AN ABSTRACT OF THE THESIS OF

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Title: The Relationship of Teacher Behaviors and Characteristics to Critical Thinking Skills Among Middle Level Students

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The purpose of this study was to investigate the effect of teachers' behaviors and characteristics upon the development of student mathematical critical thinking skills. From a pool of 20 teachers, whose students had been pre- and post-tested for a measure of critical thinking skills, 10 middle level teachers were selected to complete extensive questionnaires on their backgrounds and experiences, submit videotaped records of classroom activity, and to maintain detailed data on their classroom actions. The teachers were ranked in accordance with their respective classes' mean gain scores on the assessment tool.

From the pool of 20 teachers, the top-ranked 25% (five teachers) and the bottom-ranked 25% (five teachers) were selected for the study. Extremes of the ranking order were used to increase the probability of determining potential
differences in teacher behaviors and characteristics between the two groups. The two extremes were thus placed in two groups to identify those variables which contributed to differences between the groups.

Identified variables from pairwise comparisons of the teachers within each group were analyzed, following corroboration from a minimum of three data sources, to generate groups profiles. A $5 \times 5$ matrix was constructed for each potential group variable. Comparisons were conducted between all pairs of teachers within each group, and the differences between the two groups were compiled in the form of group profiles.

The five top-ranked teachers, based upon student performances, were distinguished from the lowest-ranked five teachers by greater use of small group instruction, math manipulatives, and warmup activities; as well as by provision for teaching higher-order thinking skills, frequency of transitions between classroom activities, and the use of activities which required the application of concepts. The lowest-ranked teachers were characterized by the greater frequency of teacher-directed instruction, a higher amount of computer usage, assignment of individual student work, highly structured classes, and extensive reliance on textbooks as the primary source of instructional materials.
The Relationship of Teacher Behaviors and Characteristics to Critical Thinking Skills Among Middle Level Students

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Typed by B. McMechan for Linda M. Cave
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To my girls, who wouldn’t let me give up, and to Maggie, who became a cherished friend.
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The Relationship of Teacher Behaviors and Characteristics to Critical Thinking Skills Among Middle Level Students

CHAPTER 1
INTRODUCTION

Since 1989, mathematics educators, national leaders, and distinguished citizens from industry have collaborated to delineate a plan for the revitalization of mathematics education (Mathematical Sciences Education Board [MSEB], 1989, 1990, 1991; National Council of Teachers of Mathematics [NCTM], 1989, 1991). Student abilities to solve real-life problems, to communicate and reason mathematically, and to bridge the gap between physical representations of problems and the symbolic images of mathematics were targeted as the major components of this revitalization process (MSEB, 1989).

The Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989) (hereafter referred to as Curriculum Standards) and the Professional Standards for Teaching Mathematics (NCTM, 1991) (hereafter referred to as Teaching Standards) were prepared to provide guidance to the reformers of mathematics education. Collectively, these two sets of standards advocated a shift toward mathematical reason-
ing as an alternative to the memorization of procedures; toward conjecture, invention, and problem solving rather than the production of specific answers; toward the application of mathematics rather than the consideration of concepts and procedures in isolation; and toward students' verification of their own thought processes in opposition to reliance upon the teacher as a mathematical authority. This emphasis upon cognitive development rather than the mastery of facts shifted the focus of mathematics instruction from lower-level algorithmic skills to the acquisition of higher-level thinking strategies.

Mathematics education in the United States has produced students with adequate algorithmic computation skills, but not necessarily students who are capable of complex problem solving (Lindquist, 1989). In Curriculum Standards (NCTM, 1989), complex problem solving is represented as the individual's ability to explore, conjecture, and reason logically, as well as his or her ability to select from a repertoire of mathematical strategies to solve realistic, non-contrived, open-ended problems. Descriptive analyses of problem solving performances suggest that the skills necessary to be successful at problem solving are the same skills generally accepted as higher-order cognitive skills (Suydam, 1980). In this context, higher-order cognition implies the ability to make mathematical
decisions based upon the analysis of data contained within problem situations or the solution of open-ended questions. Considering this expression of interest in the ability of students to solve open-ended problems, the apparent absence of research information concerning the relationship between teacher practices and student performance on tasks which require higher-order thinking skills poses an evident problem. Previous attempts to identify the characteristics of this relationship have rather focused upon student lower-level thinking skills or upon content areas other than mathematics. Initially, mathematics teaching research was predominantly process-product in nature, and sought primarily to relate instructional processes and teacher characteristics to student achievements through observational studies (Evertson, Emmer, & Brophy, 1980; Good & Grouws, 1977; Smith, 1977).

Grouws and Good (1981) subsequently identified and defined a set of teacher behaviors that seemed to hold potential for the improvement of student learning, concentrating upon identified behaviors by the use of correlational measures to connect the frequency of occurrence of behaviors to student achievement scores. However, for the implementation of reforms, process-product research hindered generalization across school settings and posed a number of drawbacks: a) The synthesis of all of the variables associated with desirable pupil performance resulted in a
composite of teachers which was unlike any of the teachers observed within the contexts of the studies; b) the question why particular combinations of teacher behaviors led to gains in student performance and why others did not was not addressed; and c) effective teachers were identified on the basis of student performance on standardized tests which measured computation skills rather than higher-order thinking (Shulman, 1986).

In response to the process-product paradigm, researchers began to apply a causal-comparative research design, a type of ex post facto research which attempted to retrospectively identify which plausible causal factors were associated with certain conditions. In place of beginning with equivalent groups, then subjecting them to different treatments to bring about different effects, an ex post facto study searches back in time for those variables which may have brought about known differences (Berkner & Tikunoff, 1976). The goal of this approach is to gather information about subjects for the generation of variables which can subsequently be investigated through experimental research. However, causal-comparative research which focuses upon improvements in student higher-order mathematical thinking has not been undertaken.

Some of the studies which have attempted to assess the effect of various strategies and techniques upon student achievements either used assessment instruments designed to
assess basic skills or they produced inconclusive results (Charles & Lester, 1984; Cohen, 1983, 1984; Ebmeier & Good, 1979; Glasson, 1989; Good & Grouws, 1977; Stiff, 1989; Zehavi, Bruckheimer, & Ben-Zvi, 1988). Other studies examined the effect of predetermined variables upon student problem-solving abilities (Baxter, Stein & Leinhard, 1991; Evertson et al., 1980; Harrison, Brindley, & Bye, 1989; Smith, 1977). However, the results of these investigations did not provide convincing evidence that experimental approaches undertaken provided either significant improvement in student performance levels on open-ended problems or contributed to the development of higher-order thinking.

Statement of the Problem

Prior to asking teachers to develop complex thinking skills among students, it is necessary for educators to clarify which teacher behaviors help move students toward the development of these higher-order thinking skills. In the absence of knowledge of which teacher behaviors provide positive contributions to student understanding and disposition toward mathematics, much of the effort undertaken by teachers may be wasted. For the teachers of mathematics to facilitate student acquisition of the skills necessary to solve nontraditional problems requiring higher-order thinking, it will be necessary to establish a relationship between student performance on problems which require higher-
order cognition and instructional practices within the classroom.

It is obvious that good teaching practices can make a difference in student mathematical performance (Brophy & Good, 1986). Good teaching can have an effect on both the rate and the quality of the acquisition of mathematical power (Grouws, 1985). Teacher characteristics, such as sex, age, training, and experience, are of interest since this type of information can be used to help explain teacher behaviors, including the selection of strategies and instructional modes. A multiplicity of factors which have influenced teacher and student behaviors have been studied, and research has been concentrated upon specific teaching philosophies and strategies as well as the use of specific materials in the classroom. However, as previously observed, the results from these studies have been inconclusive.

The purpose of the present investigation was to generate hypotheses concerning those teacher characteristics and behaviors, or combinations of teacher attributes, that contribute to the enhancement of student higher-order thinking skills. For subsequent investigations, it may be presumed that the hypotheses developed within the context of the current study will provide critical questions for additional experimental investigation.
Significance of the Study

At present, institutions within the United States are devoting extensive resources to reshaping school mathematics to the end that students will learn to solve a variety of problems, read documents involving mathematical concepts, and express themselves quantitatively in both oral and written form. The development of complex skills among students has been identified as a goal at district, state, and national levels. Extensive inservice training is taking place to assist teachers in the development of the skills needed for the use of varied strategies, aids, and technologies. As efforts are made to conform mathematics education to 21st century requirements, it is important for educators to understand how teachers may be assisted in the development of those behaviors that will result in the acquisition of higher-order thinking skills among students.

The Teaching Standards (NCTM, 1991) encouraged teacher participation in life-long professional development and inservice programs to improve their teaching skills and to enhance their professional growth. It is essential to know just which characteristics and behaviors constitute "improved" teaching as well as provide directions for professional development. In the present era of reform in mathematics instruction, the decisions that educators make will be critical in nature. The colleges and universities which
offer teacher education must determine which opportunities and experiences will enable their students to develop the degree of mathematical understanding that will enhance their futures as teachers of mathematics at lower levels.

Therefore, the general objective of the present study was to provide a contribution to the understanding of those variables which enhance higher-order mathematical thinking among students. Specifically, this study has sought to elicit hypotheses about student performances in relation to teacher characteristics and behaviors which can be subject to further experimental testing. Different teachers may reflect different combinations of variables, which in turn vary to the same degree as do educational settings, students, and/or personalities. An addition to the understanding of the effects of these variables, and of multiple effective combinations of variables, will assist educational leaders in the preparation of preservice and inservice teacher education. The present study was undertaken based upon the assumption that this transformation will take place not for the reason that a rigid set of teaching procedures can be prescribed, but for the reason that a focus for those who wish to create learning environments that will nourish student development has been provided.
CHAPTER 2
REVIEW OF THE LITERATURE

Introduction

Despite the amount of attention that has been focused upon the improvement of mathematics instruction, the traditional approach to mathematics teaching has not produced students with higher-order thinking skills that enable students to solve open-ended problems or to communicate mathematically (Peterson, 1988). Research has been centered upon a search for teaching strategies, heuristics, and the tools that support an improvement in student performances as measured by tests of basic skills. The purpose of this study was to investigate teacher variables related to student outcomes to generate hypotheses that will assist in the theoretical development of teaching higher-order thinking skills. In this approach, it is paramount to recognize that teacher behaviors and characteristics do in fact affect student performances. Therefore, this review considers (a) studies which corroborate the influences of teachers upon student achievement and (b) studies which assess the effectiveness of different teaching approaches, techniques, and strategies in mathematics classrooms.
Effect of Teaching Upon Student Performance

The classroom environment is complex, dynamic, and unique. Teachers continually try out new strategies and new styles of teaching which they hope will result in improved student outcomes. Grouws (1985) described student outcomes as the ultimate measure of the influence of teacher behaviors and characteristics. From the results of prior research, Grouws concluded that teachers may be the most important influence on student acquisition of problem solving skills.

