a regular basis	1	2	3	3	3	1	1	3	2.125
Define problems from everyday life as well as mathematical situations	1	2	3	2	2	1	2	2	1.875
Define and carry out plans to solve a variety of nonroutine problems	1	1	4	2	2	1	2	2	1.875
Verify and interpret their results	1	3	3	2	2	1	2	2	2.0
Generalize solutions and strategies to other situations	1	2	3	2	2	1	1	2	1.75
Average of scores for all indicators of Standard 1:									1.925

typically problem solving opportunities were reserved for the routine word problems which usually occur at the end of a chapter in the book. Often, these problems were considered to be 'extra' and as such, were many times simply omitted due to lack of time and pressure to cover the next chapter. The following questions summarize the questions which were discussed during the focus group.

Q. 1. Does the current curriculum provide students with the opportunity to engage in problem solving on a regular basis?

A. 1. No. With an average score of 1.925 for all indicators for the assessment of Standard 1, it was concluded that problem solving opportunities were between seldom and never.

Q. 2. How often do students engage in problem solving: --is it on a weekly basis? daily basis? etc.

A. 2. Teachers indicated that problem solving activities were usually reserved for application problems (word problems) which are found at the end of a section or chapter in the textbook. Teachers are so busy covering textbook material which might be included on end of course testing, they seldom have time for additional activities. Thus problem solving activities might occur once a month, and perhaps not even then, since many teachers view these problems as 'extra' exercises.

Q 3. Is there a variety of nonroutine problems included in the problem solving activities?

A 3. No. Problem solving activities are reserved for the routine problems (age, coin, DRT, mixture, etc.) which are usually found in textbooks.

Q 4. Do students generalize solutions and strategies?

A 4. No. Students generally wait to be taught specific methods or strategies for each set of problems, then attempt to solve all similar problems using that method.

Q 5. What type or recommendations were made?

A 5. The following recommendations were made:

--Teachers were to begin implementation of problem solving activities on a regular basis (at least once weekly in the beginning, with increasing frequency as the study progressed), thus allowing students to gradually become accustomed to this type of activity.

--Teachers were to define problems from

everyday life as well as from mathematical situations so students would begin to see the relevance of mathematics.

--Teachers were to introduce nonroutine problems into the mathematics curriculum.

--Teachers would encourage students to verify and interpret their results.

--Teachers would provide students with the opportunity to generalize their results and strategies to other situations.

--Teachers would begin to use problem solving strategies and methods to introduce new topics whenever possible.

By allowing students the opportunity to view mathematics in a more relevant and logical manner, the math faculty at SCHS hoped to improve thinking skills, reduce mathematics anxiety, and gradually improve mathematics instruction for all students enrolled in mathematics classes. At this time, using the above recommendations, teachers began the implementation period for Standard 1.

Implementation of Standard 1

This phase of the program evaluation consisted of the attempt to implement the quality indicators for Standard 1. Since the group profile curriculum inventory indicated a clear discrepancy (an average score of less than 4.5 for all indicators on the group profile for curriculum inventory, see Table 13) between the criteria of the pre-existing curriculum and the recommendations of Standard 1, six recommendations for change were made. Teachers began an indefinite implementation period, during which time they were asked to adhere to the previously mentioned recommendations. Teachers were asked to complete weekly checklists, detailing the problem solving activities which were completed each week and the degree of compliance with the above recommendations. In addition they were asked to maintain a portfolio of student work for verification, and individual journals in which they were to detail the frequency of problem solving exercises, student reaction, teacher reaction, and future plans. A copy of a completed weekly checklist from Teacher # 1 for week one is given in Table 14.

The implementation of Standard 1 began slowly, with the first week showing very little progress toward satisfying all five indicators. The easiest indicator to implement and the first to receive eight positive responses was the first indicator -- providing students with the opportunity to solve problems on a regular basis. Teachers indicated this was the easiest indicators to satisfy since all they had to do was find an appropriate activity. Providing students with nonroutine problems (indicator 3) was the second indicator to be satisfied, with providing problems from everyday life third (indicator 2). Allowing

TABLE 14

Weekly Individual Checklist for Week One

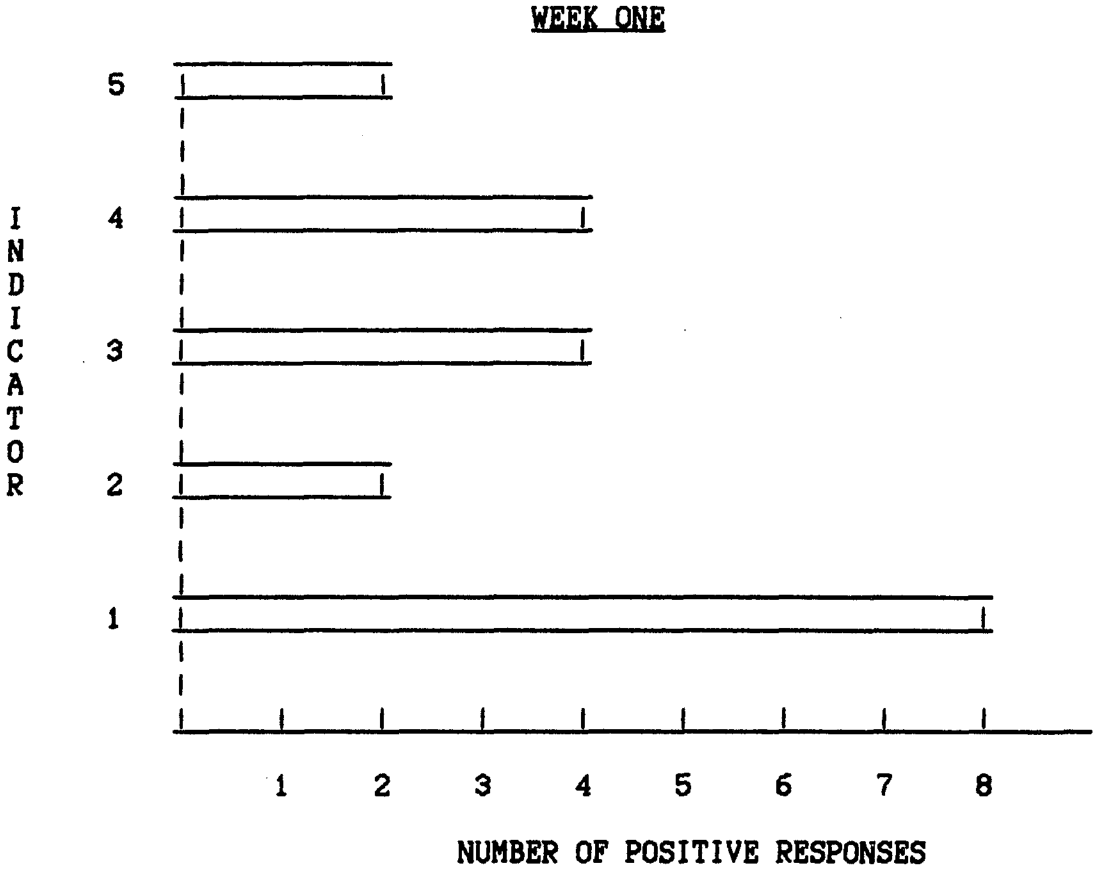
Teacher: # 1 Week: # 1

Standard 1: The curriculum provides students with the opportunity to engage in problem solving.

	Teacher Checklist	
Standard Indicator:		
The curriculum provides students opportunities to:	YES	NO
Solve problems on a regular basis.	X	
Define problems from everyday life as well as mathematical situations.		X
Define and carry out plans to solve a a variety of nonroutine problems.		X
Verify and interpret their results		X
Generalize solutions and strategies to other situations.		X
Number of positive responses:	1	

students to verify and interpret their results (Indicator 4) was the fourth indicator to be satisfied and allowing students to generalize solutions (Indicator 5) was last.

At the end of each week, individual teachers met with the evaluator in order to discuss the progress being made toward standard implementation. Using a tabulation of the checklists, the evaluator displayed progress on both weekly charts and a cumulative graph, plotting the total number of positive responses from all eight teachers as to the number of indicators which were implemented during each week. Teachers were also asked to maintain a portfolio of student work, containing one dated example of each problem solving exercise completed. These examples were used to verify the information indicated by the weekly individual checklists. Figure 1 indicates the tabulation of data found on the eight individual weekly checklists for week one. For example, all eight teachers began to provide problem solving opportunities at least once during the week. Two teachers provided problems from everyday life as well as from mathematical situations. Four teachers provided opportunity for students to define and carry out plans to solve a variety of nonroutine problems. Four teachers allowed students to verify and interpret their results, and two of the eight teachers provided opportunity for students to generalize solutions and strategies to other situations. When all eight teachers had responded 'yes' to all five



KEY

Indicator 1: The curriculum provides opportunity for students to solve problems on a regular basis.

Indicator 2: The curriculum provides opportunity for students to define problems from every day life as well as from mathematical situations.

Indicator 3: The curriculum provides opportunity for students to define and carry out plans to solve a variety of nonroutine problems.

Indicator 4: The curriculum provides opportunity for students to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 1. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week One.

indicators, a focus group was held to determine whether Standard 1 had been successfully implemented. The findings for each week are displayed in Figures 1 - 9, followed by the cumulative weekly progress graph (see Figure 10). This graph shows for each week, the combined total from all eight teachers, the number of 'yes' responses on the weekly individual checklists. The quality indicators for Standard 1 were considered satisfied when the cumulative graph reached a score of 40 (all eight teachers responded yes to all five indicators.

At the end of the first week, the investigator examined the weekly checklists for each teacher along with the individual journals and the portfolios of student work. All eight teachers had begun gradually, adding only one problem solving activity to their regular instructional process. Four of the eight teachers had elected to have their students work together in small groups, usually two to four students, while the other four had students working independently. The types of problems given to students ranged from serious problems (solving Pascal's triangle), to problems which seemed more entertaining like the following:

> Simon is designing a number triangle to quiz his classmates. If he continues the pattern below, what will the sum of the numbers be in the tenth row?

1

3 5

7 9 11

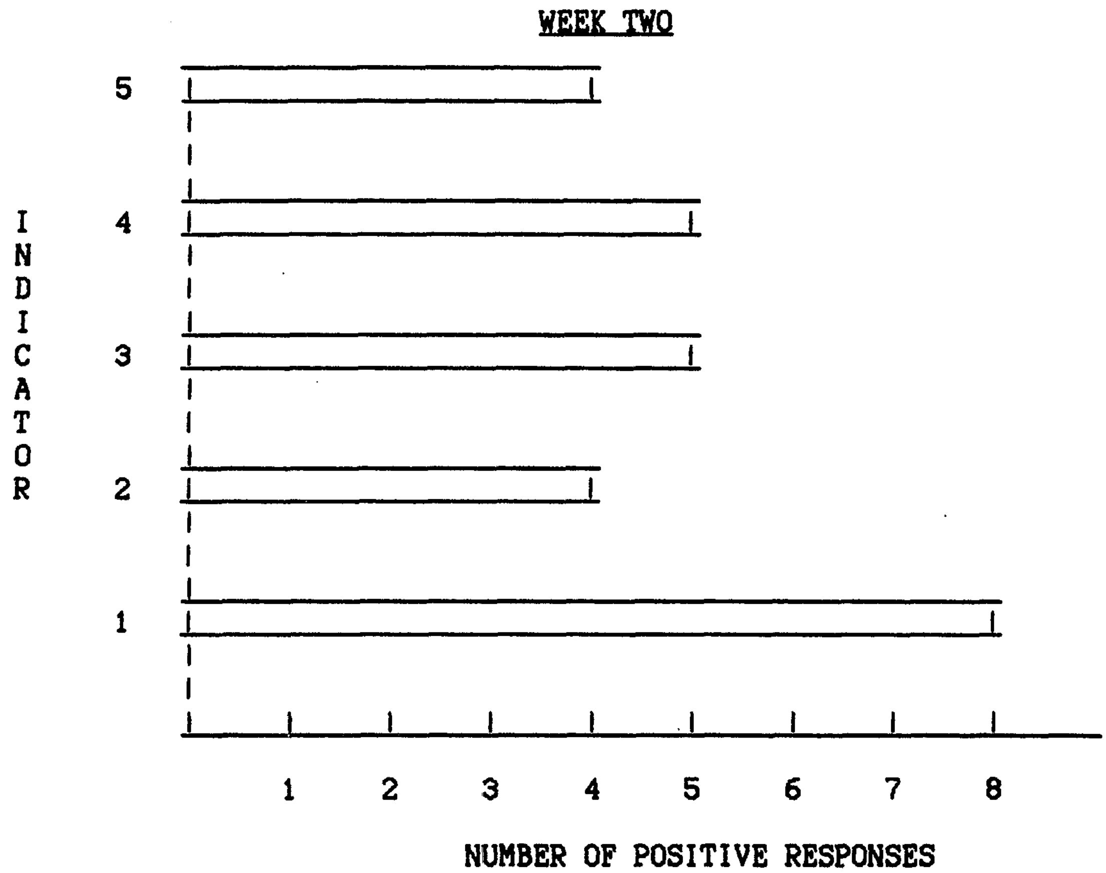
13 15 17 15

Teachers who began with less serious problems reported extremely positive results from their students, but even the more serious problems generated enthusiasm from students who seemed to welcome the change. Since only two teachers had indicated they were providing problems from everyday life as well as mathematical situations (indicator 2), this investigator examined the problems solving activities presented by these two teachers. One of the problems stated:

> A fireman was standing on the middle rung of a ladder, spraying water into a burning building. As the blaze lessened, he climbed up 3 rungs. A sudden flare sent him down 7 rungs. When the fire died down, he climbed up 9 rungs. When the fire was finally out, he climbed the remaining 4 rungs to the top of the ladder. How many rungs were on the ladder?

At this point, the investigator reminded teachers of their definition of mathematics from everyday life (see table 10). In reality, each of the problem solving activities from all eight teachers were meant to encourage the development of independent and organized thinking ability (indicator 2). However, teachers seemed to be looking for only consumer type problems rather than problems which satisfied their own definition. (Examples of problems from everyday life can be found in Appendix F.) This continued to be a problem for teachers (particularly teacher #4 and teacher #5) for the first four weeks of the study. The last area of concern for week one concerned indicator 3. While all problem solving activities were accurately classified as nonroutine (according to the definition found on table 10), there was no variety for week one since teachers began with only one exercise during this week.

After week two, an examination of the checklists, the portfolios, and the journals indicated teachers were beginning to remember their definition of problems from everyday life, however this investigator decided to discuss this problem during the weekly focus group after week three since there continued to be a discrepancy between the checklist responses and the actual problem solving activities being done by the students. After week three students were beginning to ask for additional problems, and seven of the eight teachers had increased the frequency of activities and were providing at least two activities per week during week four. After week three there was quite a variety of problems being done as most of the activities involved multiple problems. Students were being asked to verify and interpret their results by developing their own formulas or patterns which would generate solutions for any



KEY

Indicator 1: The curriculum provides opportunity for students to solve problems on a regular basis.

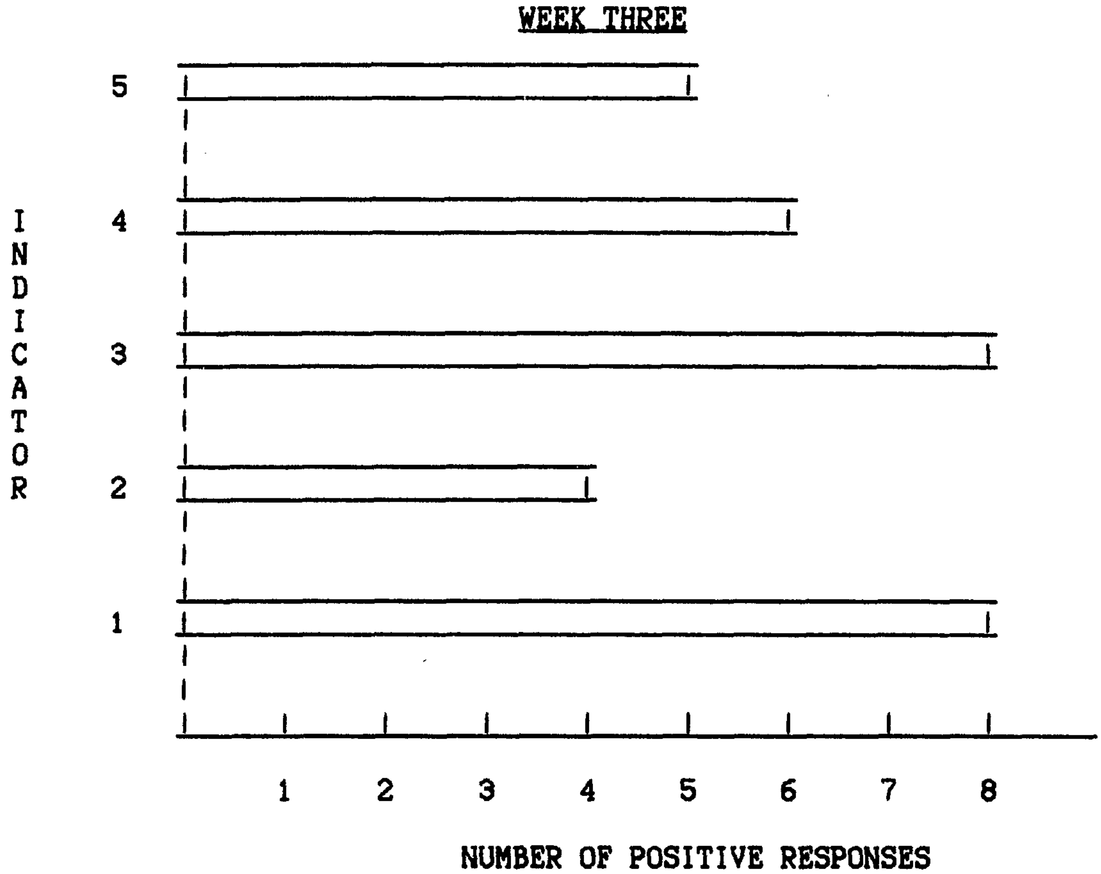
Indicator 2: The curriculum provides opportunity for students to define problems from every day life as well as from mathematical situations.

Indicator 3: The curriculum provides opportunity for students to define and carry out plans to solve a variety of nonroutine problems.

Indicator 4: The curriculum provides opportunity for student to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 2. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week Two.



KEY

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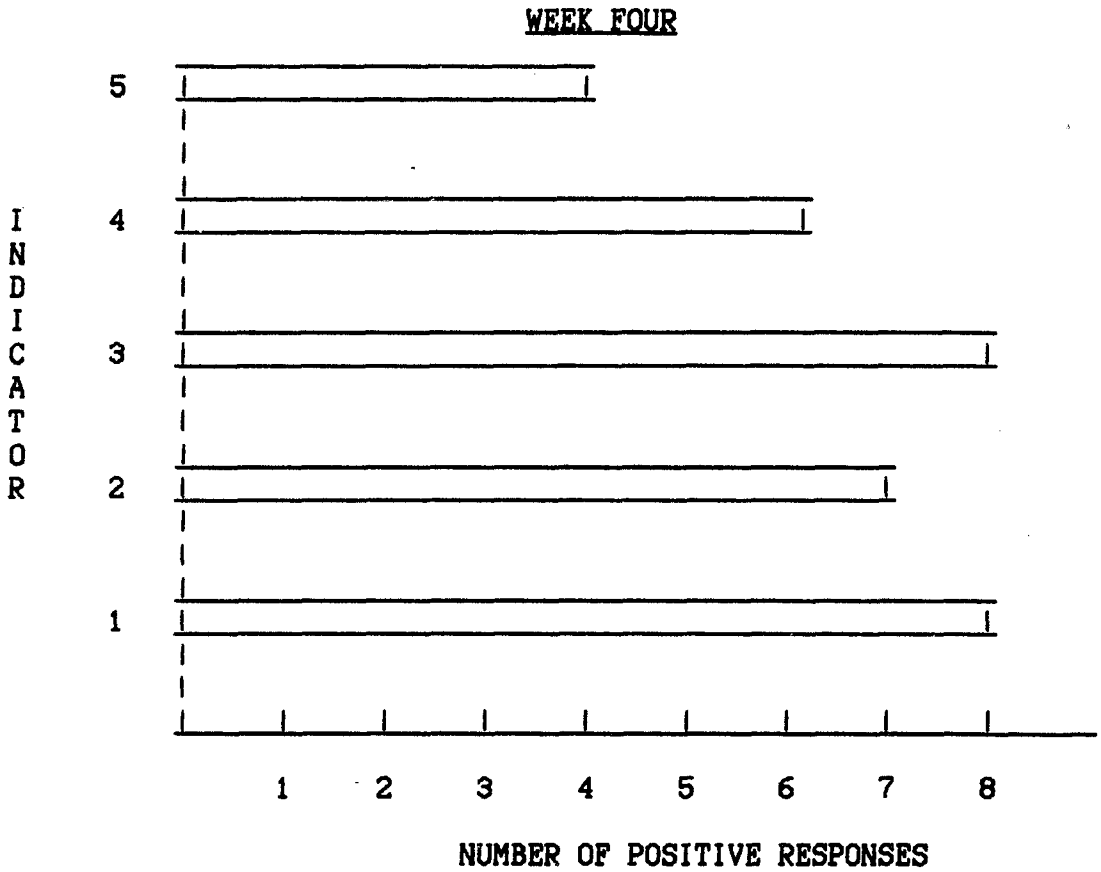
Indicator 3: The curriculum provides opportunity for students to define and carry out plans to solve a variety of nonroutine problems.

Indicator 4: The curriculum provides opportunity for students to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 3. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week Three.



KEY

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Indicator 2: The curriculum provides opportunity for students to define problems from every day life as well as from mathematical situations.

Indicator 3: The curriculum provides opportunity for students to define and carry out plans to solve a variety of nonroutine problems.

Indicator 4: The curriculum provides opportunity for students to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 4. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week Four.

situation rather than a specific one. Only one teacher (teacher #6) continued to offer only one activity per week. Teachers who began the activities as opportunities for students to gain extra credit had, by the end of week three, begun to use problem solving activities as homework grades for students. After three weeks, teachers indicated the need for additional materials, since all problem solving activities were being taken either from resource material teachers had previously, material purchased specifically for this study, or material developed by the teacher. During week three, teacher #7 quoted one student as saying, "I love this stuff," and was planning to use problem solving to introduce the concept of the distance formula the following day to see if any of the students could derive the formula on their own. (It worked!)

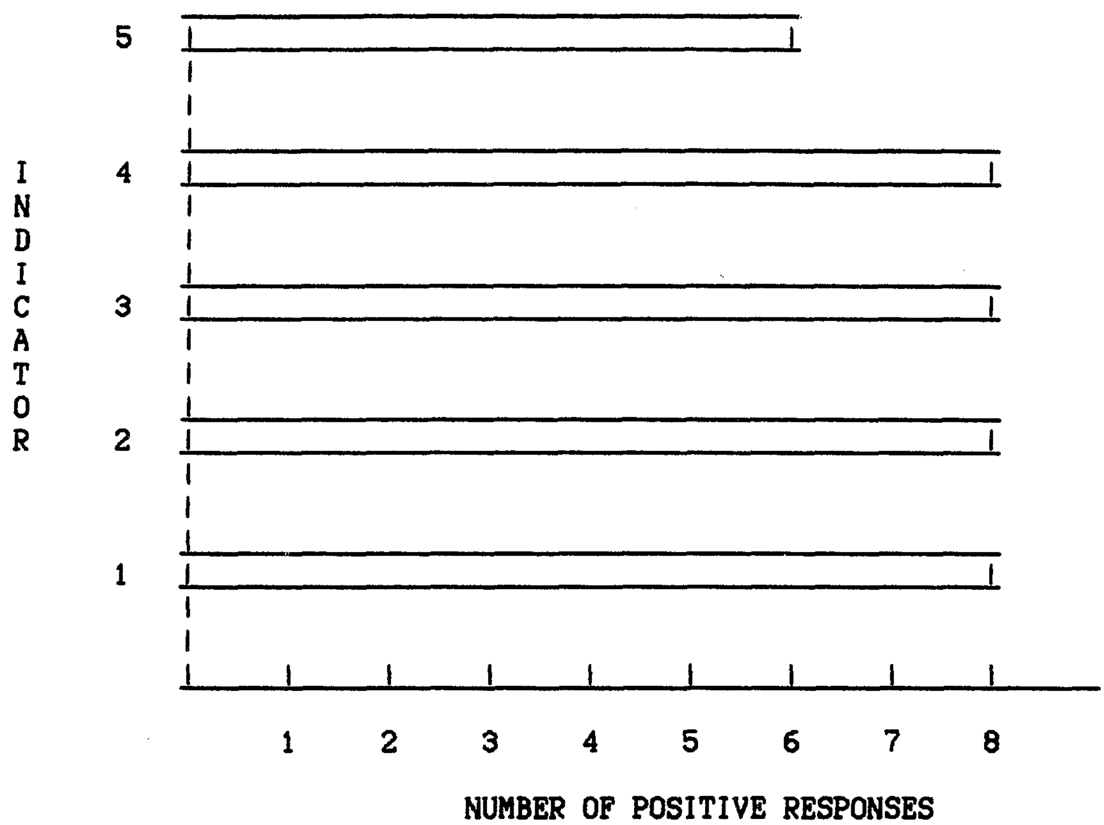
The results from the weekly individual checklists for week two, three and four appear in Figures 2 - 4. By the end of week four, triangulation procedures consisting of an examination of the weekly checklists, the portfolios, and the individual journals indicated there had been significant progress made in the attempted implementation of Standard 1. Seven of the eight teachers were providing problem solving at least two times a week, with two teachers offering some type of activity three to four times per week (some of these activities were done during class in group work, some were done by students independently outside class). Only one teacher (teacher #6) continued to provide only one activity per week. The investigator reminded this teacher that 'on a regular basis' had been defined to be once weekly in the beginning, with increasing frequency as the study progressed. The teacher indicated lack of available time and lack of appropriate materials as problems which were inhibiting an increase in frequency. The discussion of problems from everyday life during the last focus group had helped teachers realize they were satisfying this indicator with most activities. Four of the eight teachers were having difficulty allowing students to generalize solutions and strategies to other situations. During the weekly focus group, one teacher indicated she felt there was confusion as to what this indicator really meant. Therefore, the remainder of the meeting was devoted to a discussion of how to satisfy this indicator. Teacher #7 suggested using an activity much like the following:

> A cevian is a segment drawn from a vertex of a triangle to the opposite side. How many triangles are produced when:
>
> a). 10 cevians are drawn
>
> b). 20 cevians are drawn
>
> c). n cevians are drawn

There was some discussion concerning whether even though this activity allowed students the opportunity to generalize, was it in fact actually generalization to other situations. After much disagreement, all eight teachers agreed this activity satisfied indicator 5. During week four, six of the eight teachers indicated positive responses to indicator 4, however triangulation produced evidence to support only three of those responses. This too was discussed during the focus group. During the focus group discussion, it was discovered that some of the teachers had misinterpreted and were misusing the true meaning of indicator 4 (students have the opportunity to verify and interpret their results). Three of the eight teachers had interpreted "verifying results" as allowing students to check their answers. The focus group discussed the meaning of verify and eventually agreed that the true purpose of the indicator was to allow students to sample data, to analyze and make predictions on the basis of their sample, to make conjectures, to discuss and validate their conclusions, and to prepare arguments to convince others of those conclusions. Students should be analyze their own thinking, rather than depending upon the teacher to tell them whether they are right or wrong. Teachers should stress the problem-solving process, not just the right answer(s). The group determined that some of the problem solving activities should allow students to experience problems with too much or not enough information, in addition to problems with no solution or ones that have multiple solutions, each with different consequences (examples can be found in Appendix E and F). Students then would be asked to verify results, interpret solutions, and question whether a solution makes sense. Such experiences would serve to develop student confidence in using mathematics. This focus group discussion was very productive. From this point in the program evaluation, teachers reported that they had a new and very clear picture of what they needed to do and how to accomplish their objectives. Progress in the implementation of Standard 1 (as indicated in Figures 5 - 9) supports this implication.

The results from the weekly individual checklists for weeks five through nine appear in Figures 5 - 9. An examination of all data from week five produced results similar to week four. Teacher #6 continued to provide only one activity per week, with all other teachers continuing to offer activities at least three times per week. Week five produced all positive responses, from every teacher to every indicator, except indicator 5. Evidence from the portfolios of student work and the individual teacher journals supported every response on the individual checklists, with the possible exception of teacher #6 who had not increased the frequency of activities. Teachers indicated a need for additional materials and a desire to learn new methods of using problem solving to introduce new

WEEK FIVE



KEY

Indicator 1: The curriculum provides opportunity for students to solve problems on a regular basis.

Indicator 2: The curriculum provides opportunity for students to define problems from every day life as well as from mathematical situations.

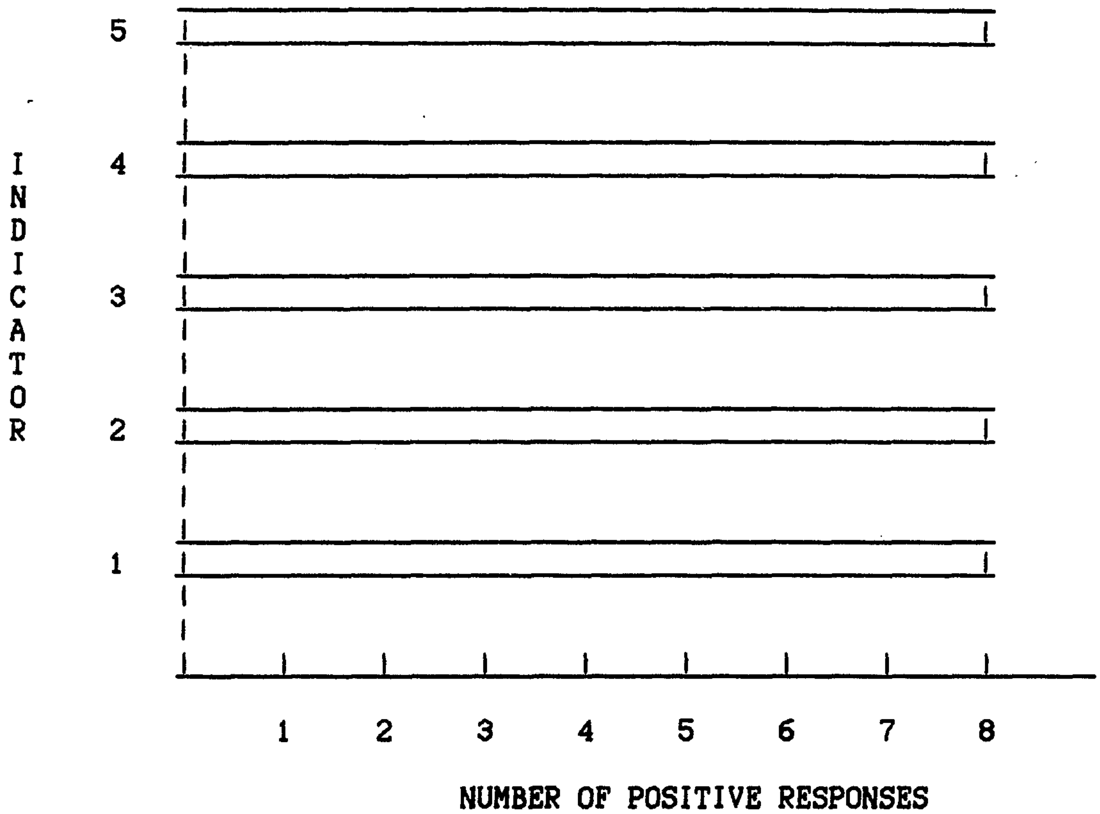
Indicator 3: The curriculum provides opportunity for students to define and carry out plans to solve a variety of nonroutine problems.

Indicator 4: The curriculum provides opportunity for students to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 5. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week Five.

WEEK SIX



KEY

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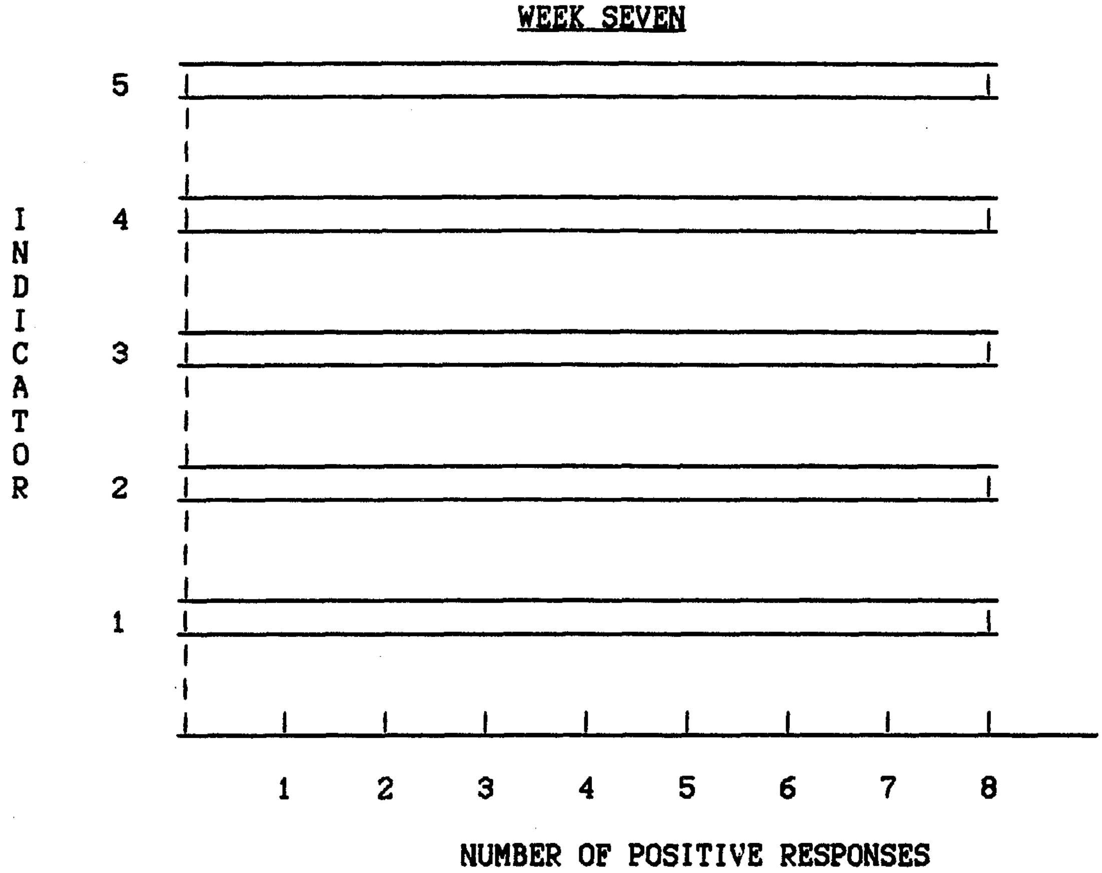
Indicator 4: The curriculum provides opportunity for students to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 6. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week Six.