In a study of the effects of teaching in a fourth-grade mathematics classroom, Good and Grouws (1977) identified some of the teacher behavioral patterns that made a difference in student learning. Based upon a process-product research model, from a population of 41 teachers nine who were considered to be relatively effective and stable and nine who were considered low effective were observed in their classrooms; all teachers used direct instructional methods as their teaching format. Effectiveness and stability were determined on the basis of residual gain scores achieved by individual students on the Iowa Test of Basic Skills, administered once in the fall and once again in the spring. The use of this testing form precluded the assessment of higher-order thinking skills among the students.
Four informational sets were collected, including measures of time to describe how time was utilized, low inference descriptions of teacher-student interaction patterns, high inference variables, and checklists that were used to describe materials and homework assignments (Good & Grouws, 1977). Data were analyzed with a one-way analysis of variance (ANOVA) to distinguish variance between behavioral variables for the two groups. The principal variables identified included managerial problems (frequent among low effective teachers), student initiated behaviors, general clarity of instruction, nonevaluative and relaxed atmosphere, frequency of feedback (frequent among high effective teachers); and frequency of homework (higher among high effective teachers). Two patterns which had been delineated prior to the study were considered to be representative of effective teachers, namely demanding more work and achievement from students and providing immediate, nonevaluative, and task-relevant feedback.

A subsequent study by Ebmeier and Good (1979) used a mathematics subset of the Scholastic Research Associates (SRA) Achievement Test series to measure fourth grade student outcomes prior to and following treatment in the classrooms of 39 volunteer teachers. An experimental group (20 subjects) was provided with an explanation of the treatment program and a teaching manual outlining a direct instruction model which encouraged teachers to: a) devote
approximately one-half of the class period to the development of conceptual understanding, b) assign and grade problems to be completed by the students at home, c) ask more questions calling for knowledge of specific "facts," d) allow only 10-15 minutes per day for practice, e) conduct regular review sessions, and f) carefully consider the rate at which material was covered, increasing the pace when possible. The control subjects (19) were asked to teach as they normally would.

A Teaching Style Inventory composed of items selected on the basis of relevance to student achievement was administered to all teachers (Ebmeier & Good, 1979). Classroom observations of the use of instructional time, student-teacher interactions, descriptions of math materials, assignments, and pacing were conducted at least five times during the course of the study. Students were administered an aptitude inventory to assess characteristics which interacted with those of the teachers, as well as the SRA subtest for traditional elementary mathematics topics. From the findings of the study, significant interactions between student types and teacher characteristics were found, accompanied by evidence that the interactions among student types, teacher types, and treatment types exerted influence upon student mathematics achievements. It was concluded that teachers can and do make a difference in student learning.
The consistency of teacher behaviors in relation to student achievement was studied by Brophy (1973) for a three-year period. The Student Metropolitan Achievement Test scores for second and third grade teachers in 88 schools were correlated across subtests, including word knowledge, word discrimination, reading, arithmetic concepts and skills, and problem solving, within years across the sex of students and within subtests across time. Teachers who were consistent in their overall relative effectiveness based on linear constancy across the three-year period were thus identified, as were those whose students consistently scored higher in one type of subtest as opposed to another (i.e., high language arts gains and low math gains, or vice versa). However, the student scores for 49 percent of the teachers did not reflect a process of linear change. It was noted that the simple linear regression model used for computing residual gain scores did not allow for curvilinearity, nor could such variables as absenteeism, class size, student aptitude, or ability grouping be controlled.

Evertson et al. (1980) adopted a process-product approach for a study which sought to link instructional processes and teacher characteristics to middle school pupil achievements, based upon a sample of effective and less effective teachers as determined by pupil achievements and attitudes. Pupil achievement was assessed with a
criterion-referenced test developed for the study and linked to the content of seventh and eighth grade mathematics textbooks. Initial differences within classes were controlled by administration of the California Achievement Test, and teachers from the upper and lower one-thirds, who were considered to have classes of comparable ability levels, were included in the study. All teachers used a direct instructional approach. Attitudes were measured with the Student Rating of Teachers scale, a nine-question Likert-type of questionnaire in which students were asked to rate their teachers on knowledge of the subject, interest in knowing the students, preparation and organization, enjoyment of teaching, and whether the student learned much in class, enjoyed the class, or felt comfortable with the teacher. Student attitudes and test scores were correlated and ranked and six of the less effective teachers and three of the more effective teachers were identified for further study.

Each classroom was visited approximately 20 times by alternating pairs of observers without knowledge of achievement records or questionnaire results (Evertson et al., 1980). The variables observed included question-response-feedback sequences, private academic or procedural contacts between teachers and students, time allocation, lesson content, student misbehavior, pupil attention, problem solving, and teacher clarity. The means for each group
for each of the variables were computed and compared. The less effective teachers were found to experience greater degrees of classroom misbehavior, whereas the more effective teachers were perceived to enforce rules with more consistency, experience fewer interruptions, assign more homework, and reflect greater confidence and enthusiasm. The two groups did not differ with respect to student-initiated contacts, task-oriented seatwork, patience, use of audio-visual aids, or command of subject matter. The amount of time spent in presenting and discussing content (e.g., developmental activities) was significantly different between the two groups. It was concluded that effective teachers spent more time on whole group instruction. However, it was also observed that all teachers used a similar instructional approach, based upon the utilization of little or no small group work. Though the predetermination of variables for this study has raised questions about the significance of the variables retained (i.e., retained if between-observer agreement on a 5-point scale was considered to be significant), the differences in student achievement supported the hypothesis that teacher behaviors affected student performance.

Smith (1977) investigated relationships between specific student classroom behaviors and critical thinking skills in college classrooms based upon a sample of 12 faculty members in the humanities, social sciences, and
natural sciences. The degree to which faculty members encouraged, praised, or used student ideas was assessed through analysis of tape-recorded class sessions, along with the degree to which faculty members asked questions and the nature of the questions. The student activities studied were the degree to which students participated in class, the cognitive level of the participation, and the degree of peer-to-peer interaction.

Two instruments were used to assess the impact of different classroom processes upon critical thinking. The Watson-Glaser Critical Thinking Appraisal was used to pretest and posttest the subjects. An instrument developed by Chickering (1972), based upon a taxonomy of thinking skills (Bloom, 1956), was used at the end of the term as a self-report form for recording behavioral activities associated with critical thinking. The inventory asked students to report the percentages of time spent in each of six course activities: a) memorizing, b) interpreting, c) applying, d) analyzing, e) synthesizing, and f) evaluating (Smith, 1977). Canonical correlations between the process variables (student participation, peer-to-peer interaction, questioning, divergent and evaluative questions, divergent and evaluative student responses, and encouragement) and the three highest critical thinking behaviors were found to be highly significant, whereas the correlation for the same process variables and all six critical thinking behaviors
was 1.00. Though significant differences in critical thinking scores were found across individual classes, mean critical thinking scores were not increased. Classes with low participation tended to demonstrate declines in critical thinking, whereas student participation, faculty encouragement and use of student ideas, and peer-to-peer interactions were positively related to changes in critical thinking and critical thinking behaviors.

In a study which investigated linkages between cognitive and affective pupil outcomes and teacher effects, Schofield (1981) administered mathematics achievement and attitude tests to 251 prospective elementary teachers during their last year of college training. The 56 teachers who taught Grades 4 and 6 the following year then became the subjects for further study. A semantic differential measure of attitude toward mathematics and mathematics teaching, developed for this investigation, was administered to the subjects at the end of the first semester and again at the end of the school year. The teachers were also given the Applied Psychology Unit Arithmetic Test (APU), a measure of competency over a broad range of mathematics concepts. The student measure of achievement encompassed mathematics concepts and applications and the mathematics computation sections of the Australian Council for Educational Research Whole Number Mathematics Tests. In
addition, a separate semantic differential measure of attitude was developed for the student subjects.

As determined by analyses of variance and covariance for relationships between teacher variables and student performance, the pupils of teachers who scored highest on the APU test were found to score significantly higher on the student mathematics test than pupils of teachers scoring low on the APU test. However, pupils of high scoring teachers were also found to have significantly less favorable attitudes toward mathematics, whereas the pupils of middle and low scoring teachers, with substantially lower mathematics test scores, expressed more favorable attitudes toward mathematics (Schofield, 1981). In turn, the pupils of teachers with highly favorable attitudes toward mathematics had consistently higher APU scores, but significantly less favorable attitudes toward math than the pupils of teachers whose attitudes toward math was considered to be middle or low. Given that the teachers included in the study were all first year teachers, the effects upon student achievement and attitudes could have been greater for more experienced teachers. However, the strength of the relationships between teachers and students corroborated the influence of teachers upon student achievement.

Baxter et al. (1991) found that the style in which a teacher communicated knowledge was related to the enhancement of learning and teaching. Based upon instructional
representations (visible, shared, concrete, or symbolic models of abstract concepts) as the observed variables, the experience of a single classroom teacher was examined. The fifth grade teacher was selected on the basis of experience and success at teaching elementary mathematics, as recognized by other teachers and district level administrators. Observations of 25 lessons on the functions and graphing of ordered pairs were conducted and three lessons were videotaped. In addition, the teacher was interviewed before and after each lesson with regard, respectively, to the lesson plan and subsequent thoughts about its success.

Questions generated by the study included: a) how must a teacher understand mathematics to use instructional representations effectively; b) how can teachers be supported and encouraged to further develop their understanding of mathematics; and c) how can topics that are mathematically important and pedagogically challenging be best identified by those in charge of educating preservice teachers (Baxter et al., 1991)? Six lessons were selected to represent the key mathematics concepts presented in the 25-lesson unit. Observational data included the amount of instructional representations and their targets, as well as the methods used to help students translate between different representations and their targets. Students were posttested to confirm that they had mastered the definitions of the terms presented by the teacher. There was no intent to assess
student mastery of the concepts, but tracing the degree to which the teacher helped students to transform information supported the hypothesis that teachers exercise an influence upon student behaviors.

Tikunoff, Berliner, and Rist (1975) conducted a causal-comparative study to determine whether an ethnographic approach to the study of teaching could provide insight into the teaching-learning process. From a population of 200 classrooms, in which the teachers were provided specially constructed two-week curriculum units in reading and mathematics, 40 second and fifth grade classrooms were selected for further study. Each of the curriculum units included both pretest and posttest, from which differences student residual gain scores were used to identify the 10 most and the 10 least effective teachers. To control for observational bias, data for all 40 classroom teachers were collected.

During a two-week period, 12 observers visited classrooms to record raw records of behavior (protocols). Six raters were then asked to read a pair of protocols for each day, one from each a less and a more effective class, resulting in description of all the possible ways in which the two classrooms differed. More than 200 concepts were thus identified, subsequently reduced to 61 dimension variables used as the basis for extensive analysis of the sample classrooms. Frequencies of occurrence for each group
of classrooms were tabulated and probability levels for differences between the frequencies were assigned to each variable. Substantial differences in frequency of occurrence occurred for such variables as awareness of developmental levels, adult involvement, sarcasm, spontaneity, warmth, manipulation, flexibility, and cooperation. From this study, it was concluded that the descriptive information derived not only helped the researchers understand the complexity of classroom instruction, it also provided insight into the variables which served to discriminate between more and less effective classrooms (Tikunoff et al., 1975).

Nonetheless, the identification of variables was entirely dependent upon the presence of observers in the classroom and the accuracy of observer reports. To assure that the observers were not distractive or intrusive, the research was constructed upon a two-dimensional approach that was seemingly self-contradictory. The first dimension consisted of the observer as an invisible nonparticipant, whereas the second established reciprocity between the teacher and observer (i.e., encouraging ethnographers to provide assistance in the classroom). Additional sources of information which did not involve the observers may have helped to increase confidence in the variables observed (Tikunoff et al., 1975).
In a review of process-product research which linked teacher behaviors to student achievement, Brophy and Good (1986) reviewed research which stressed the effect of teachers on students, while differentiating this subject from the term "teacher effectiveness," normally used to denote success in promoting social skills and affective development as well as achievement. It was concluded that studies of the teacher effect, generally based on the comparison of classroom achievement by students taught by one method to classes of students taught by another, produced only inconclusive results. The use of inappropriate units of analyses, confounded with other differences between teachers and small sample sizes, made even the most significant results achieved relatively unconvincing.

Though it was concluded from the evidence presented that teachers did in fact make a difference in student learning, other research shortcomings were stressed (Brophy & Good, 1986). First, for the purpose of improving teacher education and practices, little effort had been undertaken to use existent large databases which had linked teacher behaviors to student achievement. Second, most of the studies reviewed did not attempt to measure student achievement in terms of higher-order problem solving, but were content to describe teacher behaviors which were effective in producing students with higher scores on tests of basis skills.
Effect of Varied Teaching Methods and Techniques

Upon Student Performance

Many of the studies reviewed in this section focused upon teaching strategies which encouraged the active involvement of students in learning mathematics content. A variety of manipulative and technological materials were used and a multiplicity of strategies have been investigated. In some studies, teaching strategy was combined with one or more instructional aid(s). In most of the studies reviewed, the teacher characteristics investigated were identified prior to the collection of data.

Two studies conducted by Fuson and Briars (1990) addressed the issue of whether the effects of a learning-teaching approach could be generalized across heterogeneous populations. The teaching approach consisted of: a) linking the use of Base-Ten Blocks to written marks immediately after working with the blocks; b) linking blocks to written numbers, numerals, and block names; c) allowing students to move to the abstract form of problems when they were ready to do so; d) ensuring that students were not practicing errors when completing written problems; e) beginning addition and subtraction problems with four-digit numbers; f) combining place-value learning with the multidigit addition and subtraction work; and g) modifying the usual algorithm for subtraction.
In the first study, students in two Illinois schools were ability-level grouped, and the highest-achieving first-grade classes at each school were invited to participate in the study. Four of the participating teachers previously worked with the researchers and the remaining four were given a brief overview of instruction and materials. In all, eight classes received instruction in addition, and three second-grade classes received instruction in subtraction. Four subtraction tests were constructed and then administered to the students. Written tests on place values and meaningful multidigit addition were also administered. In addition to the written tests, individual interviews were carried out with randomly selected students from one class at each achievement level. All children were given two addition pretests, and subsequently administered the same tests as posttests. Lower achieving and first grade classes were also given the Untimed Addition Minitest (Fuson & Briars, 1990).

A McNemar's chi-square test for pretest to posttest differences on addition trading errors was highly significant, whereas a paired t-test analysis of the test score differences for each addition test and each subtraction test was reported to be significant at the .001 level for every class. Systematic classroom observations were not conducted, and how the blocks were used in the classrooms was not clarified. Consequently, no inferences could be
drawn relative to the effect of teaching strategies upon student performance (Fuson & Briars, 1990).

The second study, based upon 132 second-grade classrooms in the Pittsburgh public school system, was designed to evaluate the effect of using a Base-Ten Blocks teaching/learning approach to addition and subtraction (Fuson & Briars, 1990). In two 2-1/4 hour inservice sessions for teachers on the use of student worksheets and Base-Ten Blocks, all second-grade teachers in the district were urged to follow the lesson plans. Teachers were allowed to attend two, one, or none of the workshop(s). However, no distinction was drawn between the test scores of students in classrooms with trained teachers and students in classrooms with untrained teachers, thus gain scores were not used. Therefore, statistical interpretations used to justify the acceptance of the learning/teaching approach remained a source of concern. Moreover, during this second experiment, no teacher or student interviews were conducted, attitude scales were not administered, and classroom observations were not undertaken. Therefore, from the results, it was not possible to infer which features of the learning/teaching approach should be considered crucial or expendable with respect to student learning.

Raphael and Wahlstrom (1989) examined the influence of teacher characteristics on the use of instructional aids in relation to student mathematics achievements in (1) geome-
try, (2) ratio, proportion, and percent, and (3) measurement. The aids included geoboards, models of solids, Miras, computer graphics, construction kits, rulers and compasses, etc. The following hypotheses were examined:

1) Reliable and meaningful dimensions (used extensively, used occasionally, not used) identify patterns of variation among teachers' use of instructional aids.

2) Greater use of instructional aids is related to greater topic coverage.

3) Both the use of instructional aids and topic coverage are related to student achievement.

4) The relationship of aid-use to student achievement remains after the effects of topic coverage are removed.

The study was based upon a stratified random sample from classrooms included in the Second International Mathematics Study (Raphael & Wahlstrom, 1989). Of 479 eighth-grade teachers from 120 schools who submitted data on the use of instructional aids in the three math areas, 103 teachers were asked to complete further data sets, including a request to identify teaching methods for the three math areas. The response rate was 90 percent and such instructional aids as rulers and compasses, protractors, Miras, computer graphics, models of solids, and geoboards were provided to the participants, accompanied by instruc-
tions for their use. Respondents indicated their use of
the materials at different levels, from extensive to occa-
sional or not at all, as well as student mastery of previ-
ous materials and parent occupations (for purposes of
socioeconomic level identification).

Teaching experience, courses in mathematics pedagogy,
teaching responsibilities for classes, estimates of student
mastery, student socioeconomic status, and opportunity to
learn were the variables observed. The statistical results
indicated that the moderate use of a few aids and the ex-
tensive use of a few contributed significantly to student
achievement in geometry and informal transformations (Ra-
phael & Wahlstrom, 1989). Moreover, when teachers reported
extensive use of instructional aids in geometry, they were
more likely to have focused on informal transformation
graphy than on plane figures geometry; in contrast,
teachers reporting occasional use of instructional aids
were more likely to have covered plane geometry.

Four types of achievement test scores were considered,
including: a) average gain scores for plane figures class-
es, b) end-of-year scores for plane figures, c) average
class gain scores for informal transformations, and d) end-
of-year scores for informal transformations. Analyses of
results were also completed for ratio, proportion, and per-
cent, and again for measurement. Only teaching experience
and background in mathematics pedagogy were reported as
uniquely predictive of extensive use of a variety of instructional aids in these areas. Emphasis upon instructional aids was considered to be related to higher end-of-year student achievement scores. Teaching experience was considered to be uniquely predictive of the extensive use of instructional aids as well as higher student achievement scores for measurement. Student mastery of previous material, socioeconomic level, and coverage of noncomputation items were all reported to be predictors of higher end-of-year computation knowledge. In other-than-computation achievement, socioeconomic level was the only predictor listed. These findings were related to the initial hypotheses as follows (Raphael & Wahlstrom, 1989):

1) Greater use of aids was related to greater topic coverage for all areas except measurement.

2) Occasional use of aids, in combination with course coverage, indicated higher student achievement for both plane figures and informal transformations. In areas other than geometry, the use of aids was positively associated only with the end-of-year knowledge in percent.

3) The effects of experience, content coverage, and use of aids for student achievement could not be separated.

4) The effect of instructional aids did not remain after the effect of topic coverage was removed.
5) Predictors of the use of measurement aids were not determined. The most effective use of instructional aids for teaching measurement remains unclear.

Moreover, given that data analysis for the study was based upon quantitative mathematical exercise derived arbitrarily from qualitative data, the results with respect to the effect of teacher characteristics upon student performance were not clear.

Ball (1988) administered a pretest-posttest control group design to investigate the effectiveness of an instructional unit on fractions, using a computer and fraction strips. Five intact fourth-grade classes from two schools located in middle class neighborhoods were subjected to similar pretests and posttests. New fraction concepts were introduced with strip chart materials and were then followed by 20-30 minutes of computer time per student, per day. Control classes used activities from existing fraction workbooks, as well as the fraction strips, but did not have access to computers. The use of the computer software was the distinguishing variable between the control and the experimental groups. Analysis of the data resulted in significant mean differences between the treatment and control groups. It was concluded that the effectiveness of the treatment was validated by a highly significant F-statistic. However, since the control group teach-
ers were allowed to use the fraction strips, it was difficult to credit the interpretation of significance as a reflection of the appropriate use of a manipulative model.

Spraggins and Rowsey (1986) analyzed the outcomes of two instructional methods, based upon utilization of worksheets and participation in simulation games, for student achievement and the retention of learned information. Additional variables included educational ability and sex. The questions of interest were as follows:

1) Will there be a difference between the achievement of the students taught by simulation games and those taught by worksheets?

2) Will there be any significant interactions between the use of simulation games and worksheets, and student ability and sex for achievement?

3) Will there be a difference between the retention of information on the part of students taught by simulation games and of those taught by worksheets?

4) Will there be any significant interactions between the type of instruction (simulation games or worksheets) and students' ability and sex for retention?

Based on achievement scores in mathematics, English usage, and reading (SRA Placement Test), biology students from a single high school were assigned to one of four
classes. A cross-class selection of 44 students was assigned to the experimental group (introduction of concepts via simulation games), while a second cross-class selection of 39 students was placed in a control group (introduction via worksheets). All classes were taught by one of the researchers and participated in both simulation games and worksheets. The differences between classes were in the material covered by the games and worksheets. Experimental group games introduced the current lesson with worksheets related to a previously covered topic; the opposite was true of control group materials, for which the games pertained to past lessons and the worksheets introduced the current lesson (Spraggins & Rowsey, 1986).

From the results it was concluded that students taught by simulation game methods had comparable achievement gains and retention scores as students taught using worksheets. It was recommended that simulation games be used as an alternative instructional strategy to traditional worksheet strategies (Spraggins & Rowsey, 1986). However, since univariate tests were conducted for every interaction and main effect in the multiple analysis of variance table, the chances of a Type I error were increased. Also, placing the control and treatment groups in the same classroom may have injected some degree of sample bias. Thus, it would have been difficult for no interaction to have taken place
between groups. For these reasons, the research recommendation was not convincing.

Heid (1988) sought to evaluate the teaching strategy based upon the deemphasis of algorithmic skills in relation to study understanding of mathematics content. Using introductory calculus students as subjects, the following questions were addressed:

1) Can the concepts of calculus be learned without concurrent or previous mastery of the usual algorithmic skills of computing derivatives and integrals or sketching curves?

2) Does student understanding of course concepts and skills attained in a concepts-first course differ from that attained by students in a traditionally taught calculus course?

Using materials developed specifically for the study, 39 students in two applied calculus sections were taught by methods which required the students use the meaning of concepts to analyze problem situations. A microcomputer was used to perform most of the algorithms necessary to problem solutions, as well as to display computer-generated graphs to illustrate the concepts. An experimental group was provided with illustrations of basic rules or hand algorithms, whereas a second experimental section was not given algorithm examples until the final three weeks of class. A control group of 100 students in a large lecture class was
taught algorithmic skills as the calculus concepts were developed. Students enrolled in either the experimental or control group according to their preference for the scheduled time or the size of the class. The same final exam was given to both the treatment and control groups (Heid, 1988).