KEY

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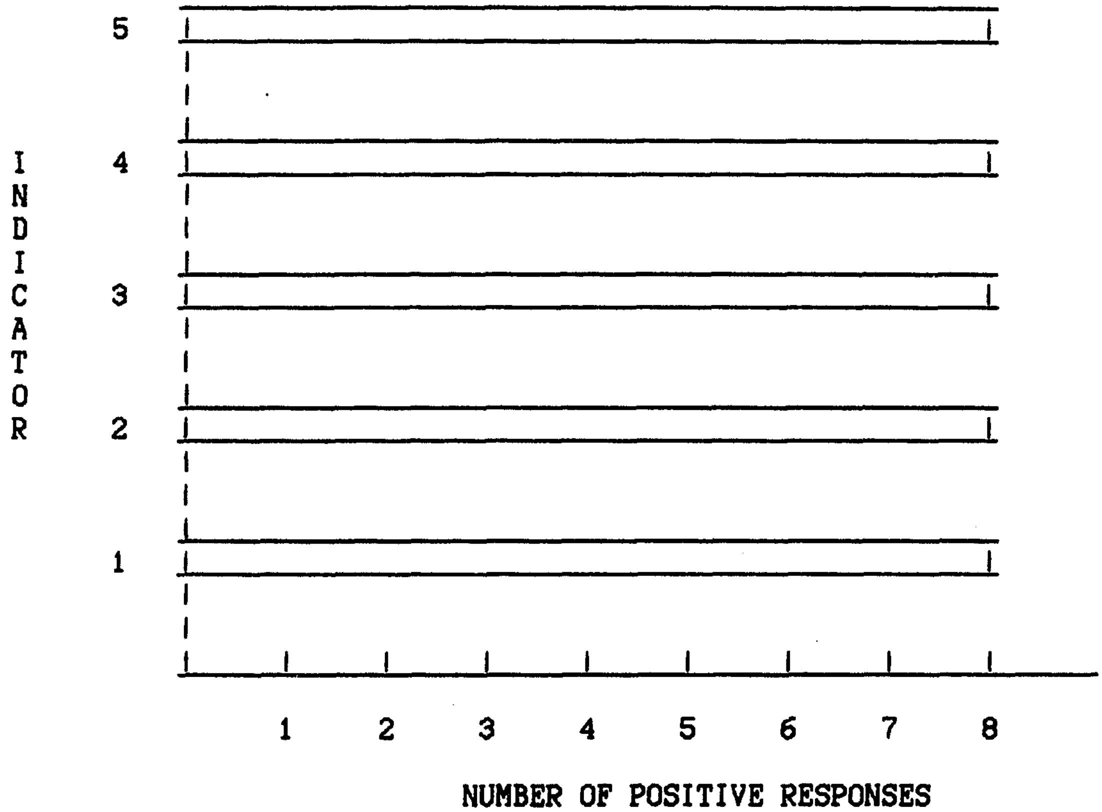
Indicator 4: The curriculum provides opportunity for students to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 7. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week Seven.

WEEK EIGHT



KEY

Indicator 1: The curriculum provides opportunity for students to solve problems on a regular basis.

Indicator 2: The curriculum provides opportunity for students to define problems from every day life as well as from mathematical situations.

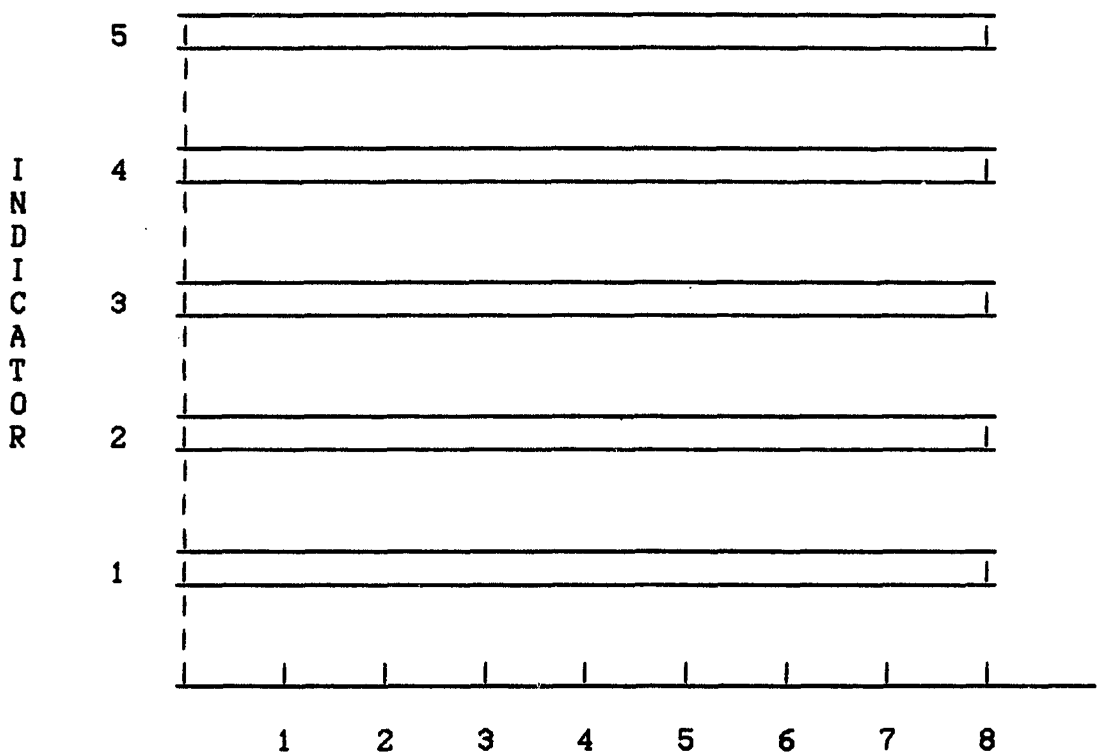
Indicator 3: The curriculum provides opportunity for students to define and carry out plans to solve a variety of nonroutine problems.

Indicator 4: The curriculum provides opportunity for students to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 8. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week Eight.

WEEK NINE



NUMBER OF POSITIVE RESPONSES

KEY

Indicator 1: The curriculum provides opportunity for students to solve problems on a regular basis.

Indicator 2: The curriculum provides opportunity for students to define problems from every day life as well as from mathematical situations.

Indicator 3: The curriculum provides opportunity for students to define and carry out plans to solve a variety of nonroutine problems.

Indicator 4: The curriculum provides opportunity for students to verify and interpret their results.

Indicator 5: The curriculum provides opportunity for students to generalize solutions and strategies to other situations.

Figure 9. Progress Toward Implementation of Indicators for Standard 1: Mathematics as Problem Solving. Week Nine.

materials and a desire to learn new methods of using problem solving to introduce new concepts. Three of the eight teachers had begun to work together, sharing ideas which might help them develop their own strategies. They, however, indicated that time was an inhibiting factor.

Week six produced across the board positive responses to all indicators from all eight teachers. Evidence from the portfolios and the individual journals supported all responses, except those for indicator 4. Examples of student work verified a positive response for seven of the eight teachers, with no evidence of students being allowed to verify and interpret their results during the activity provided by teacher #5. Two teachers indicated they had used problem solving strategies to introduce new topics during this week.

After four straight weeks of similar results (week six through nine), the weekly focus group was used to discuss whether the teachers involved in the study felt Standard 1 had been fully implemented. All eight teachers agreed that even though they believed they could accurately respond 'yes' to all five indicators, they were not 100% sure they had begun teaching in the manner advocated by NCTM in the <u>Curriculum and Teaching Standards.</u> The teachers stated a belief that any attempted implementation of Standard 1 would be limited by the definitions used during the implementation period. (These teachers did not necessarily feel their definitions were poor, they just lacked confidence in their ability to formulate their own guide for Standard implementation.) It was agreed that if teachers are to adhere to NCTM's own vision for Standard implementation, then much work remains to be done by NCTM and other professionals. Each aspect of the Standards must be clearly defined and stated precisely in order to avoid misinterpretation, misrepresentation, and misguided instruction. (For example, how does NCTM define the actual term problem solving, which is basic to any attempt to implement Standard 1, or how would NCTM assess increasing student confidence in using problem solving approaches to investigate and understand mathematical content?) All eight teachers indicated that only after much refinement of the Standards can a true comparison be made between actual teaching practices and those advocated by NCTM. At this time all eight teachers indicated that given the current curriculum requirements, the present textbooks, and the availability of appropriate materials, Standard 1 had been implemented as completely as possible. Therefore given these limitations, it was concluded that full implementation of Standard 1 where problem solving is used for instruction is not possible at this time at SCHS, and that implementation of Standard 1 into the present curriculum can only be done on a limited basis.

During the implementation period, all eight teachers attempted the implementation of Standard 1 in each of their various classes. Thus problem solving activities were provided in all courses, ranging from General and Consumer Mathematics to Advanced Math and Calculus. Teachers indicated the problem solving activities were well received by all levels of students, even eventually those in General and Consumer Math. Many of the lower level students reacted negatively at first, indicating they "just couldn't do word problems." However, a few weeks into the study, teachers were writing in their journals that even those students were responding in a more positive manner. While many students in General and Consumer Math remained adamant throughout the study that they really did not like word problems, (they continuously referred to the problem solving activities as word problems) several students began to indicate that they did in fact have the ability to do these problems and that this type of experience was probably helping them become better in mathematics. One General Math student stated, "You know, for the first time ever, I kinda like coming to math class. Sometimes, it's even interesting."

Triangulation of Data

An examination of the individual checklists, the examples of student work, and the individual teacher journals after week nine yielded the following data for each teacher involved in the study.

Teacher #1:

Beginning slowly, this teacher had spent three weeks providing one problem solving activity per week for students. Thus problems and nonroutine problems were being done on a regular basis, however, students were not generalizing solutions and strategies. Even though this teacher said problems were not being provided from everyday life as well as mathematical situations, they in fact were. The investigator discussed this discrepancy with the teacher. During week four, problem solving activities were increased to two per week, allowing students much more variety in their problem solving attempts. During week five, problem solving activities increased to three per week. During week six, teacher #1 responded 'yes' to all five indicators for Standard 1 and continued to do so for the remaining three weeks, however, there was little evidence to support a positive response to indicator 5. Teacher #1 indicated a desire to continue problem solving activities after the study concluded, stating however, that the number of activities would probably decrease to two per week. Most activities were assigned as extra credit exercises, with students receiving feed back one day after the due date.

Teacher #2:

Problem solving activities from teacher #2 were being done in class, with students working in small groups. By selecting the first problems quite carefully, teacher #2 found that by the end of week two, these activities had created quite an interest among his students; during week three, the frequency for activities increased to two per week, with three activities provided during week four. Teacher #2 stated that time became an inhibiting factor at this point, and chose to continue with three activities per week for the remainder of the study. Most of the problems provided by teacher #2 were much like the following:

> If three clocks were purchased and all set at the same time, how long would it take them to again read the same time if one clock lost 1 minute per day, one clock gained 1 minute per day, while the third clock kept perfect time?

Students were also asked to find the date on which this would occur. Teacher #2 indicated in the journal that almost every student worked hard and was quite successful during the activities, even after the problems became much harder. It was difficult for this investigator to determine whether students were allowed to verify their results until week four, but there was strong evidence that students were generalizing previous strategies to new situations two weeks before the teacher indicated such.

Teacher #2 responded 'yes' to all five indicators after week four with evidence to support those responses easily obtained from the individual journal and portfolio of student work.

Teacher #3

Teacher #3 began the problem solving activities by providing one activity per week for three weeks. Students were excited and enjoyed the change. Teacher #3 began week one by having the students work the problems independently, then allowed time for the teacher and students to demonstrate their own various methods of solving the problems. This worked well, as students elected to use those methods on later problems. During week four, teacher #3 increased the frequency for activities, providing two per week during class, with at least one additional activity being done by students independently as extra credit or homework. Teacher #3 responded 'yes' to all five indicators during week five (and for the remainder of the study), however, once again there was little evidence of students verifying their results. During week six, problem solving was used to introduce the concept of simplifying square roots. Students used calculators to verify their results. From week six until the end of the study, journal entries and student work supported all positive responses found on the weekly checklists.

Teacher #4

For the first three weeks of the study, weekly checklists from teacher #4 were identical; only indicator 1 received a positive response. (Teacher #4 was one of three teachers who had difficulty realizing that mathematics from everyday life included more than consumer type problems involving shopping, household expenses, etc. She also had difficulty getting students to generalize solutions and strategies.) Even though the activities provided during week two and three were in fact nonroutine problems from everyday life, these indicators were not answered in a positive manner on the weekly checklist. The weekly discussion during the focus group for week 3 helped her realize these indicators were being satisfied. Teacher #4 provided two problem solving activities during week three; activities were provided three times weekly for the remaining weeks of the study. Again time and available materials were inhibiting factors. Teacher #4 responded 'yes' to all five indicators for the first time during week six; indicator five was the most difficult to achieve. Teacher #4 was overly cautious in her responses, as data from the journal entries and the portfolio of student work supported all positive responses earlier than actually given.

Teacher #5

Problems solving activities were provided once weekly for a period of three weeks, with two activities during week four. Even though they were well received by the students who asked for more problems, teacher #5 found it difficult to justify lost instructional time. This investigator found no evidence to support a positive response to indicator 3 during week two, three and four. (Students were not being provided with a variety of nonroutine problems.) A focus group discussion during which other teachers gave examples of the various benefits students seemed to be getting from the activities convinced him to gradually increase the frequency. (The fact that other teachers were also willing to share their own materials was added incentive.) During week five, teacher #5 increased the frequency to three activities per week, with one activity done in class and two outside class. This seemed to work well. Teacher #5 was another of the group who satisfied indicator 2 each week after week two (he too kept looking for consumer type problems), however, he did not respond 'yes' on that indicator until week five. Teacher #5 responded 'yes' to all five indicators during week number six, however there was never any evidence of students generalizing solutions and strategies to other situations.

Teacher #6

Problem solving activities began during week one, and continued for the remainder of the study, on a weekly basis. Teacher #6 was steadfast in his belief that while problem solving is beneficial, other teaching strategies are just as worthwhile and should continue as usual. Students of teacher #6 were enthusiastic and very receptive to the change, and even though he plans to continue problem solving after the study concludes, the frequency will remain once weekly. This of course, failed to satisfy the definition of 'on a regular basis,' consequently a positive response to indicator 1 was not really warranted after week two or three. Teacher #6, however continued to respond in a positive manner to indicator 1 on each of his weekly checklists, and justified his response by stating that implementation of Standard 1 could only be done on a "limited basis" at this time due to the present curriculum and time constraints imposed by course guide lines and end of course testing. This was one of the major reasons why the implementation of Standard 1 was finally classified as being successful on "limited" basis at the end of this study. Journal entries and the portfolio of student work indicated a wise selection of activities however, and justified all positive responses to indicators 2 - 5 after week four.

Teacher #7

Teacher #7 provided one problem solving activity during week one, two during week two, and three during week three. Activities began with students being divided into small groups of 2 - 4 according to ability. Students immediately responded well. By week four teacher #7 had used problem solving to introduce the concept of distance in one class and compound interest in another. For the weeks remaining in the study, the frequency of activities varied between three and four per week. Teacher #7 responded 'yes' to all five indicators during week five, however, an examination of the data found in the portfolio of student work along with journal entries supported all positive responses during week four. Teacher #7 and her students enjoyed using problem solving as often as possible. Of all eight teachers involved in this study, teacher #7 came the closest to full implementation of Standard 1.