The data collected included (a) the final exam, (b) student interview tapes, and (c) results from seven questions constructed to address the concepts and applications of introductory calculus without requiring the ability to execute algorithms. Interviews with 15 students in the experimental group and five students in the control group were conducted to gain information about student backgrounds, as well as problem solving experience and understanding of course concepts (Heid, 1988). Statistical analyses of the final exam results with respect to the treatments was apparently not conducted, and no analysis of the interview data was presented. However, no substantially different mean scores for the three groups were reported. It was concluded that students from the experimental classes demonstrated better understanding of course concepts and performed almost as well on final exams as the control group. From the results, it was inferred that compressed and minimal attention to skill development was not necessarily harmful, even on a skills test. The study limitations (e.g., researcher as interviewer, investigator,
and instructor for the experimental groups) brings the conclusions into question and precludes useful inferences with respect to the effect of teaching methods upon student performance.

Finally, the researcher purported that the study tested the use of the computer as a tool for refashioning introductory calculus curriculum. Since testing the computer as a tool was not included in the research questions, data were not collected in relationship to use of computers, and no analyses were performed for interactions of the computer effect with the treatment (Heid, 1988). Thus, the generalization with regard to computer use was probably inappropriate. In addition, students were paid for interviews, a procedure which may have interjected a serious reactive arrangement interaction with the treatment and thus further limited the generalizability of the study.

Cohen (1983) used Piagetian tasks administered individually and in a randomized order to compare the effect of two strategies for the use of manipulatives on student achievement. Students were given tasks and then divided into two groups. Students in the experimental group were allowed to work on the floor, move the apparatus, and move themselves. For the control group, the apparatus was set up on desks and could not be moved. The sample consisted of 56 fifth-grade students from a single elementary school, selected by a stratified (gender) random method. Both
teachers involved in the study were given both a control and an experimental group. Each provided a self-reported summary of teaching techniques used, and each teacher was also subject to two observations to confirm the methods in use. All four groups received instruction utilizing materials from the Science Curriculum Improvement Study, Level 5, Energy Sources, selected for the reason they provided ample opportunity for student manipulation and thus the opportunity to view materials from multiple viewpoints.

A 2 x 2 analysis of variance on posttest scores was used to investigate the main and interactive effects of pretesting and treatment. None of the F-ratios for either of these effects for pretesting and treatment were considered to be significant. It was concluded that (a) there were no differences by gender for task performance and (b) that viewing objects from a variety of viewpoints did enhance the development of projective spatial conceptual ability among elementary-age children (Cohen, 1983). However, since the F-statistic for the treatment effect was insignificant, the second conclusion is difficult to accept.

In a second study, Cohen (1984) used a Solomon Four Group design to investigate the effects of two different strategies upon the development of logical structures: 1) encouragement to examine phenomenon and movement of students around an experimental apparatus and 2) examining the
apparatus based on predetermined behaviors and not upon student interest. Whether gender had an effect upon the development of logical structures was a secondary research interest. Four intact second grade classes from an elementary school in Arizona were selected as subjects, based on faculty and administrative agreement to participate in the study. Pretests consisted of a battery of six Piagetian-type tasks, each designed to evaluate how well students related, synthesized, clarified, ordered, predicted, inferred, and hypothesized from interactions with objects.

All classes were instructed by classroom teachers. Control groups were instructed to use science manipulatives without moving around their desks or moving the apparatus. The control group teacher was assigned pre-targeted outcomes and lines of inquiry. Experimental groups were encouraged to work on the floor and to examine phenomenon by moving about and/or moving and manipulating their apparatus in a variety of ways. Experimental group teachers interacted and guided discoveries based upon individual lines of investigation. The investigator visited the classrooms once each week to confirm teacher reports (Cohen, 1984).

With no apparent effect, a chi-square one-sample procedure was used for both the experimental and control group pretests to determine whether pretreatment observations had an interactive effect. This method of analysis was also
used to compare changes of cognitive abilities, if any, and to determine whether gender had an effect upon the development of logical structures. Data for the analysis of experimental and control group task performance were significant for all tasks at the 0.05 level, indicating the direct effect of treatment. Resultant chi-square values for the analysis of performance between males and females indicated that gender had no effect upon the development of logical structures. The results of the statistical analyses were interpreted to mean that a small change in logical development existed when students interacted with the environment in isolation, as compared to large changes when teacher intervention occurred. Cohen (1984) inferred that teachers should assume an active role as guides when students used manipulative materials, and that teachers should encourage students to examine and use materials in a variety of ways. An additional inference was that manipulative materials should be available to students to promote the development of logical structures.

A research study conducted by Harrison, Brindley, and Bye (1989) sought to differentiate between two teaching strategies for students at different cognitive levels. A process-oriented, investigational approach was used to teach fractions and ratios to subjects at 12 years of age. Specifically, the two research questions were as follows:
1) What levels of cognitive development in fractions and ratios are demonstrated by 12-year-olds?

2) Can process-oriented teaching strategies that are adaptable to students' cognitive response levels significantly improve achievement in, and attitudes toward, fraction and ratio topics?

Teachers and students from 12 Calgary schools were chosen to participate in the study by the Program Evaluation Department of the Calgary Board of Education. Pairs of seventh grade seven classes from each of the Calgary schools were identified according to mean scores on the Stanford Intermediate Level II, Mathematics Test, Form B. The classes were then assigned to either the experimental or control groups. Prior to the fall opening of school, teachers assigned to experimental groups were given workshops on the use of process-oriented teaching materials, teaching strategies were discussed, and classroom adaptation decisions were made in consultation with the teachers. The experimental teaching approaches used a variety of simple concrete materials to facilitate understanding of mathematical ideas. Students were directed to pose questions for systematic experimentation and to carry out the experimentation with the manipulatives. In contrast, control group instruction centered upon a textbook and a teacher guide from a textbook series published in the late 1970's. Instruction in these classes did not include
demonstrations or student investigations with concrete materials (Harrison et al., 1989).

A variety of assessment instruments was used, two of which assigned ratio and proportion tasks to either concrete, transitional, or formal cognitive ability levels. Students in the experimental and regular classes were pre-tested with seven of the testing instruments. Following completion of appropriate units (either ratio or fractions), student completed questionnaires and were retested for achievement and attitude. The posttest was designed to measure student ability to provide explanations, follow instructions, recognize relationships, and generate examples.

In addition to student responses, data were collected from classroom observations by observers using a Behavior Frequency Record. Behaviors rated included: a) frequency of use of real objects, b) encouragement to notice number patterns, c) frequency of small-group work, and d) valuation of student contributions. Improvement in fraction and ratio achievement was analyzed using a three-factor, repeated measures analysis of variance. No significant differences were found between the two groups at the concrete and formal levels. Gains for each cognitive level were compared by t-test. Significant differences for the transitional students in the experimental group, and the ratio test results favored the experimental group. Only one posttest subscale, Giving Explanation, favored the experi-
mental treatment, but a significant difference in favor of the experimental group was found for total scores. Since at least six subscales were considered, it would have been of additional interest to determine how these conclusions were reached (Harrison et al., 1989).

From the findings, it was concluded that the experimental group was superior with respect to measures of achievement and attitude for fractions and ratios. However, since the group × level × test interaction was significant, a statement that the group × test interaction was significant remained without meaning. It was further concluded that the transitional students had particularly benefitted from the investigational approach (Harrison et al., 1989).

A number of instruments were used for this study and a variety of factors was analyzed. Though the statistical analysis was appropriate for the particular comparative factors, several factors detracted from the strength of the conclusions: a) the lack of reported statistics, b) the excessive number of contrasts performed, and c) the attachment of meaning to a two-factor interaction when the three-factor interaction was significant. Consequently, it is difficult to attribute great weight to the conclusions of the study. Moreover, it should be noted that though class mean scores were used for subject selection, treatment was by class, and intact classrooms were selected,
student subjects were used as the unit of analysis rather than the class unit.

Using ninth-grade physical science students as subjects, the issue of teacher-demonstration versus student manipulation of objects was studied by Glasson (1989). Two instructional methods based upon declarative knowledge and procedural knowledge were compared. Declarative knowledge was defined as factual and conceptual, whereas procedural knowledge was defined as problem solving. Research interest was directed at the relative effect upon achievement in science topics for the two approaches. It was hypothesized that there would be no differential declarative knowledge gains, but that the hands-on laboratory methods would result in greater procedural knowledge achievement than the teacher demonstration method.

From ninth grade enrollments in two intact physical science classes, each of which had completed at least one semester of algebra, 27 male and 27 female students participated in the experiment and were randomly reassigned to two treatment classes. One used a hands-on laboratory method and the other was taught by means of teacher demonstrations. Two predictor variables, reasoning ability and prior knowledge of science, were assessed prior to the start of the treatment. Declarative knowledge and procedural knowledge achievement were assessed at the conclusion of the study (Glasson, 1989).
Treatment was extended over a three-week period during which both groups of students studied simple machines and were assigned identical readings and sets of problems. Each teacher had equivalent teaching experience and rotated between treatment groups at the end of each topic. Teachers also followed scripted daily lesson plans and guidelines for teacher-prompting and feedback. Each class performed three laboratory activities, differing only with respect to whether the teachers or the students manipulated the apparatus to gather experimental data. Students in the hands-on class worked in groups of two or three and were required to record the collected data and use it to solve subsequent problems. Students in the demonstration class recorded the data from the chalkboard and solved the same written problems (Glasson, 1989).

Students' declarative and procedural knowledge was assessed with two posttest measures, a textbook chapter test and a researcher-designed six-item test in which the application of algorithms and reasoning strategies were required for problem solutions. Regression of declarative knowledge achievement by teaching method, reasoning ability, prior knowledge, and an interaction between teaching method and reasoning ability indicated that neither the teaching method nor reasoning ability had a significant effect. For the same variables, regression of procedural knowledge resulted in significant differences for teaching
method. Use of a squared multiple correlation coefficient indicated that the three independent variables (teaching method, reasoning ability, and prior knowledge) accounted for 54 percent of the variance for this test. The interaction between teaching method and reasoning ability was not significant (Glasson, 1989).

From these findings, it was concluded that hands-on and teacher demonstration laboratory methods did not have a differential effect for declarative knowledge achievement, but that prior knowledge was a significant predictor of student performance for declarative knowledge. The absence of a significant interaction between the teaching method and reasoning ability, in conjunction with significantly better performance by the hands-on class for the procedural knowledge test, was interpreted as evidence that all students, regardless of reasoning ability, benefited from the hands-on laboratory approach. Therefore, it was concluded that the ability to solve problems on procedural knowledge tests (problem solving) could be enhanced if reasoning strategies had been applied previously in the course of actively performing experiments (Glasson, 1989).

The conclusions provided by Glasson (1989) may be related to mathematics classrooms insofar as the same types of strategies (teacher demonstration and student manipulation of concrete objects), involving declarative knowledge (lower-order thinking skills) and procedural knowledge
(higher-order thinking skills), are used in mathematics classrooms. These conclusions were carefully worded to avoid excessive generalization or causal inferences. Given the data presented, the conclusions were appropriate. Nonetheless, they leave educators without a clear picture of the specific teacher behaviors which contributed to enhanced student performance.