Teacher #8

Teacher #8 had been using problem solving activities once or twice weekly in all her classes as extra credit exercises throughout the year. Therefore, during the first two weeks of implementation, teacher #8 simply continued as usual. During week three, the frequency was increased to three activities per week. Week four brought an increase in activities to four per week. Evidence found in student work indicated they were generalizing strategies during week three, however, a 'yes' response to this indicator did not come until week four, with week five receiving another 'no' response. Teacher #8 responded 'yes' to all five indicators during week four and then again during week six through nine. Examples of student work and journal entries verified checklist entries. Teacher #8 expressed concern that she was unable to teach all material from a problem solving approach. However, journal entries of the reactions and attitudes of students caused this investigator to conclude that her student were developing thinking skills which would help them become mathematically functional in society.

Concluding the implementation period

The attempt to implement Standard 1 into the existing curriculum had been in progress for nine weeks when this investigator began to examine the existing data for patterns which would suggest a conclusions as to whether Standard 1 had been implemented. The criteria which was to be used in making such a determination were:

1. Standard 1 has been implemented and has become a continuing aspect of the mathematics curriculum at SCHS.

2. Standard 1 has been implemented as completely as is possible under existing conditions and

curriculum expectations at SCHS.

3. Weekly graphs show that the number of indicators with positive responses for problem solving activities have ceased to increase, or have actually begun to decrease.

4. Teacher journals and weekly graphs indicate implementation of Standard 1 is not possible.

The first data source to be examined by this investigator dealt with whether the revised curriculum was providing problem solving activities for students on a regular basis. Table 15 indicates the frequency of problem solving activities for each of the eight teachers for each week of the nine week implementation period. In every case except one (teacher #6), teachers were providing problem solving on a regular basis, increasing the number of activities from one per week to at least three. Teacher #6 did create cause for concern, and even though he failed to increase the frequency of problem solving activities during the course of this study, his students had formerly received no opportunities to engage in problem solving. Thus once per week was indeed a great improvement for teacher #6 after all. This investigator concluded that Standard 1 had been implemented as completely as possible given present conditions, teacher attitudes, and curriculum

TABLE 15

Frequency of Problem Solving Activities Provided by Each Teacher During the Implementation Period

		WEEK NUMBER								
		1	2	3	4	5	6	7	8	9
T	#1	1	1	1	2	3	3	3	3	3
E	#2	1	1	2	3	3	3	3	3	3
A	#3	1	1	1	3	3	3	3	3	3
C	#4	1	1	2	3	3	3	3	3	3
H	#5	1	1	1	2	3	3	3	3	3
E	#6	1	1	1	1	1	1	1	1	1
R	#7	1	2	3	3-4	3-4	3-4	3-4	3-4	3-4
#	#8	1-2	1-2	3	4	4	4	4	4	4

expectations at SCHS. Therefore, this aspect of Standard 1 was satisfied on a limited basis.

The investigator then began to re-examine the data from the weekly checklists, individual journals, and portfolios of student work. For the most part, six of the eight teachers had been overly cautious when submitting their weekly individual checklists. Examination of individual journals and portfolios of student work often indicated teachers were not responding 'yes' to several indicators as soon as they should. The exceptions to this have already been mentioned. Teachers approached the problem solving activities with a 'hopeful' attitude; students accepted them quickly, welcoming the opportunity to learn mathematics in a less boring, more meaningful manner. A cumulative weekly progress graph containing data from each of the nine weeks of the implementation period appears in Figure 10.

Since all eight teachers had given across the board positive responses for each of the five indicators for four straight weeks, this investigator made the decision to administer the assessment for congruence between the revised curriculum and the recommendations of Standard 1. Using the same likert scale checklist for curriculum inventory which began the initial step of the evaluation phase, teachers were asked to indicate the frequency of problem solving opportunities for students in the revised

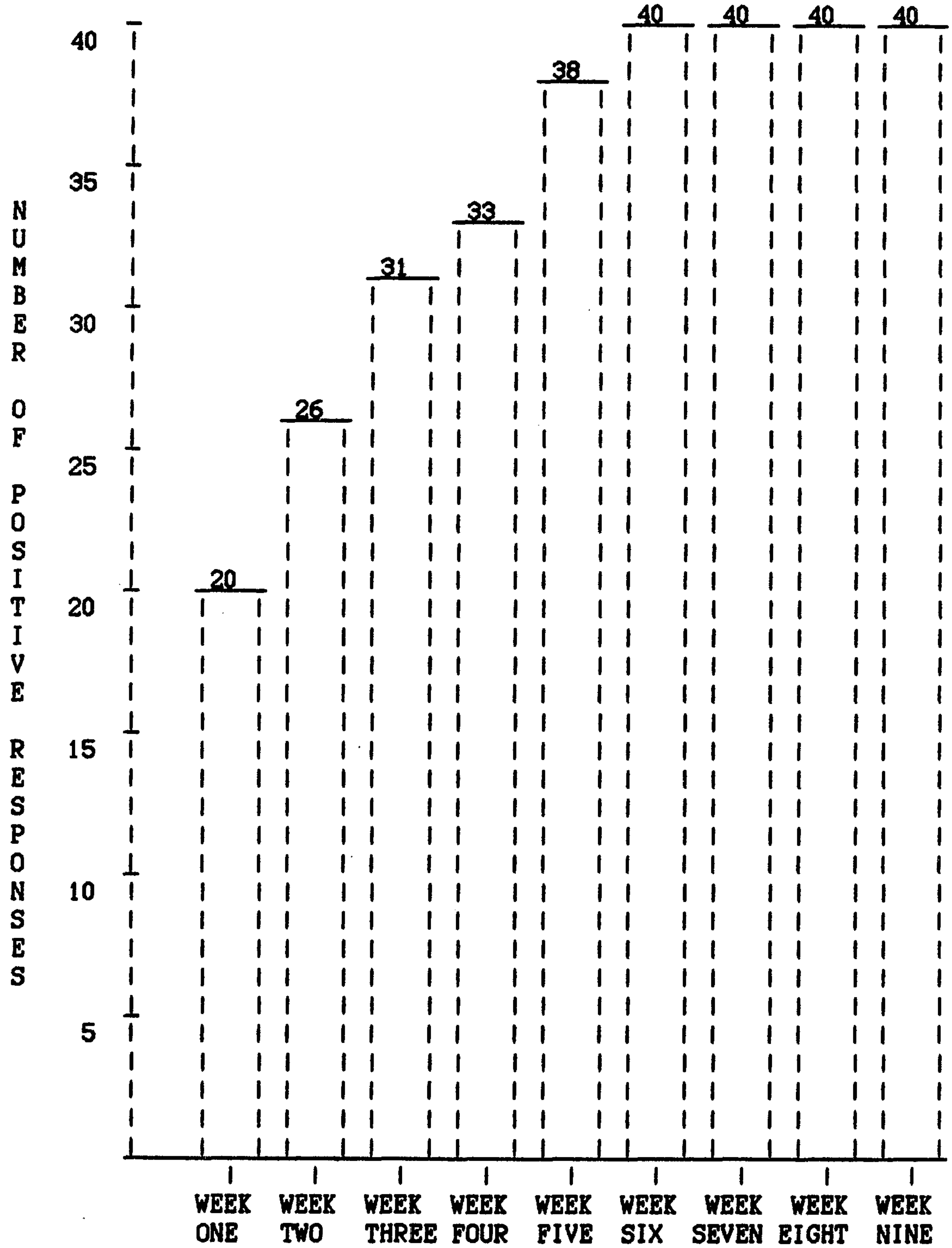


Figure 10. Cumulative Weekly Progress Graph, Showing Combined Number Of 'YES' Responses From All Eight Checklists.

curriculum. A compilation of the results on a second group profile checklist, shown in Table 16, indicated an average of 5.0 (5 = on a regular basis) for all five quality indicators of Standard 1.

At this time the implementation period seemed complete. However, a comparison of Standard 1 and the indicators of quality being used to assess Standard 1 resulted in a small discrepancy. The recommendations of Standard 1 and the indicators of quality which were used to evaluate problem solving in the mathematics curriculum parallel one another in all but one area. Standard 1 recommends that the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can use with increasing confidence, problem solving approaches to investigate and understand mathematical content. The quality indicators do not address this recommendation. Therefore, this aspect of Standard 1 was assessed in the following manner: comments found in the individual teacher journals, examples of students work from the teacher portfolios, and the examination of the results of a problem solving attitude assessment survey which was given to students.

Individual teacher journals were examined by this investigator. Teachers indicated that students began the problem solving activities with a degree of apprehension.

TABLE 16

Second Group Profile for Curriculum Inventory Results

SCALE: 1 to 5 where:
1 = never, 2 = seldom, 3 = occasionally,
4 = frequently, and 5 = on a regular basis

STANDARD 1: The curriculum provides students with the opportunity to engage in problem solving.

Standard Indicator: The curriculum provides students opportunity to:	Scale indicated by each: Teacher One	Two	Three	Four	Five	Six	Seven	Eight	Analysis: Average of all scores for this indicator
Solve problems on a regular basis	5	5	5	5	5	5	5	5	5.0
Define problems from everyday life as well as mathematical situations	5	5	5	5	5	5	5	5	5.0
Define and carry out plans to solve a variety of nonroutine problems	5	5	5	5	5	5	5	5	5.0
Verify and interpret their results	5	5	5	5	5	5	5	5	5.0
Generalize solutions and strategies to other situations	5	5	5	5	5	5	5	5	5.0
Average of scores for all indicators of Standard 1:									5.0

Students were reluctant to try new methods and waited for examples and teacher input. However, by the third week, students seemed more comfortable and relaxed, indicating a desire to do more problems. By the end of the seventh week, students on the whole were eager to begin the activities, did not ask for, or want, teacher assistance, and showed increased competence and success in attaining correct answers. Teachers also reported in their journals that the unexpected and extremely positive response from the students served to re-enforce their own positive attitudes toward the problem solving activities. All but teacher #6 reported additional motivation to try new methods of instruction as a direct result of student enthusiasm and interest.

The portfolios of student work were examined. Problem solving activities began at first with simple activities, rapidly becoming more involved and more sophisticated, with the last problems of the portfolio becoming quite complicated and involved. Teachers indicated that students, for the most part became more successful at solving problems correctly as the study progressed, even though the difficulty of the problems increased.

Lastly, a Problem Solving Attitude Assessment was administered to students involved in this study. Results of the survey can be found in Table 17. Teachers were curious to determine student reaction to the change in

TABLE 17

Problem Solving Student Attitude Assessment Survey Results

1. I believe the problem solving activities in which I have participated will improve my mathematics ability.

   88% AGREE 12 % DISAGREE

2. I enjoy finding different methods for solving problems.

   73% AGREE 27% DISAGREE

3. If I had a choice, I would not continue the problem solving activities.

   20% AGREE 80% DISAGREE

4. I believe the problem solving activities are a waste of time.

   10% AGREE 90% DISAGREE

5. I would rather the teacher just do the sections in the book.

   17% AGREE 83% DISAGREE

6. I would like the teacher to use a problem solving approach when teaching.

   74% AGREE 26% DISAGREE

7. I believe working a wide variety of problems will help improve my confidence in my ability to solve problems.

   89% AGREE 11% DISAGREE

8. Working with different types of problems will not help my mathematics ability.

   14% AGREE 86% DISAGREE

9. Having experience in a wide variety of problem solving will help me attempt problems which I do not know how to solve.

   92% AGREE 8% DISAGREE

TABLE 17 (Continued)

10. Participating in the problem solving activities has helped me to realize I have to ability to solve various problems.

    78% AGREE   22% DISAGREE

11. I do not like problem solving.

    31% AGREE   69% DISAGREE

12. I would rather the teacher just told me how to do the problems.

    29% AGREE   71% DISAGREE

13. I feel better about my ability to solve problems since the problem solving activities.

    78% AGREE   22% DISAGREE

14. Problem solving has improved my ability to think in a logical manner.

    80% AGREE   20% DISAGREE

15. Because of the problem solving activities, I am more confident about my ability to use different strategies to find a solution for problems.

    78% AGREE   22% DISAGREE

curriculum. The questions were formulated by the teachers participating in this study using a mixture of positive and negative statements in order to avoid 'patterned responses.' Students were simply given the questionnaire, asked to read and answer each question with no further instruction or discussion. A total of 864 or 96.5% of the students involved in the study responded (31 students were absent; surveys were not administered to special education students since they were not participating in the study).

Questions #7, #9, #10, #13, #14, and #15 were designed specifically to determine whether students had perceived an increase in their confidence to use problem solving approaches to investigate and understand mathematical concepts. In question #7, 89% of students indicated a belief that problem solving would help improve individual confidence to solve problems. Question #10 with a 78% positive response indicated that students have increased confidence in their ability to solve various problems. Question #9, #10, #13, #14 and #15 all indicate a positive response greater than 75%. An analysis of the responses for each of these questions led this investigator, and the teachers involved, to conclude that more than three-quarters of the students participating had assumed increasing confidence in their use of problem solving strategies to understand mathematics (there is an average of 83% positive responses for the combined six questions).

The remaining questions were designed to determine whether the participating students liked the problem solving activities, and wished to continue with them, or whether they would simply prefer teachers to use their regular methods of instruction. Again results and attitudes toward problem solving were very positive. Only 69% of students admitted they actually liked problem solving (question #11), however 88% believe it will improve their mathematics ability (question #1) and only 20% of students would choose not to continue using problem solving techniques (question #3).

A final examination of the student survey results revealed that students in the more advanced classes were typically more positive in their attitudes toward the problem solving activities. However, even those students from the General Math classes indicated eagerness to continue with the activities and a belief that they were learning more useful mathematics from the problem solving activities than they typically reported learning from worksheets and drill. It was also observed by this investigator that the positive attitudes of students and teachers concerning the problem solving activities were directly related to one another.

After an analysis of all three information sources (checklists, journals, and portfolios of student work), this investigator was able to conclude that Standard 1 had been implemented, with certain pre-specified limitations. Those limitations specify implementation would begin gradually with students engaging in problem solving activities at least once weekly, increasing in frequency as the curriculum allowed and eventually being used as an instructional practice. Teacher #6 failed to satisfy the true spirit of Standard 1 implementation, however problem solving activities had increased from 0 activities to one per week. It was not possible to persuade him to increase the frequency beyond one activity per week. Resistance to change by some teachers will be a major concern which will be difficult to control during implementation of any type of program or instructional change. As a result, at this time, the implementation period ceased.

Post Implementation Period

The last phase of the study consisted of an analysis of the attempt to implement Standard 1 into the existing curriculum. The last four weeks of the study began with a second set of individual interviews. There follows a brief profile of each teacher's comments in response to the following questions:

1. What are your present perceptions of the NCTM Standards in general, and Standard 1 in particular?

2. Have your perceptions of problem solving changed during this study?

3. Can mathematics education be improved by implementation of the NCTM Standards?

4. What factors will inhibit the implementation of the type of mathematics curriculum advocated by the NCTM Standards?

5. Can the NCTM Standards be implemented into the present mathematics curriculum?

6. What were the benefits/liabilities of this program evaluation?

7. Will this program evaluation impact the mathematics curriculum at SCHS?

Teacher # 1

"I believe the goals of the NCTM Standards are good, but there are too many factors involved to implement the entire set of Standards at once. I think the Standards could help improve mathematics education, but I still believe mathematics improvement has to start with interested, qualified, willing teachers. On that topic, I have not changed my mind. But I have seen improvement in my students after working with the indicators of Standard 1. I didn't expect this study to change the way I teach, but it has. I think I can help my students more by making them think, rather than just concentrating on covering the next page in the book. Right now the biggest factors which will inhibit Standard implementation are textbooks and qualified instructors. There was a lot of positive reaction from my students to the problem solving activities; they responded well to my efforts to change teaching methods. When I give them an opportunity to find their own solutions and strategies, they're much more interested and involved. I think that's great. I will continue to use problem solving as an instructional method whenever possible, however finding appropriate materials isn't easy. It was difficult to show students how to generalize solutions and strategies sometimes. I think overall, we're making progress."

Teacher # 2

"I believe the recommendations of Standard 1 are realistic and as a result, they can be implemented into the present mathematics curriculum. However, once again I think lack of time will be a problem. Some of the other Standards look good on paper, but are not realistic. Teachers could never implement them all in the present curriculum. My students truly enjoyed the problem solving activities, and since there has been such positive results, I plan to continue providing them with problem solving opportunities after this study concludes. I started out giving problems once a week for a couple of weeks. Then I increased the frequency. I've even used problem solving to introduce a couple of topics. That's hard, but now the kids expect it. I've seen many of my students actually 'think' for the first time. I feel I have learned a lot from this study. First of all, I am now aware of the NCTM Standards and recommendations, which is a benefit. Second, I now view problem solving in a different light; before, I considered problem solving to be just the word problems at the end of the chapter. Last, I've learned that covering the next section in the book may not be the best way to teach my students. I found it difficult to find appropriate problem solving material and that may be a problem for the future. It was hard to provide students with the opportunity to generalize solutions and strategies. Sometimes I found it difficult to draw a connection between mathematical situations and mathematics from everyday life. In order for me to teach mathematics in the manner advocated by the NCTM Standards, someone must elaborate on some of the standards and what they actually mean. But most of all I think teachers need to review the Standards and recommendations and provide input and clarification based on practical experience. As to the results of this study, I'd say, implementation of Standard 1 was a success."