Based upon fifth- and seventh-grade classes, Charles and Lester (1984) conducted a study of the effectiveness of the process-oriented Mathematical Problem Solving (MPS) instructional program. The MPS focuses upon the Polya problem solving model, involving extensive experience with process problems, emphasis upon the development of the ability to select and use a variety of strategies, and teaching a specific problem solving strategy. Study design was based upon a pretest-posttest control group approach.

Thirty-six schools in West Virginia with similar levels of achievement on the Comprehensive Test of Basic Skills (CTBS) were identified, from which number 23 fifth-grade and 23 seventh-grade teachers were asked to participate. Classes were assigned to either treatment or control groups to maintain approximate parity for mean CTBS scores. None of the schools contained both a control group and a treatment group. Treatment groups were given instruction in problem solving using the MPS materials and guidelines, whereas the control groups were given instruction using
only the problem solving unit from a regular textbook (Charles & Lester, 1984).

Four forms of a test for the evaluation of problem solving performance in the areas of translation and processing were administered to all students. Test items were written by math educators with prior problem solving performance experience gained through the analysis of students' written work. For the following research questions, student scores were determined for each of the three dimensions of (a) understanding, (b) planning, and (c) results (Charles & Lester, 1984):

1) How do students who have received systematic instruction in mathematical problem solving compare with respect to various measures of performance to students who have received no systematic problem solving instruction beyond that provided by the mathematics textbook?

2) Is there constant improvement in students' problem solving performance or are there periods of time when improvement is most pronounced? On which measures of performance are the improvements most evident?

3) What are teachers' attitudes toward, and confidence in, teaching problem solving after using the MPS for 23 weeks?
One-hour teacher interviews were conducted in a two-week period following the administration of the posttests. In addition, analyses of covariance were conducted to determine treatment and control class means for the three problem solving measures, using pretest scores as a covariate and the corresponding posttest scores as the dependent variable. For classes in both grades, the treatment group scored significantly higher on every posttest measure. Moreover, graphing the mean test scores for the treatment classes showed significant linear trends over time. Thus, the following conclusions were determined (Charles & Lester, 1984):

1) The MPS is more effective with process problems than with complex translation problems, particularly with respect to understanding and planning.

2) The MPS does not substantially improve students' ability to obtain correct results for complex translation problems.

3) The MPS improves students' ability to understand problems and to plan solution strategies faster than it improves their ability to obtain correct results.

4) Program structure is a significant factor in forming teacher attitudes toward problem solving programs.
5) Among the most important benefits of the MPS are that (a) the program improves student willingness to engage in problem solving, (b) students gain confidence in their ability to succeed in problem solving, and (c) students learn "how to think."

6) Consideration of the extent to which a program requires specialized expertise in the material to be implemented, is fundamental to the successful evaluation of any instructional program.

Given the study design and the means of statistical analysis used, conclusions four, five, and six were seemingly inappropriate. In particular, part (c) of the fifth conclusion caused concern about the credibility of the study. Conclusion three used the term "faster," apparently derived from the analysis of the intermediate tests, but otherwise an undefined qualitative term. Threats to the internal validity of the study prompt the question whether the observed changes in the experimental group were due to the treatment or to an extraneous variable. Although all teachers were trained in MPS, some of them were consequent-ly assigned to control groups; there may have been some carry-over from familiarity with MPS which influenced the control classes. The experimenters observed each treatment class at least three times to assure proper implementation. Control classes were monitored by a district level adminis-trator (Charles & Lester, 1984). The use of different
observers, in particular an administrator, likely jeopardized the external validity of the study.

Two related studies on the effects of fact-oriented versus problem-oriented acquisition of memory access were conducted by Adams et al. (1988). Sixty-three undergraduate students enrolled in introductory psychology courses were randomly assigned to one of three experimental conditions, either (a) a fact-oriented condition, (b) a problem-oriented pause condition, or (c) a problem-oriented no-pause condition. Each group received audiotaped information directly related to the solution of problems which they were subsequently given to solve. The condition to which they were assigned determined the type of sentence structure which was used in presenting the acquisition material. In a first trial, without mention of the connections between the two experiments, students were given booklets with problems which could be solved with the previous clues. For a second trial, students were told that clues which they had received during the first part of the period would provide answers to the problems. They were given the same five problems as in the first trial, plus five new problems.

A one-way, between-groups analysis of variance was used to investigate how information that was acquired differently could affect later transfer situations. Mean percentages of correct solutions were analyzed by condition
and by trial. Planned orthogonal contrasts were performed on the two problem-oriented conditions, "pause" and "no pause," generating nonsignificant results. Combining the means of these two conditions to compare with the fact-oriented acquisition revealed that the problem solving groups performed significantly better than the fact-oriented groups (Adams et al., 1988).

It was concluded that students prompted to use clues for problem solving performed better than students given the same clues who were not explicitly prompted. It was also concluded that the form in which clues were presented affected their transfer to problem situations, with the problem-oriented form producing significantly higher statistical results than the fact-oriented clues. Moreover, results were interpreted to indicate that processing acquisition and test materials in a similar manner led to enhanced abilities specific to particular acquisitions and test items, but not to general acquisition and testing situations. It should be noted that no determination of the validity of the instruments was provided.

A follow-up by Adams et al. (1988) looked more closely at the similarity relationship between information acquisition and subsequent problem situations. The experimental design was similar to that used for the initial study, with the exception that there were four treatment conditions: fact-oriented (FO), knowledge-specific (KS), general set A,
and general set B. Students were assigned to conditions in groups of 7 to 11 persons, whereas the manner of assignment to groups was not specified. During the acquisition stage, students assigned to the FO condition listened to ten clues, all of which were fact-oriented, whereas students in the knowledge-specific condition were given five fact-oriented clues and five problem-oriented clues in that order, then in a first trial were given five problems to solve that corresponded to the five problem-oriented clues. The third condition (General Set A) students received five fact-oriented clues followed by five problem-oriented clues, and in the first trial were given problems that could be solved by use of the fact-oriented clues. Students in the final condition (General Set B) were given the same number of problem-oriented clues followed by fact-oriented clues, and were then given problems related to the fact-oriented problems. For all conditions, the second trial (informed cued recall) consisted of five old and five new problems.

Contrasts indicated that performance of the two general groups were not significantly different. The combined performance of A and B was not significantly different from that of the fact-oriented (FO) group. Jointly, these three groups differed significantly from the knowledge-specific or problem-oriented groups. On the informed cued recall test, a significant main effect for conditions and a non-
significant value for the interaction were found (Adams et al., 1988). It was then argued that the enhanced solution rates for new items, compared to the older items, demonstrates an item-specific interference effect, and that the superior problem solving performance for the knowledge-specific condition was a primary contributor to the main effect for conditions. Thus, the results of the two studies is perhaps suggestive that students who acquire concepts in a problem-oriented settings can use memory production to recreate initial learning contexts and to find answers relevant to new problems.

The effects of teaching strategy, relevant knowledge, and strategy length upon learning contrived mathematical concepts ("mats") were examined by Stiff (1989). The contrived concepts were devised and defined so that they would be approached by students without relevant prior knowledge. Students were given instruction in strategies to learn a "mat." An E strategy consisted of giving examples and non-examples, whereas a C strategy consisted of stating definitions and analogies. The length of a strategy consisted of either one, four, or seven examples/nonexamples or definitions/analogies. Four research hypotheses were tested:
1) The greater the student's relevant knowledge (RK), the better the students will learn the "mat."

2) Overall, the C-strategy instruction is better for learning the concept than the E-strategy instruction.

3) No single strategy length (SL) value is best for concept acquisition; as SL increases, concept attainment improves for E and C instructional strategies.

4) E-strategies are more beneficial than C-strategies for students who have low relevant knowledge (RK), C-strategies are more beneficial than E-strategies for students at high RK.

On the basis of above-average ability to learn mathematical concepts, as determined by enrollment in advanced mathematics courses, seniors from two high schools were selected to take part in the study. Students were given prepared booklets designed to fit the treatment and were subsequently administered a series of three criterion tests. There was a significant interaction effect for RK and teaching strategy on each criterion test, thus corroborating the first hypothesis. The interaction of relevant knowledge and strategy length was significant for tests 2 and 3, results which were interpreted in support of the second hypothesis. The interaction of teaching strategy and strategy length was significant only for test 1. An
analysis of variance of the simple interaction effects for teaching strategy and strategy length on test 1 indicated significance at all levels of relevant knowledge. On the basis on these results, the research question that suggested seven E strategies would best facilitate learning of the concept mats for students with low relevant knowledge was not rejected (Stiff, 1989).

Stiff (1989) was careful to summarize his findings only in terms of the specific study concluded. However, he did generalize about teacher behaviors which could serve to improve student learning. On the basis of this study, it was suggested that teachers should use C-strategies for students with high relevant knowledge to improve the likelihood that they would learn mathematics concepts. It was also suggested there may be an optimal strategy length for learning new mathematical concepts, but it was stated that this relationship was not exhibited by the study findings. Rather, it was inferred that teachers must consider not only the intelligence of students, but also how adequately they are prepared for instruction. It was stated that the data on the interaction of relevant knowledge and teaching strategy supported this inference.

Buchanan (1987) conducted a study which compared the problem solving skills of gifted third-grade students with average fifth-grade students, identifying the effect of such factors as attitude, motivation, and belief systems
upon mathematical performance. Subjects were selected for
the study on the basis of their scores on the Otis-Lennon
Mental Ability Test. From this pool, random samples of
three girls and three boys were drawn to form four problem
solving groups: a group of third-grade boys, a group of
third-grade girls, a group of fifth-grade boys, and a group
of fifth-grade girls.

An experimenter met with each group twice each week
for eight weeks, during which periods the groups solved a
variety of mathematical problems defined as nonroutine
questions requiring more than algorithmic procedures in the
solution process. Students were allowed the use of calcu-
lators, graph boards, rulers, and other aids, and were
urged to cooperate with one another to seek solutions. The
researcher interacted with the students by probing, guid-
ing, encouraging, and questioning. Each session was taped
and the tapes were reviewed for differences in experimenter
behavior, student responses, and time spent working on
problems. No differences in experimenter behavior were
observed by the researcher. Student comments were tallied
in three categories: directly related to the problem
(DRP), self comments/meta-cognitive comments (SC/MC), and
digressions (D) (Buchanan, 1987).

One-way analyses of variance were performed on the
number of self-comments/meta-cognitive comments between
groups, and on the number of comments directly related to
the problem and the number of digressions. No significant
differences were found for the self-comments/meta-cognitive
comments, but it was reported that a significant difference
in the number of DRP comments was found to be in favor of
fifth-grade girls with respect to fifth-grade boys. Sign-
ificant differences were also found for working times by
group. Post-hoc analysis of the tapes produced evidence of
four types of students. Type 1 students enjoyed the tasks
and were challenged by them. Type 2 students relied on the
experimenter for support and direction. Type 3 students
wanted to be first and to beat the others. Type 4 students
avoided failure at all costs and were inconsistent perform-
ers. The same three classifications of statements (DRP,
SC/MC, and D) were tabulated and compared by student type.
Significant differences were again reported between groups
in the number of DRP and D comments (Buchanan, 1987).

It was concluded that the factors which contributed to
problem solving abilities reflected attitude, motivation,
and belief systems. A final conclusion determined that
there were major differences in problem solving by sex.
Analysis of working time by group indicated that this dif-
ference was based strictly upon the time required to arrive
at a correct answer. In subsequent discussion, it was
noted that girls socialized to a greater degree than the
boys. One of the questions posed by Buchanan (1987) was
whether these differences reflected prior school experience
or social learning associated with sex norms. The question of whether differences in student performance while engaged in small group work using manipulatives and calculators would have been the same if algorithmic-type (lower-order thinking) problems were presented was not addressed. Further holistic research to describe the complex interactions that occur during problem solving in group situations was recommended.

Shumway et al. (1981) investigated the effects of the availability of calculators to students, and the availability of calculator-related curriculum resources, consultant resources, and in-service workshops for teachers on student achievement. The project design was described as experimental, with pretests and posttests for two treatment groups, (1) no calculator and (2) calculator. A site director was specified for each of five states. In turn, site directors then selected an elementary school from their local areas to participate. From each site, for each grade level and treatment, a single teacher and classroom was selected for further study.

Identified areas of concern were: a) change in children's attitude toward calculators and school mathematics, b) possible interference with children's growth in knowledge of basic facts and paper-pencil computation, c) changes in children's scores on standardized achievement tests in mathematics, d) potential development of additional
mathematics concepts related to the calculator, and
e) change in computational power of children of grade
levels two through six when using calculators. The two
treatment groups differed in the availability of calcula-
lators, the amount of training given to teachers on the use
of calculators in the classroom, the availability of calcu-
lator-based instructional materials, and researcher inter-
actions with teachers as consultants. Teachers in the no
calculator group were instructed to ask students not to use
calculators. Consultants who visited the classrooms pro-
vided no suggestions in relation to calculator use among
the no calculator groups (Shumway et al., 1981).

From observations, various potential treatment effects
were described, including (a) the amount and nature of cal-
culator use among calculator groups, (b) the availability
of calculators in the home, (c) the administrative position
on the use of calculators for instruction, (d) goals for
instruction, (e) instructional strategies used, (f) student
attendance, and (g) teaching styles, among others (Shumway
et al., 1981). However, the procedures undertaken to con-
trol for these possible effects were not specified.

Treatments took place over an 18-week period. Testing
was accomplished with an attitude scale, a basic facts
test, the Mathematics Test of the Stanford Achievement
Test, and estimation and special topics tests designed for
the study. Scale scores were used to compare the two dif-

ferent levels of the Stanford Achievement Tests administered as pretests and posttests. In addition, site directors observed each class once every 11 days. From pretests to posttests, significant gains were reported for grades two and three in basic facts, mathematics achievement, and calculator-related mathematics achievement. Significant gains were also reported for grades four through six in mathematics achievement and calculator-related mathematics achievement. No significant gains between treatment groups were found at any grade level for attitude, basic facts, mathematics achievement, or calculator-related mathematics achievement (Shumway et al., 1981).

Comparisons of student attitudes toward mathematics with attitudes toward calculators resulted in differences which were significant at the .001 level. By hypotheses, conclusions were as follows: a) Use of calculators influenced student attitudes toward mathematics; b) students had more positive attitudes toward calculators than toward mathematics; c) students with and without calculators demonstrated gains for basic facts and for mathematics achievement independent of calculator use; d) there was no evidence of the effects of calculator use on student knowledge of basic facts or on student mathematics achievements; e) there was no evidence of effects of calculator use on student achievement for estimation skills or special topics in mathematics; and f) the use of calculators on computa-
tion tests increased student computation test scores (Shumway et al., 1981).

It should be noted that the possible absence of random site or school selection, the use of intact classes, and the non-random assignment of classes to treatment groups, served to restrict the generalizability of the study. The absence of systematic treatment administration allowed varying degrees of calculator use among the calculator groups, in addition to which the availability of calculators was an inconsistent variable. In addition, some calculators may have been used in the no calculator groups. These factors contributed to possible internal validity bias, thus making it difficult to interpret the applicability of the experiment.

Szetela and Super (1987) conducted a nine-month experiment designed to assess the effect of special instruction involving problem solving strategies and calculator use upon computation skills, and their effect upon student attitudes toward problem solving. Two treatment groups and a control group were formed from the classrooms of 24 volunteer seventh-grade teachers in an urban-rural school district. The first group received special instruction on the use of problem solving strategies. The second group received the special instruction and was allowed to use calculators. The control group received conventional instruction in problem solving. The variables of interest were
(a) student success in solving translation problems, process problems, and more complex problems; (b) attitude toward problem solving; and (c) computational skills. Sex differences in problem solving performance and the effects of the strategies and calculators upon teacher perceptions of problem solving were items of secondary interest.

Teachers of the two treatment groups were given instruction in teaching problem solving strategies, guidelines for teaching, and supplementary student problems. Students in the classes which were allowed to use calculators received a calculator from the school district. All groups were pretested with the Operations With Whole Numbers Test at the beginning of the experiment. The researchers and graduate assistants visited each teacher in the two treatment groups to monitor and discuss the study on a minimum of two occasions. During the school year, students took the first forms of two problem solving tests; in April, students were given the Whitaker Attitude Test; in May, all students took the Operations With Rational Numbers Test; and three additional problem solving tests were administered in random order at the end of the school year. Class mean scores were used in a partially nested analyses of covariance with treatment by sex nested within class. When significant F-ratios were obtained, the Tukey test was used to determine how the groups were different (Szetela & Super, 1987).
The Tukey test indicated that the problem solving group scored significantly higher than the control group on both midyear tests at the .05 significance level. The calculator/problem solving group was also significantly different from the control group. No significant differences were found between sexes within the treatment groups. However, when all three groups were combined, the boys scored significantly higher than the girls on two of the seven tests. In addition, the results of the teacher questionnaire were interpreted to indicate that the teachers were extremely positive about their participation in the program (Szetela & Super, 1987). Since the question from which this inference was drawn was not asked of the control group, it is difficult to generalize that this type of teaching approach provides teachers with a more positive outlook toward problem solving than might otherwise be expected.

It was noted that neither of the treatment groups scored significantly higher than the control group on the end-of-year tests, nor did the students using calculators score significantly lower than the other two groups. In addition, no explanation was provided for the use of three different end-of-year tests in unequal numbers. Though the tests were distributed randomly, only one or two students per class were expected to take the Complex Problems Test (Szetela & Super, 1987). Students who had developed good
problem solving skills might reasonably have been expected to do well on tests requiring them to analyze, compare, synthesize, and evaluate, or exercise the skills typically necessary to solve complex problems. Thus, if all students had been tested with this measure, or if equal numbers of these tests had been distributed with the others, then the results might have provided a more realistic picture of the relevance of the experimental teaching approach. Post-testing students with another form of the pretest would also have allowed the experimenters to use gain scores in place of mean test scores for their analysis.

Fifth- and sixth-grade students were subjects in an experiment conducted by Anand and Ross (1987), the purpose of which was to assess the effect on student achievement of the use of computer-assisted instructional materials based upon personalized arithmetic problems. It was hypothesized that the use of personalized contexts would improve both task attitudes and achievement, especially for tests of meaningful learning or transfer. Thus, 96 elementary school students were randomly assigned to three treatment groups and one control group, each composed of both fifth- and sixth-grade students.

The treatment conditions were (a) personalized, (b) concrete, and (c) abstract. The abstract group received a version of a computer-assisted instruction unit which provided examples and questions with such general
referents as "quantity" and "solid" without association to a meaningful theme. The concrete group received specific hypothetical referents such as "your teacher" and "candy bar." The personalized group received instruction which presented examples and problems with uniquely personalized preferences, as determined prior to the start of the experiment through administration of a biographical questionnaire to all students. Treatments were administered in one session, followed by posttesting and the administration of a Likert-type attitude questionnaire (Szetela & Super, 1987).

The total posttest mean for the control group was compared to that for combined treatment groups and was found to be significant. Using the Tukey Honestly Significant Difference (HSD) procedure, the personalized group performance was significantly superior to the performance of the abstract group. Analyses subsequently performed on the formula-recognition results indicated that the personalized-context group scores were superior to those of the abstract-context group. Based upon results of the California Achievement Test (CAT) subtests for Reading, Language, and Mathematics, for determination of possible aptitude-treatment interactions, supplemental analyses were performed for the student performance results. Tukey HSD analyses suggested that low-to-middle achievers benefited most from personalized contexts, whereas high achievers
performed equally well with either personalized or concrete contexts (Szetela & Super, 1987). No significant main effect for sex was reported. From these results, it was inferred that adapting problem contexts to student interests could have provided an effective means of reducing comprehension problems, and might have simultaneously improved attitudes toward learning mathematics.

Zehavi, Bruckheimer, and Ben-Zvi used a pretest-posttest control group design to appraise the effect of assignment projects on student mathematical problem solving abilities. Projects were structured to allow students to work at home to extend their solutions, extend their problems, and to go beyond algorithmic operations. A contrived sampling procedure was used. Initially, the experimental group was composed of 11 intact ninth-grade classes and the control group was composed of 30 intact ninth-grade classes. Following administration of an achievement test, classes with an average score of less than 40 were excluded since "most students in such classes could not work on the projects at a high cognitive level" (p. 427), and classes whose average was above 75 percent were equally excluded. The remaining 16 classes (eight in each group) formed the sample. Since it had been previously stated that research interest was directed at the top 40 percent in any particular school, the exclusion of the higher scoring classes would not seem to be consistent with the study purposes.
All students were administered an assignment pretest and an attitude questionnaire. Posttests consisted of alternate forms of the assignment test, the achievement test, and the attitude questionnaire. Treatment incorporated the assignment of long-term projects to be worked on in class and at home. Student work was checked periodically, advise was given on procedures, and projects were presented for final evaluation. The researchers administered the treatment in each of the experimental classes (Zehavi, Bruckheimer, and Ben-Zvi, 1988).

Mean class scores for the pretests and posttests were compared by t-test. The experimental group did significantly better on the second achievement test, but the control group showed no significant difference in scores. There was a significant decline on the attitude test for the control group, but not for the experimental group. It was noted that there was an actual decline in attitude scores for the experimental group, but the differences were not deemed to be significant. On the assignment test, a significant increase was found for the experimental group (Zehavi, Bruckheimer, and Ben-Zvi, 1988).

A Wilcoxon-Raatz test was applied to individual students' pretest and posttest scores for the second assignment. An improvement in scores for the experimental group was highly significant, which was not the case for the control group scores. The goal of the study was to assess the
effect of assignment projects on problem solving abilities, abilities which are difficult to assess on the basis of achievement test results. Consequently, the classroom activities which took place during the experiment were considered to be of importance in drawing inferences from the results of the study. It was stated that as students progressed from one project to another, it became easier for them to overcome unfamiliar obstacles, the quality of their solutions improved, and more and more extensions of solutions and of problems were found (Zehavi, Bruckheimer, and Ben-Zvi, 1988).