Teacher # 3

"I believe the NCTM Standards are very idealistic and very difficult to implement in a typical high school curriculum. However, I'm glad we tried Standard 1 and I've been quite surprised by the results. I would resist the idea of full implementation of all fourteen Standards at once though. I just don't think you could do it and still cover all the basics these kids have to know also. I already see this lack of basic knowledge now and lack of traditional instruction would make it worse. I think teachers themselves will be the major obstacle for Standard implementation; they just resist change of any sort. Personally, I believe the Standards don't stand a chance of implementation until our society gets away from their fixation on standardized test scores. I'm surprised to say that I will continue with the problem solving exercises after this study concludes. My students demand it. They truly look forward to the activities and because of their excitement, I was able to increase the frequency right away. I can fit lots of examples into my Pascal class without any real problem. It's hard to find good activities for all levels, but they're out there if you dig. The biggest benefit of using the problem solving strategies for me had to be students who were using their reasoning ability for the first time. Another big plus has been that students don't seem afraid of 'word' problems anymore. The only real liabilities are the time factor and the lack of available quality problems. For me the hardest part of the Standard to implement was generalizing solutions and strategies. I believe mathematics instruction will improve at SCHS as a result of this study. We just have to make a conscious effort to maintain the progress we've made. I'm not really sure I have the ability to implement all the Standards. Before I have to try, I hope someone will provide the training and the materials to help me."

Teacher # 4

"I think implementing Standard 1 has been a realistic goal and has been very beneficial to most of my students. Some of the other Standards would be much harder to attempt, and many of them I don't understand well enough, at this time, to even try. During the course of this study, I have at least become familiar with the Standards (I wasn't familiar with them at all before). I see the problem solving strategies as a definite way to improve mathematics education. It teaches students to reason logically and use strategies of their own to solve problems, rather than waiting to imitate the teacher. However, some courses already have so much material which has to be covered, that it is difficult to get it all done. It's going to be a problem finding enough time to do everything. With so much emphasis on end-of-course testing, and the pressure to produce high scores on them, it will be extremely hard to concentrate on what's really best for the students. However, I do plan to continue with the problem solving activities, and to use problem solving to introduce new material when it seems possible. My students welcomed the change and actually looked forward to working on strategies of their own. The hardest thing for me to implement was getting students to understand how to generalize strategies and solutions. I really think the Standards would be easier to implement if students had a better math background. Then new materials and new concepts could be presented rather than using so much time to review old material again and again. I think that's one reason students find math so boring and consequently, unstimulating. I really would like to take a course which would help me teach in a manner more consist with the recommendations of the Standards."

Teacher # 5

"The Standards sound good, but they certainly can't be implemented across the board. Standard 1, unlike several others, was quite realistic and reasonable. I believe implementation of some of the Standards could help improve mathematics education eventually. I will continue the problem solving activities after this study ends. I've seen a big change in some of my students; many have asked for more problems, have seemed more motivated, and have actually shown signs of thinking on their own. I believe though that in order to be truly successful, teachers must start problem solving in early grades and expand and intensify gradually until mathematics is taught routinely in a problem solving manner. Right now, time is a major concern. How do I continue to cover all those pages in the book, while I also instruct more slowly using problem solving? I will certainly try, because I realize students are not satisfied with the old memorization techniques either. The hard part is finding appropriate materials. Most textbooks don't even come close to problem solving techniques; I'd like to see one that did. It would be nice to be able to have a staff development class on how to teach from a problem solving perspective."

Teacher # 6

"I see problem solving as a meaningful activity, but I think if we try to use this as the total approach to mathematics education it would be placing too much emphasis on a single facet of mathematics. Concepts and skills need development also. Overall, however the Standards are worthwhile and with proper implementation could definitely improve mathematics education. However, lack of appropriate materials and teacher training will be serious problems for Standard implementation. At first my students were quite reluctant to try anything different. They waited for me to guide them, prod them, and give them hints. Now they work independently, eagerly, not wanting my guidance. At first I was skeptical about problem solving activities; but now it's working beautifully. This evaluation gave students a chance to see applications of mathematics beyond the normal scope of the course, which was definitely a plus. Materials for this type of activity are in fairly short supply, however I will continue to provide problem solving opportunities for my students on a regular basis. The hardest indicator for me to implement was the last one -- providing students the opportunity to generalize solutions. Defining problems from everyday life was difficult in the higher math classes. This study has caused me to be more alert to the need to involve students in situations requiring logical reasoning and realistic thought processes. While I would not teach any topic consciously trying to incorporate these or any other set of standards, I will use problem solving techniques when appropriate."

Teacher # 7

"Standard 1 is not only realistic, it should be an essential part of our curriculum. However, measuring a student's ability to think critically may be the difficult part of implementing the Standard. My perception of this Standard has certainly changed during the course of this study. I believe I now have a clearer understanding of what actually constitutes problem solving. Also I now believe implementation of Standard 1 can improve mathematics instruction which I had reservations about before the study. I was surprised at my students' reactions to the problem solving activities; they truly enjoyed doing them. It will make it more difficult to cover the required material for end-of-course testing, but I plan to continue offering problem solving activities to my classes. I started out slowly, but the students caught on quickly. They worked hard to find their own solutions and strategies. One day I just walked into class, gave them three points and told them to find a way to determine the distance between them. It felt great, for the kids and myself, when they came up with the distance formula. Another of my classes figured out the formula for compound interest. I plan to attempt similar methods anytime I can. I have always tried to get my students to think and to show divergent methods for solving problems, however I feel that now I will be more aware to allowing them to discover their own methods and solutions. I believe I am capable of teaching mathematics in the manner advocated by NCTM, but I would certainly appreciate a course or a book which could help provide appropriate materials. Even though it's always difficult to measure the success in any attempt to improve critical thinking skills, I feel the implementation of Standard 1 may eventually help our students in ways we can't even be aware."

Teacher # 8

"The NCTM Standards are positive and necessary. However, I feel that in order to give more attention to them, we will have to relieve some of the pressure on the end-of-course testing for a couple of years. Problem solving, like all the Standards, needs to be introduced gradually, allowing students time to gain skills before all, or most, ideas in mathematics can be taught using this approach. I believe this study has helped do exactly that. I started out slowly with the problem solving, but now my students are hooked. I try to teach using problem solving techniques whenever possible. End-of-course testing and Senate Bill #2 requirements will inhibit implementation of NCTM Standards. If we try to implement the Standards, at first I think test scores will go down. But in the long run a generation of 'thinkers' will be produced and that can only help society. The most difficult aspect of Standard 1 to implement is allowing students to generalize to other situations. I am still not teaching from a problem solving approach. I need more planning time to revamp an entire subject area into a problem solving approach. I'd like to take some courses which might help; I'd also like to see good material made available. But as always on education, patience pays off. With the proper help and a little time, we will improve mathematics education through problem solving and the other NCTM Standards."

Following the second series of individual interviews, it was noted by this investigator that the teachers in this program evaluation had not changed their views of the NCTM Standards in general, however, their impressions of Standard 1 were much more favorable. All eight teachers seemed genuinely surprised and pleased by the response of their students; none of them had honestly expected to see a difference in their teaching attitudes and methods. However, all eight teachers indicated a desire to continue with the problem solving activities in an effort to help create an attitude among students that mathematics is reasonable, interesting, and useful. The general attitude among the eight teachers toward the usefulness of this type of study was a positive one. They stated a belief that this study had helped them see a need to change their teaching styles; something which would not have happened otherwise. Finally, all eight teachers indicated a belief that the implementation of Standard 1 into the present curriculum (even though it was not a full implementation) would gradually improve mathematics education at South Caldwell High School. The teacher responses to the interview questions can be summarized as follows:

Q 1. What are your present perceptions of the NCTM

Standards in general, and Standard 1 in particular?

A 1. Standard 1 is worthwhile and with work and dedication can be implemented at least on a limited basis into the present curriculum. Individual teachers however must be willing to change for the sake of improving mathematics education. By following the recommendations of Standard 1, teachers can help students organize and develop their ability to reason and think and provide them the opportunity to increase their confidence in their own ability to use mathematics. Implementation of all fourteen Standards, however would be difficult and would necessitate drastic change, something most educators would resist.

Q 2. Have your perceptions of problem solving changed during this study?

A 2. Yes. Most teachers have a concept of problem solving as working the word problems at the end of each chapter. This study has helped teachers realize that problem solving can be any activity which allows students to attempt to find an unknown solution to an existing question. Teachers also stated a belief that the use of problem solving strategies would improve mathematics instruction at SCHS.

Q 3. Can mathematics education be improved by the implementation of the NCTM Standards?

A 3. Probably yes. However, time and materials will be inhibiting factors which will be difficult to overcome.

Q 4. What factors will inhibit the implementation of the type of mathematics curriculum advocated by the NCTM Standards?

A 4. Teachers will interpret the Standards in varying ways.
Educators at all levels will be resistant to change.
The assessment of student progress would be more difficult.
Teacher evaluation would be more difficult.
Local school units will need increased funding in order to supply the necessary materials.
Teachers would require massive retraining.
As long as teachers feel accountable for and continue to teach toward End of Course Tests, the recommendations found in the NCTM Standards will not be taken seriously.

Q 5. Can the NCTM Standards be implemented into the present mathematics curriculum?

A 5. Perhaps, but only partially. Until teachers at all levels are given an opportunity to learn new methods and techniques of instruction and understand completely the recommendations of each Standard, implementation will be only on a limited basis at best.

Q 6. What were the benefits / liabilities of this program evaluation?

A 6. There were several benefits. Students enjoyed the opportunity to think, and to reason logically. They seemed much more receptive to making attempts to solve new problems without waiting for teacher instruction and guidance. Students also seemed more receptive to and less afraid of typical word problems. Teachers became more aware of problem solving strategies and new techniques for teaching. There seemed to be an overall positive effect on students and teachers. The biggest liability was the one concerning time spent away from material in the book. Another was the unavailability of appropriate materials.

Q 7. Will this program evaluation impact the mathematics curriculum at SCHS?

A 7. Definitely. Teachers will continue to provide problem solving activities for students after the study concludes. In addition, teachers will continue to look for methods of introducing topics through the use of problem solving activities.

The study concluded with one last focus group. Due to the overall positive response to problem solving activities by students and teachers, all eight teachers plan to continue problem solving activities and hope to find methods of introducing new topics using problem solving techniques. The actual results from the implementation of Standard 1 are not easily measured, but the teachers involved in this study have indicated that students are learning to think and inquire in new and different ways, and as a result mathematics instruction has been affected in a positive manner. The questions which were answered during the last focus group can be summarized as follows:

Q 1. Was the implementation of Standard 1 successful and complete?

A 1. Teachers classified the attempt to implement Standard 1 as being very successful, even though at this time the implementation remains limited. Both students and teachers indicated a belief that mathematics education could be improved by the continuation of the problem solving activities. Those teachers involved in this study have indicated also that they began the implementation period with an attitude of acceptance, thinking problem solving activities would cease when the implementation period was complete. However, teachers now plan to continue using problem solving strategies whenever possible. The implementation of Standard 1 into the mathematics curriculum at SCHS not only produced lasting instructional changes, it has also helped create new attitudes toward and interest for mathematics among students and teachers.

Q 2. If the implementation of Standard 1 was not complete, what were the inhibiting factors?

A 2. Teachers indicated the implementation of Standard 1 was not complete, since the introduction of new material from a problem solving perspective remained very difficult and as yet was not a common occurrence in mathematics classes at SCHS. Before problem solving can become a routine method of instruction, teachers will need to adopt a new role in their classrooms--a role as a facilitator of knowledge rather than as the source of and dispenser of all information. Before this can be done, teachers will need new materials, additional training, more freedom to decide what and how to teach, more time and smaller classes, all combined with the public and professional support necessary to get the job done. A present lack of all these items helped inhibit the implementation of Standard 1 into the present curriculum.

Q 3. How did students react to the change in curriculum?

A 3. An examination of the results of the problem solving assessment survey which was administered to 96.5% of the students involved in this study show a very positive response by students to the problem solving activities. Teachers have also indicated that many students made comments that for the first time ever, math class was interesting and even fun. Students requested an increase in the number of activities, and even suggested using their own time to work on special projects. Student reaction was indeed not only very positive, but very surprising and gratifying.

Q 4. What problems were encountered during the implementation of Standard 1?

A 4. The major problems teachers expressed repeatedly pertained to lack of appropriate materials and an inability to develop their own. There were also major concerns over the amount of time spent away from the textbook and whether this would result in lower scores on end of course testing. In addition, teachers felt uncomfortable with the lack of precision and direction from NCTM regarding implementation of their Standards. Recommendations for improvement are fine, but teachers need to know how to put them into practice.

Q 5. Did teacher perception of Standard 1 change during the course of the study?

A 5. Definitely. First, none of the teachers involved in this study expected to make any lasting changes in their methods of instruction. Implementation of Standard 1 into the SCHS curriculum has resulted in a re-assessment of individual teaching styles by at least seven of the eight teachers participating. Second, problem solving is a term familiar to every mathematics teacher; it's a topic teachers commonly believe is covered in math class every day. This study helped teachers at SCHS to understand that not all mathematics is true problem solving and that students can benefit from more than one type of instruction.

Following the final focus group, this investigator utilized the remainder of the post implementation period to examine and synthesize the data which had been collected. After a four week post implementation period, this evaluation case study officially came to an end, however teachers at SCHS continue to use the benefits of this study in an effort to improve the mathematics curriculum and their own methods of instruction.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

> In summary, there are many possible next steps to improving mathematics teaching and learning. If we make a long-term commitment to the standards set forth within this document, if we approach the task with the will to persevere, if we are critical of the steps we take, and if we make needed mid-course corrections, we will make progress toward the goal of developing mathematical power for all students.
> The National Council of Teachers of Mathematics, 1989.

This chapter contains four sections. First, a summary of the study is presented. The second section gives the conclusions of the research. Section three sites limitations of the study. Finally, the chapter concludes with recommendations for further study.

Summary of the Study

The purpose of this inquiry was to assess the current status of problem solving in a mathematics curriculum in a typical high school, and to examine the process involved in the implementation of the recommendations found in Standard 1: Mathematics as Problem Solving, which was developed by NCTM in the Teaching and Curriculum Standards of High School Mathematics. More specifically, the following questions were used to guide this program evaluation:

1. To what extent is the criteria of Standard 1 not being satisfied by the current mathematics curriculum in grades 9 - 12 in a specified high school?

2. What are the changes perceived by teachers to be necessary before the curriculum standards found in Standard 1 can be fully implemented?

3. What are the factors which may inhibit or enhance the implementation of NCTM's vision for a more relevant and useful mathematics curriculum within a specified school?

The NCTM Curriculum Standard which was selected by this investigator to guide this evaluation case study is:

Standard 1: Mathematics as Problem Solving

In grades 9 - 12, the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can --

--use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content;

--apply integrated mathematical problem-solving strategies to solve problems from within and outside mathematics;

--recognize and formulate problems from situations within and outside mathematics;

--apply the process of mathematical modeling to real-world problem situations.

During the evaluation of Standard 1: Mathematics as Problem Solving, this investigator utilized those indicators of quality for Standard 1 which were developed by the Center for Educational Research and Evaluation at UNC-G for the evaluation of mathematics programs. Those indicators are:

Standard 1: The curriculum provides students with the opportunity to engage in problem solving.

1.1 The curriculum provides students with the opportunity to solve problems on a regular basis.

1.2 The curriculum provides students with the opportunity to define problems from everyday life as well as mathematical situations.

1.3 The curriculum provides students with the opportunity to develop and carry out plans to solve a wide variety of nonroutine problems.

1.4 The curriculum provides students with the opportunity to look back at the original problems to verify and interpret their results.

1.5 The curriculum provides students with the opportunity to generalize solutions and strategies to other situations.

A comparison of the recommendations of Standard 1 and the five indicators of quality which were used to evaluate problem solving in the mathematics curriculum show they parallel one another in all but one area. The first recommendation of Standard 1 states that the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students can use with increasing confidence, problem solving approaches to investigate and understand mathematical content. The quality indicators do not address this recommendation. Therefore, this aspect of Standard 1 was assessed in the following manner: comments found in the individual teacher journals, examples of student work from the teacher portfolios, and the examination of the results of a problem solving attitude assessment survey administered to students.

South Caldwell High School was selected as the site for this program evaluation with all nine members of the mathematics department participating. As one of those nine teachers, this investigator was a participant in all activities involving this case study. However, personal reflections and data from this investigator has not been included in the data collection or data analysis which documents results from the remaining eight mathematics teachers only.