Summary

That teachers can exercise an influence upon student performance has been clearly substantiated by the research considered in this chapter. However, research on the types of teacher behaviors and characteristics which serve to enhance student performance has produced inconclusive results. Much of previous research on teacher behaviors and characteristics has sought to delineate which influences enhance student performance by the examination of teacher personalities, teacher-student interactions, instructional approaches and strategies, motivational techniques, and/or teacher preparation. To attempt to find distinctly effective teacher attributes, research has often been focused on specific predetermined variables in relation to teachers or
teaching. Consequently, the other variables which may have affected student performance were often ignored. Rather, the variables investigated may have been inferred from prior research or have been suggested by the experience of the investigators. In addition, previously conducted research has almost exclusively used instruments which measured algorithmic (lower-order) skills to determine student success, even when measurement of higher-order skills was in order.

Changes in society, in worldwide competitiveness, in mathematics, and in the uses of mathematics have caused educators to reexamine mathematics education in the United States. The Curriculum Standards (NCTM, 1989) were a result of five years of extensive investigation into what students should know to assure that they are able to compete in the twenty-first century. The NCTM outlined a philosophical vision of future mathematics, and the Mathematical Sciences Education Board called for a restructuring of the mathematics curriculum in the United States (MSEB, 1990). The redesign of mathematics education must include not only what is taught, but the way it is taught, and this will require educators to know and understand those teacher behaviors and characteristics which affect critical thinking skills among students. The results of this research project support the reforms inherent in the Curriculum Standards.
To study those variables which contribute to the development of critical thinking skills among students, all possible variables needed to be identified and then considered. This study has used a test of student critical thinking skills to differentiate between two groups of middle-grade teachers and to analyze teacher behaviors and characteristics.
CHAPTER 3
DESIGN AND METHOD

Introduction

This study has utilized qualitative data collection and analytical procedures based upon a causal-comparative (criterion-group) research design. The causal-comparative design bridges the gap between descriptive research methods and true experimental research, allowing the researcher to explore relationships between variables and outcomes in situations where it is unrealistic to control all variables, except for a single independent variable (Cohen & Manion, 1989). This research project was conducted in conjunction with the Oregon Mathematics Teachers of Middle School Mathematics (TOMTOMS) curriculum development and leader training project. Data on teacher behaviors and characteristics were collected through journals, portfolios, calendars, videotapes, and teacher questionnaires. Additional data to support perceived patterns were gathered through interviews with participating teachers. Summarizing these data sources provided a representative description of teacher actions in the classrooms.
TOMTOMS Curriculum Development Project

From a statewide pool of applicants, 20 mathematics teachers in Oregon were selected for the TOMTOMS project. The teacher selection process was designed to obtain a sample group of teachers representing a variety of school situations and certification areas, as well as teachers who enjoyed positive support from school administrations. Applicants completed questionnaires (Appendix A), detailing teaching experience, training, and assignments; previous experience with manipulative materials and technology; projected use of manipulative materials and technology; curriculum flexibility; and level of administrative support for participation in the project.

From the questionnaires, it was determined that the applicants' schools represented small rural communities, mid-sized towns, and large urban population centers. The schools were also diverse in form, from middle schools containing students in grades seven and eight, middle schools containing students in grades six through eight, junior high schools with students from grades seven through nine, elementary schools with students in grades kindergarten through eight, and upper elementary schools containing students in grades five through eight. All 20 teachers selected had earned a bachelor's degree in education. In addition, six had completed master's degrees in education.
and an additional 12 were completing work toward master's degrees (See Table 1).

<table>
<thead>
<tr>
<th>Table 1. Project Demographics.</th>
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<tbody>
<tr>
<td><strong>Type of Community</strong></td>
</tr>
<tr>
<td>Rural</td>
</tr>
<tr>
<td>Mid-size towns</td>
</tr>
<tr>
<td>Urban population centers</td>
</tr>
<tr>
<td><strong>Type of School</strong></td>
</tr>
<tr>
<td>Middle school (grades 7-8)</td>
</tr>
<tr>
<td>Middle school (grades 6-8)</td>
</tr>
<tr>
<td>Junior high (grades 7-9)</td>
</tr>
<tr>
<td>Elementary (grades K-8)</td>
</tr>
<tr>
<td>Upper elementary (grades 5-8)</td>
</tr>
<tr>
<td><strong>Degrees Earned</strong></td>
</tr>
<tr>
<td>Bachelor's degree</td>
</tr>
<tr>
<td>Master's degree</td>
</tr>
</tbody>
</table>

TOMTOMS participants had taught students whose ability levels ranged from low fifth-grade to high school sophomore. Although teachers of seventh-grade math classes were targeted for the project, selected participants taught a variety of grades and courses, including five-six and seven-eight combination classes, algebra, and geometry as well as seventh-grade. Participants were asked to designate one seventh-grade class as a target class for purposes of the project. The seventh-grade class was to be monitored during 1990-91 school year and the data collected
were to reflect the students and the environment of the target class.

During the summer of 1990, the TOMTOMS participants received eight weeks of instruction on the nature of mathematics, curriculum design and implementation, learning theory, the integration of appropriate tools and manipulatives, and techniques and strategies for teaching middle level mathematics. For the opening of fall term, 1990, a mathematics pretest was administered by TOMTOMS teachers to all target class students of the TOMTOMS participants. Subsequently, in May 1991, the target class students were administered a posttest based upon a form parallel to the first test. Throughout the school year, the 20 teachers maintained records on the target mathematics class and videotaped presentations of five of the lessons to target classes. The lessons to be videotaped were selected by the teacher, subject to the specification that typical lessons be selected. Project directors also specified that two lessons taped be from the first nine weeks of school, two from the second nine weeks, and the final lesson in either the third or fourth nine-week periods.

Project participants were also asked to maintain a portfolio of written materials prepared for distribution in target classrooms throughout the year, a journal, and a calendar (i.e., outlining the daily plans of the teacher throughout the year). During the school year, participants
were visited by project staff and a newsletter was circulated to provide information and networking opportunities to the TOMTOMS teachers.

Instrumentation

For the present study, two groups of teachers were identified, differentiated according to student performances on a test of critical thinking. To select the two groups, class mean gain scores for the pretests and posttests (Appendices B and C) were calculated for each teacher in the TOMTOMS Project and then rank-ordered.

The evaluation instrument was developed by the project staff and pilot tested for a group of 10 middle school students prior to use by the TOMTOMS project. The pilot group of students was chosen to match students in the proposed TOMTOMS project on the basis of grade, age, and ability levels. Adjustments for test difficulty, spread of scores, and distortion due to chance factors were effected from interpretation of the results of pilot testing.

The pretests and posttests developed represented different forms of the same test. The open-ended structure of the questions precluded a distortion of the results due to such chance factors as guessing during multiple choice tests. The use of a scoring rubric reduced the possibility of scoring one student higher than others for essentially the same answer, and the large size of the sample (62
classes) assured a wide spread of scores. The establishment of interrater reliability contributed to testing objectivity.

Three members of the Oregon Department of Education Mathematics Assessment Team reviewed the test and suggested modifications for the establishment of face validity. These members consisted of a mathematics curriculum coordinator, a middle school mathematics teacher, and a secondary mathematics teacher. Face validity was further established according to the methods described by Farrell and Farmer (1988), correlating questions with the cognitive objectives of Bloom’s Taxonomy (Appendix D), and asking a group of five experts in math education to verify the correlations. The levels of each test question were correlated with the objectives at the appropriate level of the Taxonomy for purposes of verification. Questions were continuously adjusted until the five consulted experts reached 100 percent agreement on each question.

As suggested by Farrell and Farmer (1988), the specific objectives for higher-level cognition used to classify the instructional objectives included: a) break-down of material into component parts so that the relationships among ideas are made explicit; b) assembling the parts to form a whole pattern or structure of ideas not otherwise clearly present; and c) arriving at judgments about the value of materials and methods for given purposes. After
correlating all of the test questions with Bloom’s Taxonomy, the referenced criteria were used to identify a subset of the instrument for the specific assessment of the critical thinking skills which could be used to differentiate among TOMTOMS participants.

Questions included in the identified subset required students to make mathematical decisions based upon their ability to analyze, synthesize, and evaluate the data presented. The subset problems were highly interrelated and were judged by the project directors to provide a relevant and representative measure of critical thinking. According to the cognitive objectives’ correlation performed by the math experts, 87 percent of the subset questions assessed higher-level cognition (analysis, synthesis, evaluation). The remaining 13 percent of the questions assessed student abilities to apply knowledge to realistic situations. A description of each instrument question and the level of cognition required for seventh grade students is provided in Table 2.

An estimation of reliability of the instrument was calculated according to the methods described by Carmines and Zeller (1979). The Cronbach alpha coefficient, as a measure of internal consistency, was computed from the interitem correlations. The pretest, as administered to 1,400 students, had an alpha coefficient of 0.7461. The posttest, as administered to 930 students, had an alpha
<table>
<thead>
<tr>
<th>TQ</th>
<th>Level*</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>II</td>
<td>Understand the concept of multiplication.</td>
</tr>
<tr>
<td>2</td>
<td>I</td>
<td>Know the meaning of exponential notation.</td>
</tr>
<tr>
<td>3</td>
<td>II</td>
<td>Understand the concept of negative numbers.</td>
</tr>
<tr>
<td>4</td>
<td>II</td>
<td>Use the methods for changing percentages to decimals and multiplying decimals.</td>
</tr>
<tr>
<td>5</td>
<td>II</td>
<td>Use the algorithm for dividing decimals.</td>
</tr>
<tr>
<td>6</td>
<td>II</td>
<td>Translate the problem from one form to another.</td>
</tr>
<tr>
<td>7</td>
<td>III</td>
<td>Know and apply the order of operations.</td>
</tr>
<tr>
<td>8</td>
<td>II</td>
<td>Know the approximate size of one centimeter.</td>
</tr>
<tr>
<td>9</td>
<td>III</td>
<td>Apply knowledge of modular arithmetic and use learned material in a new situation.</td>
</tr>
<tr>
<td>10a</td>
<td>III</td>
<td>Apply percentage notation to a 10 X 10 matrix.</td>
</tr>
<tr>
<td>10b</td>
<td>IV</td>
<td>Recognize the relationship between fractional notation and a 10 X 10 matrix.</td>
</tr>
<tr>
<td>10c</td>
<td>IV</td>
<td>Select the larger value.</td>
</tr>
<tr>
<td>11</td>
<td>IV</td>
<td>Break down the problem into component parts so that the structural form of the problem can be understood.</td>
</tr>
<tr>
<td>12a</td>
<td>III</td>
<td>Apply the concept of repeated subtraction or division to a realistic situation.</td>
</tr>
<tr>
<td>12b</td>
<td>V</td>
<td>Produce an organized explanation of the process used.</td>
</tr>
<tr>
<td>13</td>
<td>III-IV</td>
<td>Solve a fraction problem which involves an understanding of the notation.</td>
</tr>
<tr>
<td>14</td>
<td>IV</td>
<td>Identify spatial positions which meet the specifications of the problem. Identify component parts from overlapping triangles.</td>
</tr>
<tr>
<td>15</td>
<td>VI</td>
<td>Judge the adequacy with which conclusions were supported by the data given. Recognize logical fallacies.</td>
</tr>
</tbody>
</table>
Table 2. Continued.