The study consisted of three phases: preparing to evaluate, program evaluation, and a post implementation period which was used to examine the attempt to implement Standard 1. The first phase began with a series of individual interviews, during which teacher background, educational views, attitudes concerning the status of the current mathematics instruction and outside demands for reform, as well as knowledge of the NCTM Curriculum and Teaching Standards were discussed. A focus group of all eight teachers was held, during which time Standard 1 was discussed in the following manner: importance within the mathematics curriculum; methods which might ease implementation; and, changes perceived to be necessary to achieve complete implementation. Teachers were given the five indicators of quality which were developed for the evaluation of problem solving within the mathematics curriculum. Since several terms used within these indicators can be interpreted differently, a second focus group was held to define for use in this study the following terms: curriculum, problem solving, on a regular basis, nonroutine problems, and mathematics for everyday life.

The evaluation phase of the study began after four weeks of preparation, beginning with the assessment of the congruence of problem solving in the pre-existing curriculum and the recommendations of Standard 1. Each of the eight mathematics teachers were asked to complete a likert scale checklist for curriculum inventory detailing the status of problem solving opportunities for students in the pre-existing curriculum. Individual checklist were returned to the investigator, who used the data to compile a group profile, indicating by an average the degree to which the mathematics curriculum was used to provide problem solving activities for students. This group profile for all eight teachers indicated the opportunity to solve problems in the pre-existing curriculum with an average of 1.925 was some where between 1 (never) and 2 (seldom). Since the group profile checklist indicated a clear discrepancy between the criteria of the pre-existing curriculum and the recommendations of Standard 1, six recommendations for change were made:

1. Begin implementation of problem solving activities on a regular basis (at least once weekly in the

beginning, then with increasing frequency as the study progressed).

2. Introduce nonroutine problems into the mathematics curriculum.
3. Encourage students to verify and interpret their results.
4. Provide students opportunity to generalize results.
5. Define problems from every day life as well as from mathematical situations.
6. Make every effort to utilize problem solving strategies to introduce new material when appropriate.

Teachers began an indefinite implementation period, during which time they were asked to adhere to the above recommendations. Teachers were asked to complete weekly checklists, detailing the problem solving activities which were completed each week and the degree of compliance with the above recommendations. A portfolio of dated student work was used to verify results, along with individual teacher journals which recorded teacher concerns and perceptions of each activity. After a period of six weeks, all eight teachers were able to respond in a positive manner to each of the five indicators found on the weekly checklist and after four weeks of across the board positive responses, a second assessment of the congruence between the curriculum and the criteria of Standard 1 was completed. Using the same likert scale checklist for curriculum inventory which began the initial step of the evaluation phase, teachers were asked to indicate the frequency of problem solving opportunities for students in the revised curriculum. A compilation of the results on a second group profile checklist indicated an average of 5.0 (5 = on a regular basis) for all five indicators for Standard 1. After an examination of the data from the individual journals, the portfolios of student work, and the Problem Solving Student Attitude Assessment results, this investigator was able to conclude that Standard 1 had been implemented. At this time the implementation period concluded.

The last phase of this study consisted of an examination of the attempt to implement Standard 1 into the existing curriculum. The last four weeks of the study began with a second set of individual interviews during which the questions asked were:

1. What are your present perceptions of the NCTM Standards in general, and Standard 1 in particular?
2. Have your perceptions of problem solving changed during this study?
3. Can mathematics education be improved by the implementation of the NCTM Standards?

4. What factors will inhibit the implementation of the type of mathematics curriculum advocated by the NCTM Standards?
5. Can the NCTM Standards be implemented into the present mathematics curriculum?
6. What were the benefits / liabilities of this program evaluation?
7. Will this program evaluation impact the mathematics curriculum at SCHS?

The study concluded with one last focus group of the eight teachers, during which teacher reactions to the implementation were discussed as well as plans for future problem solving activities. Due to the overall positive response to problem solving activities by students and teachers, all eight teachers plan to continue problem solving on a regular basis. Actual results from the implementation of Standard 1 will probably never be conclusively known, but the teachers involved in this study indicated that students were learning to 'think' and 'inquire' in new and different ways, and as a result mathematics instruction has been affected in a positive manner.

Conclusions of the Research

Data from the research support the following conclusions to the questions which were used to guide this evaluation case study.

1. To what extent are the recommendations of Standard 1 not being satisfied by the current mathematics curriculum in grades 9 - 12 in a specified high school?

   Conclusion: The recommendations of Standard 1 are not being satisfied by a typical mathematics curriculum. Data from teachers indicated an average of 1.925 on the First Profile for Curriculum Inventory. With 1 = never and 2 = seldom, this data indicated that students were participating in problem solving on a very limited basis. Data from teacher interviews indicated that teachers continue to teach mathematics in the manner it was taught decades ago -- teachers prescribe; students transcribe. Students continue to learn mathematics from imitation, lectures, worksheets and routine homework. Problem solving is an activity in which many students never (or very seldom) have an opportunity to engage.

2. What are the changes perceived by teachers to

be necessary before the curriculum recommendations found in Standard 1 can be implemented?

Conclusion: Teachers must first recognize the need for change. Second, teachers must be given the opportunity to change. This will include providing them with new materials, appropriate training, smaller classes, more time, less pressure to produce high test score averages, the freedom to make choices on what and how to teach, and the public and professional support to required for each of these. And last, but perhaps most important, teachers must not resist change.

3. What are the aspects of current mathematics education which may inhibit or enhance the implementation of NCTM's vision for a more relevant and useful mathematics curriculum within a typical school?

Conclusion:

Those aspects which may enhance NCTM Standard implementation:

--Students take more responsibility for their own learning.

--Learning mathematics becomes more relevant to the individual student.

--The study of mathematics becomes less stressful for students as they realize mathematics can be interesting and stimulating.

--Students gain strength as problem solvers and independent thinkers.

Those aspects which may inhibit NCTM Standard implementation:

--Time.

--Class size.

--Lack of appropriate teacher training.

--Lack of materials.

--Lack of general agreement on how to 'fix' mathematics education.

--Lack of planning time.

--Parents and students who are not ready to accept change or new trends in education.

--Pressure to produce high test score averages, and to cover textbook material first.

--Difficulty in student assessment.

--Teacher evaluation.

--Teachers who resist change.

Conclusions from this study have also been derived from each of its three phases. During the preparing to evaluate phase, data from the individual interviews support the following conclusions:

--Teachers resist pressure from outside influences.

--Teachers in general are not familiar with NCTM Standards.

--Teachers will not make radical changes in mathematics instruction, but are willing to make slow, gradual change for the sake of improved instruction.

--Teachers do not believe a set of Standards can cure the present lack of mathematics knowledge among the nation's youth. They believe educational improvement will only come if parents, teachers, students, professionals, and the general public join together to find workable solutions.

--Teachers do not feel motivated to try new techniques which have excluded the expertise of teachers during their formulation.

--Teachers currently feel pressured to teach to end-of-course tests, and to cover each section in the textbook. Problem solving is viewed as an 'extra' activity and as such is often excluded from the curriculum.

--The NCTM Standards are considered to be vague and easily mis-interpreted. Teachers will need further explanation and clarification before implementation will be attemptable.

--Implementation of the NCTM Standards will require massive teacher re-training combined with the adoption of appropriate materials and textbooks.

All eight teachers involved in this case study agree that reform is needed in the present mathematics curriculum, yet there is widespread disagreement as to which course of action will best accomplish this reform. Two teachers indicated a need for back to basics, with the necessary skills being stressed in earlier grades, in much the same manner as reading skills. Two teachers indicated a need for additional and more relevant mathematics courses at every grade level for average students. They stated that much time and effort is spent on advanced mathematics instruction for the top ten percent and remedial instruction the lower twenty percent of students, yet there is almost no effort toward instruction of, and very few courses designed specifically for, the majority of students who are considered average. Teachers indicated that many of these students simply avoid mathematics, particularly during high school and later become one of the many individuals who are unprepared mathematically to function in society today. Two other teachers indicated a belief that the apparent lack of adequate education among youth in general is a direct result of the beliefs and attitudes propagated in our present society. Teachers say students are encouraged to memorize rather than learn, and to believe that test scores are more important than learning and retention, and that grades, rather than ability, determine one's future. These teachers believe education will improve only when the views so prevalent in society change.

Only one of the eight teachers involved in this study had previous knowledge of the NCTM Standards, and then only because of college course work encountered while working on a Master's Degree. The other seven teachers had never seen a copy of the fourteen Curriculum and Teaching Standards for High School Mathematics. These teachers stated that if they are not kept informed and made aware of recommendations for improved instruction, that these recommendations were not likely to be implemented. Professional organizations and state officials should find a way of keeping teachers well informed of all developments and curriculum updates. (This investigator has also concluded that teachers should join their professional organizations and should take the initiative to find out what innovations are taking place in their field. This was based on the fact that only one of eight teachers in this high school belonged to NCTM. See Table 7.) Teachers report that if they are not involved, it seems unlikely that instruction will improve. It is also understandable why none of these teachers seemed too concerned by outside influences who demand change in the present educational system. None of the eight teachers involved in this case study respond to demands for higher test scores and indeed are not convinced that test scores are accurate indicators of mathematics instruction. They are concerned for the progress of their students and are willing to develop new teaching methods if students can benefit from them.

While none of the eight teachers recognized the NCTM Standards as a cure-all for mathematics education, each of them indicated a willingness to attempt a slow, gradual implementation of the Standards. However, they feel many of the Standards will need to be clarified and defined, otherwise many teachers will assume they already satisfy most, if not all, of the recommendations. They agree that they teach math today in much the same manner as they were taught twenty to thirty years ago, and any drastic change will require extensive re-training and the development of new teaching techniques. Currently teachers report that they simply do not have the time to develop on their own the type of material which would allow them to teach mathematics in the manner advocated by the Standards.

All eight teachers indicated that presently they have a tendency to teach toward the end-of-course tests and that they feel obligated to cover each section in the textbook. This too is understandable, due to the current emphasis on test scores and the inevitable comparisons of local test score averages with state and national averages.

Implementation of the Standards will slow down those teachers who seem proud of the number of pages covered in the textbook each year.

Finally, teachers indicated a belief that educational trends are cyclic and that problem solving is not a new method of mathematics instruction. During the pre-evaluation interview, Teacher # 8 produced a copy of the preface to a book titled General Mathematics: A Problem Solving Approach. The preface addressed the revision and refinement of a former text with the new text seemingly containing all the features and criteria contained in NCTM's Standard 1. Yet the surprising fact was not the suggestion of a problem solving approach, but a copyright date of 1965. This seemed to support these teachers' beliefs that educational trends are repetitive over a cycle of about twenty-five years. This mathematics faculty is experienced and has seen various reform movements come and go, most of which have made no significant impact toward improving mathematics education. As such, this mathematics faculty reported that they are not yet convinced that the fourteen Curriculum and Teaching Standards are not just another quick-fix remedy which may or may not work. These teachers state that they would like to be a part of the process when solutions are suggested for improving mathematics education. They have indicated a believe they have the knowledge and experience necessary to make wise choices and a responsibility to make those choices carefully.

Data from the evaluation phase of this inquiry supports the following conclusions:

--The recommendations from NCTM's Standard 1 are not currently being satisfied by the typical mathematics curriculum.

--Problem solving activities are generally reserved for end of the chapter routine problems, perhaps once a month or less often.

--Students are typically taught specific methods for solving these routine problems.

--Standard 1 can be implemented into the existing mathematics curriculum, with certain pre-specified conditions. Those conditions specify implementation will begin as 'add on' activities, which will increase in frequency and gradually become part of the normal instructional process and eventually an integral part of the curriculum.

--Allowing students to generalize solutions was the most difficult aspect of Standard 1 to implement, followed closely by defining mathematics from everyday life as well as mathematical situations. Very few textbooks address either concept and material is limited.

--Teachers will require the provision of new materials, since lack of time will prevent them from developing their own.

When this case study began, problem solving 'on a regular basis' was defined to be at least once weekly. As such, problem solving opportunities began as 'add-on' activities which were done in addition to the regular mathematics instruction. Teachers in essence were not changing their methods of teaching, they were simply adding problem solving activities which they previously had excluded. They began by introducing new types of problems, some with routine solutions, others with multiple solutions, and still others with possibly no solution at all. Teachers attempted to provide activities for students which would allow them to view mathematics in a more useful and personal manner. Students who often think of mathematics as an exercise in memorization were encouraged to simply reason through a situation in a logical, systematic and organized manner. Results were surprising. Journals which were kept by individual teachers indicated that students enjoyed the change and looked forward to the exercises. Students began to find their own methods for solutions and were able to show others why certain strategies work and others failed. The frequency of the problem solving activities began to increase steadily. By the end of the implementation period, teachers were beginning to search for methods which would allow them to introduce and teach new topics through a problem solving orientation. This however proved to be difficult. While some topics lend themselves to problem solving strategies, most topics seem to revert back to teacher lecture methods, while students copy and imitate. This fact was discouraging. However, all eight teachers indicated a desire to continue offering problem solving opportunities to their students on a regular basis, and to continue searching for methods which would allow them to use problem solving as an instructional method. All eight teachers indicated positive results from the implementation of Standard 1.

Post Implementation

Data from the last phase of this case study was obtained from a second series of individual interviews and a final focus group. According to the information obtained, this investigator was able to make the following conclusions:

--The implementation of Standard 1 was successful with certain pre-specified limitation. Those limitations specify that implementation would begin gradually, with students engaging in problem solving activities at least once weekly, increasing in frequency as the curriculum allowed and eventually being used as an instructional practice.

--Teacher perception of Standard 1 became more positive during the course of this study.

--Students became more willing to attempt solutions for problems without waiting for teacher instruction.

--The major factor which will enhance or inhibit the implementation of the Standards will be the willingness or reluctance of the teachers themselves.

--Students enjoyed the opportunity to explore and think for themselves.

--Teachers plan to continue problem solving activities on a regular basis.

--Teachers expect to be more aware of the manner in which new material is presented and will try to use problem solving techniques to do so when possible.

--Teachers want textbooks and renewal courses which will help them implement the Standards in the manner advocated by NCTM.

All data collected from teachers during the initial interviews indicated that even though they were willing to try implementation of Standard 1, they were not expecting much in terms of results and they were far from convinced that their curriculum and subsequent instruction would undergo any significant change. This investigator developed a distinct impression that problem solving opportunities would simply be extra activities for the duration of this study and would then cease. The most surprising and gratifying aspect of the entire investigation was the realization that teachers and students indicated a desire to continue problem solving on a regular basis, after the study was completed. Even more surprising was the indication by teachers of the intent to use problem solving as an instructional tool whenever possible. During the last focus group, this investigator asked teachers to share ideas which would allow them to present new topics using problem solving techniques. Seven of the teachers responded with well thought out examples, while only Teacher # 6 indicated that time constraints would not allow him to develop his own teaching materials.

Each of the eight teachers indicated that providing students the opportunity to generalize solutions and strategies to other situations was the most difficult indicator of Standard 1 for them to implement; it was also the last of the five indicators to receive across the board positive responses on the weekly checklists. Once again, lack of available material seemed to be a problem.

The teachers involved in this study believe the NCTM Standards will be difficult to implement into the existing curriculum. They would like to see an implementation period, during which time test scores and student achievement comparisons would be eliminated as indicators of educational success. Teachers indicated a desire to see mathematics instruction emphasize learning rather than memorization, quality rather than quantity. They ask for the time and training required to do both; only then will the reality of mathematics education resemble the professional views of what mathematics education should be.

The final conclusions of this study pertain to the question of instructional techniques. Why do teachers continue to teach mathematics using the same methods of instruction which were used decades ago, when they apparently see the need and value of teaching in the manner advocated by NCTM? There appears to be three major factors which propagate the use of outdated modes of instruction: time; materials; and teacher evaluation.

The decade of the 1980s brought increased demand for improvement in public education. Many individuals advocated a back to basics approach to instruction, where students are presented with more material and more topics, and are expected to retain more information thus becoming more knowledgeable. As a matter of efficiency, teachers learned that the quickest way to cover new material was the 'teacher presentation, student imitation' method. As more and more teaching became expected of our educators, teachers report less and less time became available to them to experiment, to try new techniques, and to involve the student in his own learning. At the same time, teachers have indicated there is strong evidence to show that students concluded that the most efficient way to deal with the increase in information was the 'memorization' method, where they learn what they need for the upcoming test, then discard old information and replace it with new. Teachers report that outside pressures have caused them to become more concerned with finishing the textbook than with providing students the opportunity to reason, to think, and to make sense of what they are expected to learn. Therefore, teachers have indicated that students are just not learning all they are expected to learn. Teachers say the idea of minimum competency and end-of-course testing is forcing them into a frantic cycle which demands maximum output and no variation in teaching methods.

The second reason which causes teachers to continue using outdated methods of instruction concerns available materials. State adopted textbooks offer no new teaching techniques, no problem solving strategies for the introduction of new material and no new suggestions for teachers who wish to improve or change their instructional methods. Again, teachers report that they do not have the time, nor perhaps the ability or inclination to develop their own materials. Textbooks are written to utilize the concept of the economy of time and the plethora of materials presented.

The last reason teachers continue to use old methods of instruction pertains to teacher evaluation. Many states have adopted the concept of a 'six-step' lesson plan which is used when observing and evaluating teachers. Teacher lecture methods or teacher presentation methods readily lend themselves to this type of lesson plan, while problem solving strategies in which the student is responsible for much of his own learning do not. Teachers have indicated a belief that it seems easy for an administrator, or other observer, to determine the effectiveness of a teacher who is presenting material for his students to 'learn' but another matter entirely for that observer to determine the effectiveness of a teacher who serves mainly as a guide or a catalyst for learning. Throughout the course of this study, all eight teachers repeatedly expressed concerns pertaining to each of the three factors just mentioned (there were fewer concerns about teacher evaluation than the other two factors, however it remains a valid concern). Teachers say they are being forced, more or less, to use the familiar teacher lecture method of instruction.

The following suggestions or recommendations can be made as a result of the conclusions of this study:

1. Since one of the major concerns of the eight teachers involved in this study was lack of appropriate training, this investigator will request that the administrative office consider providing a

series of workshops and/or staff development classes which will address this concern.

2. A textbook committee should be appointed for the purpose of seeking out and identifying appropriate materials and making them available to teachers.

3. Some type of network system should be developed in order to inform and involve teachers in local and national curriculum planning and reform.

4. The National Council of Teachers of Mathematics should provide training for teachers which would enable them to begin using the Curriculum and Teaching Standards, in the manner in which they were intended.

5. End-of-course testing should cease along with state and local comparisons of other test score averages for an undetermined period of time to allow teachers the freedom and opportunity to implement teaching styles similar to those recommended by the Standards, without teachers having to deal with the criticism which could result from any initial decrease in test score averages.

6. All definitions to be used during the course of Standard implementation should be developed and fully explained by professionals in order to avoid misuse or misinterpretation.

Limitations of the Study

There are three primary limitations of this case study. The first limitation arises from the fact that this inquiry made an attempt to implement only one of the fourteen Curriculum and Teaching Standards for High School Mathematics. Therefore, it would not be prudent to speculate on the degree of success for implementation of the remaining thirteen Standards. Several of those Standards seemed unclear when discussed by the teachers involved in this study, while problem solving is a concept with which most mathematics teachers feel comfortable. Teachers expressed concern with more than one of the remaining Standards, indicating doubt for successful implementation and uncertainty for reliable methods of assessment. However, the concept of problem solving forms the basic framework for the type of mathematics curriculum proposed by NCTM and others. In order to improve student learning and achievement, particularly student learning and achievement of higher-order thinking skills, the development of problem solving skills must become a priority. Thus Standard 1 was selected as the foundation of this inquiry. A second reason for the selection of only one of the fourteen Standards for the duration of this study pertains to teachers and their attitudes toward change. Teachers seem willing to make gradual curriculum change and for the most part not only feel uncomfortable with the concept of radical change, they also feel students adapt best to slow methodical change. In the opinion of this investigator, any attempt to implement more than one Standard would have created not only added resistance, but perhaps an impossible task with disastrous results.

The second limitation of this study pertains to the time period involved. In any study of this type, it would be preferable to continue the investigation over a longer period of time, perhaps one to two years. An extended period of time would allow a true test of Standard 1 implementation and would allow the investigation of long-term permanent results, and whether the change in mathematics instruction was accompanied by the desired increase in student knowledge. It would be interesting to re-evaluate this mathematics program in a year or two and assess the problem solving opportunities available to students at that time in comparison to those available at the conclusion of this study.

The third and final limitation of this study pertains to generalizability. In any evaluation study, it is desirable that most results and outcomes can be generalized to other similar situations. The findings for this study were based on one school and consequently on one mathematics curriculum. Therefore the results should not be generalized to any other existing mathematics curriculum or program. A similar program evaluation replicated in a different location with different teachers, students and problem solving activities would perhaps produce dramatically different results. Thus this investigator encourages extreme caution in any attempt to generalize the conclusions from this study.

Recommendations for Further Study

Listed below are several recommendations for further study.

1. Since this program evaluation was done in only one high school with only eight mathematics teachers, this study should be replicated in other schools in order to compare the results of this study.

2. Since there were virtually no minority students in this sample, the study should be replicated in a school with a larger minority sample in order to compare the results.

3. The entire study should be replicated in a different school system and/or geographic location to compare results with a different population.

4. The entire study should be replicated using a different NCTM Standard, or more than one Standard in order to compare the results.

5. The entire study should be replicated over a longer period of time, allowing the investigation of permanent long-term results.

> Change is needed in the way all children learn mathematics. As a matter of equity, we should stop ignoring 90 percent of our population when we teach mathematics. Equally important for society, we cannot hope for the solution of the problems that will face us in the 21st century if we fail to educate all children to the limit of their capacity. In a world that is becoming steadily more quantitative, we must provide better mathematics education, for everyone, from kindergarten through graduate school.
>
> The activities suggested here require more work on the part of authors, teachers, and pupils. But activities that are meaningful to the students are more likely to be remembered and more likely to leave the learners with a feeling that mathematics is useful and worth learning. Surely that is better than having students believe that mathematics is a subject they are required to learn to satisfy other people, and that it should be put out of their minds as soon as possible.
>
> Stephen S. Willoughby, 1990

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APPENDICES

Appendix A

NCTM Curriculum and Teaching Standards for High School Mathematics

STANDARD 1: MATHEMATICS AS PROBLEM SOLVING

In grades 9 - 12, the mathematics curriculum should include the refinement and extension of methods of mathematical problem solving so that all students --

--use, with increasing confidence, problem-solving approaches to investigate and understand mathematical content;

--apply integrated mathematical problem-solving strategies to solve problems from within and outside mathematics;

--recognize and formulate problems from situations within and outside mathematics;

--apply the process of mathematical modeling to real-world problem situations.

STANDARD 2: MATHEMATICS AS COMMUNICATION

In grades 9-12, the mathematics curriculum should include the continued development of language and symbolism to communicate mathematical ideas so that all students can--

--reflect upon and clarify their thinking about mathematical ideas and relationships;

--formulate mathematical definitions and express generalizations discovered through investigations;

--express mathematical ideas orally and in writing;

--read written presentations of mathematics with understanding;

--ask clarifying and extending questions related to mathematics they have read or heard about;

--appreciate the economy, power, and elegance of mathematical notation and its role in the development of mathematical ideas.

STANDARD 3: MATHEMATICS AS REASONING

In grades 9-12, the mathematics curriculum should include numerous and varied experiences that reinforce and extend logical reasoning skills so that all students can--

--make and test conjectures;

--formulate counterexamples;

--follow logical arguments;

--judge the validity of arguments;

--construct simple valid arguments;

and so that, in addition, college-intending students can-

--construct proofs for mathematical assertions, including indirect proofs and proofs by mathematical induction.

STANDARD 4: MATHEMATICAL CONNECTIONS

In grades 9-12, the mathematics curriculum should include investigation of the connections and interplay among various mathematical topics and their applications so that all students can--

--recognize equivalent representations of the same concept;

--relate procedures in one representation to procedures in an equivalent representation,

--use and value the connections among mathematical topics;

--use and value the connections between mathematics and other disciplines.

STANDARD 5: ALGEBRA

In grades 9-12, the mathematics curriculum should include the continued study of algebraic concepts and methods so that all students can--

--represent situations that involve variable quantities with expressions, equations, inequalities, and matrices;

--use tables and graphs as tools to interpret expressions, equations, and inequalities;

--operate on expressions and matrices, and solve equations and inequalities;

--appreciate the power of mathematical abstraction and symbolism;

and so that, in addition, college-intending students can--

--use matrices to solve linear systems;

--demonstrate technical facility with algebraic transformations, including techniques based on the theory of equations.

STANDARD 6: FUNCTIONS

In grades 9-12, the mathematics curriculum should include the continued study of functions so that all students can--

--model real-world phenomena with a variety of functions;

--represent and analyze relationships using tables, verbal rules, equations, and graphs;

--translate among tabular, symbolic, and graphical representations of functions;

--recognize that a variety of problem situations can be modeled by the same type of function;

--analyze the effects of parameter changes on the graphs of functions;

and so that, in addition, college-intending students can--

--understand operations on, and the general properties and behavior of, classes of functions.

STANDARD 7: GEOMETRY FROM A SYNTHETIC PERSPECTIVE

In grades 9-12, the mathematics curriculum should include the continued study of the geometry of two and three dimensions so that all students can--

--interpret and draw three-dimensional objects;

--represent problem situations with geometric models and apply properties of figures;

--classify figures in terms of congruence and similarity and apply these relationships;

--deduce properties of, and relationships between, figures from given assumptions;

and so that, in addition, college-intending students can--

--develop an understanding of an axiomatic system through investigating and comparing various geometries.

STANDARD 8: GEOMETRY FROM AN ALGEBRAIC PERSPECTIVE

In grades 9-12, the mathematics curriculum should include the study of the geometry of two and three dimensions from an algebraic point of view so that all students can--

--translate between synthetic and coordinate representations;

--deduce properties of figures using transformations and using coordinates;

--identify congruent and similar figures using transformations;

--analyze properties of Euclidean transformations and relate translations to vectors;

and so that, in addition, college-intending students can--

--deduce properties of figures using vectors;

--apply transformations, coordinates, and vectors in problem solving.

STANDARD 9: TRIGONOMETRY

In grades 9-12, the mathematics curriculum should include the study of trigonometry so that all students can--

--apply trigonometry to problem situations involving triangles;

--explore periodic real-world phenomena using the sine and cosine functions;

and so that, in addition, college-intending students can--

--understand the connections between trigonometric and circular functions;

--use circular functions to model periodic real-world phenomena;

--apply general graphing techniques to trigonometric identities;

solve trigonometric equations and verify trigonometric identities;

understand the connections between trigonometric functions and polar coordinates, complex numbers, and series.

STANDARD 10: STATISTICS

In grades 9-12, the mathematics curriculum should include the continued study of data analysis and statistics so that all students can--

--construct and draw inferences from charts, tables, and graphs that summarize data from real-world situations;

--use curve fitting to predict from data;

--understand and apply measures of central tendency, variability, and correlation;

--understand sampling and recognize its role in statistical claims;

--design a statistical experiment to study a problem, conduct the experiment, and interpret and communicate the outcomes;

--analyze the effects of data transformations on measures of central tendency and variability;

and so that, in addition, college-intending students can--

--transform data to aid in data interpretation and prediction;

--test hypotheses using appropriate statistics.

STANDARD 11: PROBABILITY

In grades 9-12, the mathematics curriculum should include the continued study of probability so that all students can--

--use experimental or theoretical probability, as appropriate, to represent and solve problems involving uncertainty;

--use simulations to estimate probabilities;

--understand the concept of random variable;

--create and interpret discrete probability distributions;

--describe, in general terms, the normal curve and use its properties to answer questions about sets of data that are assumed to be normally distributed;

and so that, in addition, college-intending students can--

--apply the concept of a random variable to generate and interpret probability distributions including binomial, uniform, normal, and chi square.

STANDARD 12: DISCRETE MATHEMATICS

In grades 9-12, the mathematics curriculum should include topics from discrete mathematics so that all students can--

--represent problem situations using discrete structures such as finite graphs, matrices, sequences, and recurrence relations;

--represent and analyze finite graphs using matrices;

--develop and analyze algorithms;

--solve enumeration and finite probability problems;

and so that, in addition, college-intending students can--

--represent and solve problems using linear programming and difference equations;

--investigate problem situations that arise in connection with computer validation and the application of algorithms.

STANDARD 13: CONCEPTUAL UNDERPINNINGS OF CALCULUS

In grades 9-12, the mathematics curriculum should include the informal exploration of calculus concepts from both a graphical and a numerical perspective so that all students can--

--determine maximum and minimum points of a graph and interpret the results in problem situations;

--investigate limiting processes by examining infinite sequences and series and areas under curves;

and so that, in addition, college-intending students can--

--understand the conceptual foundations of limit, the area under a curve, the rate of change, and the slope of a tangent line, and their applications in other disciplines;

--analyze the graphs of polynomial, rational, radical, and transcendental functions.

STANDARD 14: MATHEMATICAL STRUCTURE

In grades 9-12, the mathematics curriculum should include the study of mathematical structure so that all students can--

--compare and contrast the real number system and its various sub-systems with regard to their structural characteristics;

--understand the logic of algebraic procedures;

--appreciate that seemingly different mathematical systems my be essentially the same;

and so that, in addition, college-intending students can--

--develop the complex number system and demonstrate facility with its operations;

--prove elementary theorems within various mathematical structures, such as groups and fields;

--develop an understanding of the nature and purpose of axiomatic systems.

Appendix B

Problem Solving Attitude Assessment Survey

1. I believe the problem solving activities in which I have participated will improve my mathematics ability.

   __________ AGREE __________ DISAGREE

2. I enjoy finding different methods for solving problems.

   __________ AGREE __________ DISAGREE

3. If I had a choice, I would not continue the problem solving activities.

   __________ AGREE __________ DISAGREE

4. I believe the problem solving activities are a waste of time.

   __________ AGREE __________ DISAGREE

5. I would rather the teacher just do the sections in the book.

   __________ AGREE __________ DISAGREE

6. I would like the teacher to use a problem solving approach when teaching.

   __________ AGREE __________ DISAGREE

7. I believe working a wide variety of problems will help improve my confidence in my ability to solve problems.

   __________ AGREE __________ DISAGREE

8. Working with different types of problems will not help my mathematics ability.

   __________ AGREE __________ DISAGREE

9. Having experience in a wide variety of problem solving will help me attempt problems which I do not know how to solve.

   __________ AGREE __________ DISAGREE

10. Participating in the problem solving activities has helped me to realize I have to ability to solve various problems.

    __________ AGREE   __________ DISAGREE

11. I do not like problem solving.

    __________ AGREE   __________ DISAGREE

12. I would rather the teacher just told me how to do the problems.

    __________ AGREE   __________ DISAGREE

13. I feel better about my ability to solve problems since the problem solving activities.

    __________ AGREE   __________ DISAGREE

14. Problem solving has improved my ability to think in a logical manner.

    __________ AGREE   __________ DISAGREE

15. Because of the problem solving activities, I am more confident about my ability to use different strategies to find a solution for problems.

    __________ AGREE   __________ DISAGREE

Appendix C

Results of Focus Group Discussion for the Fourteen NCTM Curriculum and Teaching Standards

Standard 1: Mathematics as Problem Solving

a. Importance in curriculum: vitally important. Mathematics is problem solving, therefore if students are not learning problem solving, they are not learning mathematics.

b. How to implement: Teachers can begin implementation through a series of exercises, where students are introduced to a variety of problems, including both nonroutine problems and nonroutine methods for finding solutions. Students should be taught to view mathematics in a more personal and relevant manner, and to learn to generalize solutions to different problems in mathematics and in everyday life. Teachers should gradually increase the frequency for problem solving activities and make every effort to incorporate problem solving strategies into appropriate teaching methods.

c. Changes required for full implementation (where problem solving is part of the mathematics curriculum): Teachers must realize the importance of problem solving in the mathematics curriculum. Second, teachers believed that before they could teach most topics from a problem solving approach, they would require extensive re-training. There should be less emphasis placed on end-of-course testing and less pressure to cover all the pages in the text. Finally, and perhaps most important, there must be development and provision of new textbooks with appropriate materials which emphasize mathematics through a problem solving approach, since most textbooks currently emphasize drill and practice.

Standard 2: Mathematics as Communication

a. Importance in curriculum: important.
Students should be able to express mathematical ideas, both orally and in writing. They should be able to read mathematics content with comprehension. When giving explanations and discussions of problems, appropriate modes of communication would allow them to convey to others what they actually mean without pointing and gestering in meaningless ways.

b. How to implement: Allow students to give oral explanations and instructions for working problems. Have students research and actually present some topics to the class. Introduce mathematics vocabulary lists.

c. Changes required for full implementation: Teachers need to become more passive in their classrooms, allowing students the opportunity to discuss mathematics topics.

Standard 3: Mathematics as Reasoning

a. Importance in curriculum: very important. The ability to reason allows students to make sense of the world around them, to make good judgements, and to become better citizens. Mathematically, the ability to reason is the basis of all problem solving; it enables students to hypothesize, conjecture, and to formulate solutions and strategies.

b. How to implement: This can begin in the mathematics curriculum as one facet of problem solving and then continue into formal proof through Algebra I, Geometry, etc. Teachers should allow students the opportunity and time to think through mathematical situations before supplying a solution. Allow student to develop their own theories and to discuss these during class time.

c. Changes required for full implementation: Teachers should allow more 'think time.'

More minutes per class period would be helpful. Teachers require additional training and the development of new attitudes toward their own role in the classroom. Eliminate standardized testing in the mathematics classroom, and begin tests which require discussion and the formation of conclusions.

Standard 4: Mathematical Connections

a. Importance in curriculum: Important. Students should use and value the relationships and connections among the various mathematical topics. It is also necessary that students realize mathematical relationships are applicable in other disciplines. They should be able to apply their mathematical knowledge to situations in the real world.

b. How to implement: Teachers should use examples from business, social studies, science, physics, drafting, and all other disciplines. It is important to allow students to view mathematics as useful and applicable in all areas.

c. Changes required for full implementation: Teachers need more time to plan and develop lessons relative to other disciplines. Course requirements would need to focus more on inter-disciplinary applications. Teachers must first understand the standard and believe in its importance. New textbooks would need to be written and made available.

Standard 5: Algebra

a. Importance in curriculum: extremely important. Algebra provides the framework and language through which most mathematics is communicated. Therefore, algebra is an important processing tool for applying mathematics in many disciplines. All students should have a proficiency in algebra.

b. How to implement: Begin a Pre-Algebra course for all students in the seventh grade, with Algebra I offered in the eight grade for advanced students, and in the ninth for all others.

c. Changes required for full implementation: Students and parents must realize the importance of Algebra proficiency. Counselors should stop advising students to avoid Algebra courses.

Standard 6: Functions

a. Importance in curriculum: important.

An understanding of functions allows students to conceptualize the relationships and correspondence between the elements of two sets. A study of functions begins with simple arithmetic operations and should continue through the study of mathematics.

b. How to implement: Teachers should establish a strong conceptual foundation before the formal notation and language of functions are presented. The study of functions should begin with those relationships which exist in the student's own world. The use of graphs in depicting data is also a useful method of showing the relationships of functions.

c. Changes required for full implementation: The concept of functions and the relationships between numbers should be introduced to students very early in arithmetic. New materials and teacher re-training would be essential.

Standard 7: Geometry from a Synthetic Perspective

a. Importance in curriculum: very important. Students must have an understanding of shapes and their properties, with an emphasis on their applicability in human activity.

b. How to implement: Teachers should use examples of how geometry is used in recreations, in practical tasks, in the sciences, and in the arts. Students should have the opportunity to visualize and work with three-dimensional figures. Teachers should use physical models and other real-world objects to help students develop a geometric intuition.

c. Changes required for full implementation: Student must develop a strong foundation in the K - 8 programs. Teachers should focus on more than deductive reasoning and proof. Teachers must be able to visualize, provide pictorial representation and application of geometric ideas, and to answer questions about natural and physical phenomena. This will require teacher training and new materials.

Standard 8: Geometry from an Algebraic Perspective

a. Importance in curriculum: somewhat important. This standard was difficult for this group of teachers to actually visualize. Transformations are not usually considered by most teachers to be of great importance.

b. How to implement: Other than continuing the methods currently being used, there were no suggestions.

c. Changes required for full implementation:
Teachers did not know.

Standard 9: Trigonometry

a. Importance in curriculum: very important. Trigonometry is based on the study of triangles. Many real-world problems require the solution of triangles. All students should apply trigonometric methods to practical situations involving triangles.

b. How to implement: Using calculators, trigonometry should be introduced to students at much earlier ages. Continue current curriculum practices. Other strategies not known.

c. Changes required for full implementation:
Offer teacher workshops and develop new materials.

Standard 10: Statistics

a. Importance in curriculum: increasingly important. Collecting and representing data are activities of major importance in today's society. Knowledge in statistics allows students to test hypotheses and to draw inferences.

b. How to implement: Students should be exposed to data analysis in grades K - 8, and should be encouraged to apply statistical tools to other academic subjects such as English, social studies, and biology, as well as athletics and other out of school activities.

c. Changes required for full implementation: Massive re-training of teachers in all subject areas and at all grade levels. Development of new materials.

Standard 11: Probability

a. Importance in curriculum: somewhat important. Probability provides the methods for dealing with uncertainty and for interpreting predictions based on uncertainty. Students should know how to make informed observations about the likelihood of events, and to judge the validity of statistical claims. Although probability provides useful models for solutions of problems in physics, medicine and economics, many problems in daily living can also be better understood using probability.

b. How to implement: Not readily known.

c. Changes required for full implementation:

Teacher training and development of appropriate materials.

Standard 12: Discrete Mathematics

a. Importance in curriculum: somewhat important
Discrete mathematics is a relatively new term and as such was not fully understood by this group of teachers.

b. How to implement: Not known.

c. Changes required for full implementation:
Extensive teacher training along with the development of appropriate teaching units and materials.

Standard 13: Conceptual Underpinnings of Calculus

a. Importance in curriculum: important.
Today, methods of calculus are applied increasingly in the social and biological sciences and in business as well. Students should appreciate the value of calculus in the improvement of the world's economic status.

b. How to implement: Teachers should provide students an opportunity to informally explore some of the central ideas of calculus, while introducing and answering questions about real-world phenomena.

c. Changes required for full implementation:
Develop a course for teachers which would allow them to experience those recommendations found in section b. above.

Standard 14: Mathematical Structure

a. Importance in curriculum: somewhat important
An awareness of the broad structure of the principles of mathematics provides them with a framework which facilitates long-term retention.

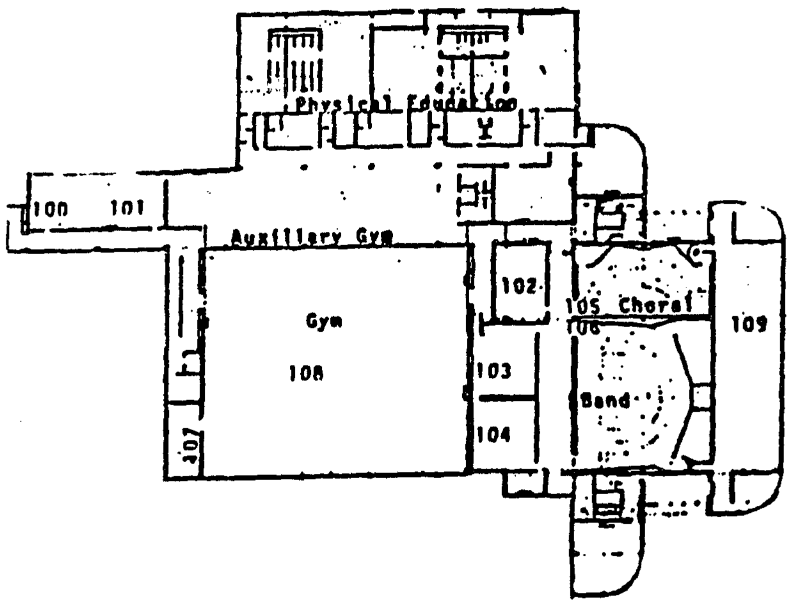
b. How to implement: Allow students the opportunity to understand the idea of structure through the observation of the common properties of systems that seem on the surface to be quite dissimilar. How this could be done is not readily known.

c. Changes required for full implementation:
Teacher re-training, along with the development of relevant and appropriate materials. New textbooks would be helpful.

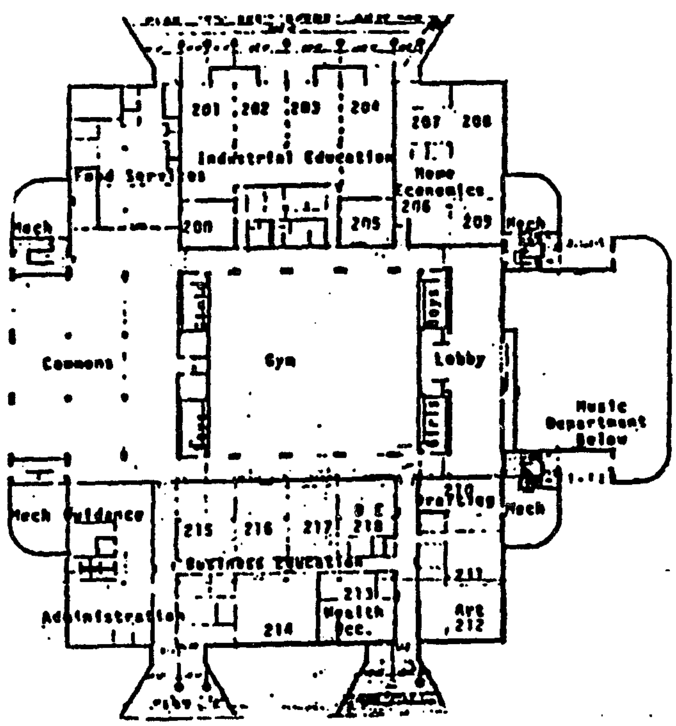
Appendix D

South Caldwell High School Floor Plan

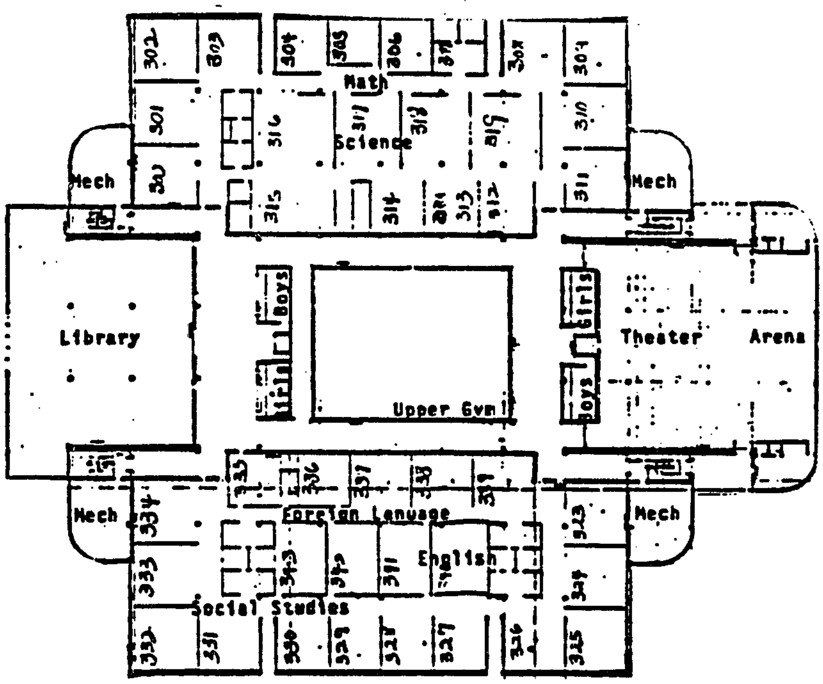
FIRST FLOOR



SECOND FLOOR



THIRD FLOOR


Math
Science
Mech
Mech
Library
Boys
Girls
Upper Gym
Girls
Boys
Theater
Arena
Mech
Mech
Foreign Language
English
Social Studies

Appendix E

Examples of Nonroutine Problems

Example 1: Suppose that one-third of the population smokes, that 60% of all smokers are female. What is the fraction of the population represented by smoking males?

Example 2: Suppose a dress is sold at full price on Monday. The dress is marked down 30% on Tuesday, then marked down 20% from Tuesday's price on Wednesday. If the final price is $28, the what was Monday's price?

Example 3: If one-third of the air in a container is removed with each stroke of a vacuum pump, what fraction of the original amount of air remains in the container after 5 strokes?

Example 4: Mr. Kato had some paperback books that he no longer wanted. Rather than throw them away, he put them in a box and brought them to school for his students. At the end of each class period, he let the students in that class take a fraction of the books that were still left in the box. He told first period to take 1/6 of the books; second period to take 1/5 of the remaining books; third period to take 1/4 of those that remained; fourth period to take 1/3 and fifth period to take 1/2 of the remaining books. This left 14 books for the sixth period, who took all 14 books. How many books did Mr. Kato start with?

Example 5: Find the sum of

$$1 + 3 + 5 + 7 + 9 + 11 + \ldots + (n-2) + n$$

Example 6: A cake shaped like a cube falls into a vat of chocolate creme. It is then cut into one inch squares. What are the dimensions of the cake if there are 384 pieces with one side frosted? What are the dimensions if there are n pieces with one side frosted?

Example 7: Two friends, Al and Bob, and their dog, spent their vacation in the Maine woods. One day Al went on a walk, alone, while Bob, followed him an hour later, accompanied by the dog. He ordered the dog to follow Al's trail. When the dog reached Al, Al sent him back to Bob, and so on. The dog ran to and fro between the two friends until Bob caught up with Al, who happened to be a slow walker. Indeed Al was making no more than 1 1/2 miles an hour, while Bob made 3. The dog's speed was 6 miles an hour. Now, what is the distance the dog ran to and fro until Bob caught up with Al? We may presume that the dog lost no time playing with his two masters or hunting rabbits.

Example 8: Find the product of

$$(1 - 1/2)(1 - 1/3)(1 - 1/4) \ldots (1 - 1/98)(1 - 1/99)(1 - 1/100)$$

Example 9: I have a robot. It is not very smart. There are two buttons on the machine. The first causes the robot to take one step and the second causes the robot to take two steps. How many sequences of button pushes will cause the robot to take 12 steps? How about 20 steps?

Example 10: The new high school has just been completed. There are 1000 lockers in the school and they have been numbered 1 to 1000. During recess, the students decide to try an experiment. When recess is over, each student will walk into the school one at a time. The first student will open all the locker doors. The second student will close all the locker doors with even numbers. the third student will change all the locker doors with numbers that are multiples of three. The fourth student will change the position of all locker doors numbered with multiples of four; The fifth student will change the position of the lockers that are multiples of five, and so on. After 1000 students have entered the school, which locker doors will be open?

Appendix F

Examples of Mathematics Problems from Everyday Life

Example 1: How many handshakes will occur at a party if every one of the 15 guests shakes hands with each of the others?

Example 2: Jean is attending a two week (14 day) summer camp. Her parents gave her $50 for 'incidental' expenses for the entire two weeks. After three days at camp she had spent $15. Assuming she continues to spend at the same rate, will her budget of $50 hold out for the two weeks? If not, when will she run out of money and how much more will she need?

Example 3: A farmer wishes to buy a piece of land that is adjacent to his farm. The real estate agent tells him that the plot is triangular in shape, with sides of 20, 75 and 45 meters. The land will cost only $5.58 a square meter. How much should the farmer pay for the piece of land?

Example 4: Six people, let's call them A, B, C, C, E, and F, have witnessed a burglary and are only too willing to let the police know what the burglar -- who by the way, managed to escape -- looked like. But you know how eyewitnesses' accounts go; the descriptions of the criminal differed in every important point, particularly with regard to the color of his hair and eyes, the color of his suit and probable age.

This is the testimony the police got from these six witnesses:

	Hair	Eyes	Suit	Age
A	brown	blue	grey	34
B	blond	black	dark blue	30
C	red	brown	dark brown	34
D	black	blue	not dark brown	30
E	brown	black	grey	28
F	blond	brown	dark blue	32

Through these contradictory reports the police finally got their man and compared his real appearance with the six descriptions. They found that each of the six witnesses had made three erroneous statements and that each of the four questions had been answered correctly at least once. What did the burglar really look like?

Example 5: An office manager must assign offices to six staff members. The available offices, numbered 1 - 6 consecutively, are arranged in a row, and are separated by six-foot high dividers. Therefore, voices, sounds, and cigarette smoke readily pass from each office to those on either side. Miss Braun's work requires her to speak on the telephone frequently throughout the day. Mr. White and Mr. Black often talk to one another in their work, and prefer to have adjacent offices. Miss Green, the senior, employee is entitled to Office 5, which has the largest window. Mr. Parker needs silence in the office(s) adjacent to his own. Mr. Allen, Mr. White, and Mr. Parker all smoke. Miss Green is allergic to tobacco smoke and must have non-smokers in the office(s) adjacent to her own. Unless otherwise specified, all employees maintain silence while in their offices. Find the best locations for each individual's office.

Example 6: Plan the food for a group party. What quantities should you get? What is the total cost? Don't forget the cost of items such as ice, napkins, paper plates, cups, etc. Decide how much to charge each person?

Example 7: During the census, a man told the census-taker that he had three children. When asked their ages he replied, "The product of their ages is 72. The sum of their ages is my house number." The census-taker turned, ran outside to look at the house number displayed over the door. He then re-entered the house and said, "Using the information you have given me, I cannot tell their ages." The man then said, "I should have told you that the oldest likes angel food cake." Hearing this, the census-taker promptly wrote down the ages of the three children. What did he write?

Example 8: Six gamblers play a remarkable game of chance. The game itself is rather primitive but the loser is in a bad spot. He is supposed to double the pool of each of the other five gamblers. Altogether, they play six games and by chance each of the men loses just once. When the men later counted how much is left to each of them, they discover that each owns exactly $64. How much had each of them when they started?

Example 9: The Smith family, which consists of Mr. and Mrs. Smith, their son, Mr. Smith's sister, and Mrs. Smith's father, has for years dominated the community life of Plainsville. At the present time the five members of the family hold among themselves the positions of grocer, lawyer, postmaster, preacher, and teacher in the little town. The lawyer and the teacher are not blood relatives. The grocer is younger than her sister-in-law but older than the teacher. The preacher, who won this letter playing football in college, is older than the postmaster. What position does each member of the family hold?

Example 10: According to the U. S. Department of Agriculture, the amount shown for each of the following foods yields 20 grams of protein. Check current prices in the community and then decide which of these foods is the most economical source of protein.

2 1/3 ounces, center-cut pork chop

1 1/3 cups, whole milk

3 1/2 hot dogs

4 1/2 tablespoons, peanut butter

3 ounces, ground beef

3 1/3 ounces, cured ham

3 large eggs

9 slices of white enriched bread