<table>
<thead>
<tr>
<th>TQ</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>16a</td>
<td>IV</td>
<td>Analyze the implications of place value positions for the numerals.</td>
</tr>
<tr>
<td>16b</td>
<td>V</td>
<td>Generate a plan for positioning integers to result in the same number.</td>
</tr>
<tr>
<td>17a</td>
<td>IV</td>
<td>Recognize the structure of the parts of the problem.</td>
</tr>
<tr>
<td>17b</td>
<td>III</td>
<td>Application of the concept of area to a real life situation.</td>
</tr>
<tr>
<td>18</td>
<td>V-VI</td>
<td>Formulate a well-organized scheme. Contrast schemes to select the most cost-efficient</td>
</tr>
<tr>
<td>19a-e</td>
<td>IV</td>
<td>Analyze the relationship between pentagons and toothpicks.</td>
</tr>
<tr>
<td>19f</td>
<td>IV</td>
<td>Understand the organizational structure and predict an outcome abstractly.</td>
</tr>
<tr>
<td>19g</td>
<td>V</td>
<td>Produce a scheme for summarizing the sequence in mathematical terms.</td>
</tr>
<tr>
<td>19h</td>
<td>V</td>
<td>Produce a scheme for classifying information. Put the parts together to form a new mode of presentation for the data.</td>
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</table>

*Level is defined according to Bloom's Taxonomy (Appendix D).
TQ = test question.

coefficient of 0.8047. From the coefficients, it was determined that the pretest contained a higher number of omissions than the posttest. Since the instrument was designed to expect student responses at the seventh-grade level, it was anticipated that in September, during pretesting, a greater number of students would omit items which were not familiar to them from the sixth-grade curriculum. Since alpha determination is dependent upon average interitem correlation and the number of items in the
scale, a lower alpha coefficient was anticipated for the pretest.

Interrater agreement for the pretest and posttest was established during scoring of the pilot pretest. A scoring rubric (Appendix E), designed by the Assessment Committee of the California Mathematics Council (Stenmark, 1989), was used to assure that similar ratings were assigned to the same behaviors and were not unduly influenced by the values, attitudes, or other personality characteristics of the observers. Individual practice and group comparison of the results continued until 90 percent agreement was reached among the experts consulted with respect to scoring.

Selection of the Subjects

From the pool of 20 teachers participating in the TOMTOMS project, two groups were identified. To select two groups whose obvious differences had the potential to reveal the differing effects of teacher behaviors and characteristics as reflected in increased student performances on tests of critical thinking skills, the class mean gain scores of TOMTOMS participants were compiled. The process was supervised by the project directors, thus the present investigator was unaware of the status of the groups of teachers selected for this study.

Students in all classes were pretested in September, 1990 and then posttested in May, 1991 with the described
test instrument. Scores on the instrument subset containing questions 11 through 19 from the pretests and posttests were computed to obtain the gain score for each student. An average gain score for the class was then assigned to each of the teachers considered for selection. One teacher failed to posttest students, and two teachers each collected data on two separate classes. Consequently, 21 gain scores were assigned to classes for 19 teachers.

Only the scores of students who had remained in a target class with the same teacher for the entire year were used. Each student number was checked against the pretest results and the scores of the nonremaining students were dropped from the data set. To decrease the possibility of bias, all posttest scoring and the assignment of class mean scores were completed by project directors to ensure that the present investigator was without knowledge of the ranking of the teachers.

Project directors converted class mean scores to Z-scores, thus 21 Z-scores were assigned to 19 teachers. Project directors then rank-ordered the Z-scores and all classes were assigned a randomly selected identification number to allow the investigator to assess differences in the mean gain scores. The use of Z-scores was considered necessary because of the potentially small range of scores. The rank-ordered continuum of classes was used to differentiate between class mean scores and to identify teachers
selected for this study. For the purposes of the present study, the top and the bottom 25 percent, or five teachers from each of these ranges, were selected for further study. The ranking order extremes were used to increase the probability of finding potential differences in teacher behaviors and characteristics. Teachers in the two extremes formed Group A and Group B. If two classes from the same teacher had both been in either the top or the bottom 25 percent of all ranked teachers, then the sixth or sixteenth ranked classes would have been chosen. However, the problem remained moot since no two classes from the same teacher were ranked in either the top or the bottom 25 percent.

Class mean gain scores and Z-scores are given in Table 3. Student performances in the classes of the highest and lowest ranked teachers differed by a standard deviation of 3.486. The Z-score difference between the teacher ranked fifth and the teacher ranked sixteenth was 0.964, or approximately one standard deviation. The range of Z-scores and the interval between the fifth and sixteenth scores were sufficient to assume that a difference existed between the Groups A and B. After analysis of the data, the investigator was informed that Group A included class numbers Eight, Thirteen, Twenty-two, One, and Seven and Group B included class numbers Fifteen, Nineteen, Eighteen, Eleven, and Sixteen.
<table>
<thead>
<tr>
<th>Class ID (random)</th>
<th>Mean Gain Score</th>
<th>Z-Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eight</td>
<td>13.100</td>
<td>2.578</td>
</tr>
<tr>
<td>Thirteen</td>
<td>12.143</td>
<td>2.262</td>
</tr>
<tr>
<td>Twenty-two</td>
<td>10.294</td>
<td>1.653</td>
</tr>
<tr>
<td>One</td>
<td>7.562</td>
<td>0.751</td>
</tr>
<tr>
<td>Seven</td>
<td>6.476</td>
<td>0.393</td>
</tr>
<tr>
<td>Three</td>
<td>5.571</td>
<td>0.094</td>
</tr>
<tr>
<td>Seventeen</td>
<td>5.000</td>
<td>-0.094</td>
</tr>
<tr>
<td>Five</td>
<td>4.933</td>
<td>-0.116</td>
</tr>
<tr>
<td>Twenty-one</td>
<td>4.333</td>
<td>-0.314</td>
</tr>
<tr>
<td>Nine</td>
<td>4.235</td>
<td>-0.347</td>
</tr>
<tr>
<td>Twenty</td>
<td>4.000</td>
<td>-0.424</td>
</tr>
<tr>
<td>Fourteen</td>
<td>3.958</td>
<td>-0.438</td>
</tr>
<tr>
<td>Four</td>
<td>3.688</td>
<td>-0.526</td>
</tr>
<tr>
<td>Two</td>
<td>3.625</td>
<td>-0.548</td>
</tr>
<tr>
<td>Six</td>
<td>3.600</td>
<td>-0.556</td>
</tr>
<tr>
<td>Ten</td>
<td>3.556</td>
<td>-0.571</td>
</tr>
<tr>
<td>Fifteen</td>
<td>3.545</td>
<td>-0.574</td>
</tr>
<tr>
<td>Nineteen</td>
<td>3.214</td>
<td>-0.684</td>
</tr>
<tr>
<td>Eighteen</td>
<td>2.821</td>
<td>-0.806</td>
</tr>
<tr>
<td>Eleven</td>
<td>2.800</td>
<td>-0.820</td>
</tr>
<tr>
<td>Sixteen</td>
<td>2.533</td>
<td>-0.908</td>
</tr>
</tbody>
</table>
The names of teachers comprising each group were given to the investigator. Group A included Tracy, Karla, Maria, Jean, and Ed, and Group B included Denny, Tony, Megan, Stephanie, and John. However, the investigator remained unaware of the individual ranking of the teachers and the relative position of each group on the continuum. Consequently, the groups were compared in the absence of knowledge of which group's students had the highest mean gain scores.

Classroom sizes of the teachers in Groups A and B ranged from 15 to 30 students, with a mean of 25 students. Ability levels varied from high sixth-grade to low eighth-grade. Teaching experience ranged from two years to 30, with a mean of 14 years. The attributes of the teachers' schools also encompassed a broad range of demographic characteristics. In addition, the group members varied extensively with respect to personality, teaching style and background, university training, and educational philosophy. The credentials of teachers in Groups A and B included all of the types of mathematics certification offered by the Oregon Teacher Standards and Practices Commission (OTSPC), including Basic Mathematics, Basic Advanced Mathematics, Standard Advanced Mathematics, and Basic Integrated Science. Five of the ten teachers included in the study held Basic Elementary certificates, and one held a Basic Integrated Science certificate. Four of the five elementa-
ry teachers also had math endorsements. Four of the teachers held Standard Advanced Mathematics certificates.

Sources of the Data

All teachers included in the TOMTOMS project completed questionnaires, maintained journals, calendars and portfolios, videotaped lessons, and were interviewed by the investigator. Data were collected on all target classes. For the purposes of the present study, only the data from the 10 participants in Groups A and B were reviewed.

Teacher Questionnaires

Teacher questionnaires were administered twice, in June, 1990 and June, 1991 (Appendix A). The questionnaires elicited background information pertaining to the teachers as well as information concerning teaching practices. Teachers responded to questions concerning the use of instructional aids, teaching experience, teaching workloads and schedules, certifications, experience, planning emphases, the availability and use of technological innovations in the classroom, the understanding and use of instructional aids, and the ability levels of students in their classes.
Journals

Journals provided a running commentary on the materials covered in the target classrooms and rates of progress for each units and/or activity. The advantages or disadvantages of using particular techniques or instructional aids were described, as were all classroom activities. Journal entries also included comments about teachers' perceptions of how well the activities accomplished teacher objectives and goals and how well the activities were received by students. Entries were submitted by teachers in personal narrative form. Data from this source was compared to that derived from other sources and was the basis for further questions during interviews.

Portfolios

Portfolios consisted of a file of all written materials used in the target classrooms during the year (e.g., worksheets, overheads, tests, quizzes, or parent communications). Portfolio material was analyzed in the manner described in the methods section and was used to verify information from the journals and calendars.

Calendars

Teacher calendars required entries for each activity that students in the selected classes engaged throughout the course of each class period during the year. Each
entry was coded to include the source, purpose, name, instructional mode, and type of instructional aids used, if any (Appendix F). The sources included textbooks, TOMTOMS materials, course materials, original materials, and material otherwise unclassified. Purposes included warmups (short problems given to students at the beginning of classtime), checking for prerequisite skills, foreshadowing coming developments, developing positive attitudes, motivation, developing understanding, practice, application, maintenance of skills, recreation, filler, developing problem solving skills, closure, assessment, or appropriate areas otherwise unclassified. Instructional modes included teacher instruction, large group discussion, small group work, individual seatwork, homework, lab discovery, pairs, cooperative learning, project work, or others. Instructional aids were designated by name.

Videotapes

Teachers were asked to videotape five lessons presented to the target class during the school year. The object was to present a holistic view of the true classroom environment which may not have been possible in the presence of the investigator. Only six of the 10 teachers selected for the study submitted videotapes. Triangulation of variables for those teachers without videotapes was made with written notes taken by project staff during two class-
room observations conducted during the school year. The observations were performed either by the researcher or by the project directors.

Teacher Interviews

Audiotaped interviews of all TOMTOMS participants were conducted by the investigator during the period from June through July, 1991, following analysis of the teacher questionnaires, portfolios, videotapes, calendar information, and journal narratives. To reduce the possibility of bias and to increase the validity of the investigation, neither the subjects nor the interviewer was aware whether those interviewed were ranked in the upper or lower 25 percent of the rank order. The teachers knew only that they were interviewed to gather additional information for the project.

The interviews constituted a source of data as well as a source of verification of the elements identified as other data sources. Consequently, the interview consisted of both focused and nondirective parts (Appendix G). The focused interviews were distinguished by concentration upon respondents' subjective responses to known situations in which they had been involved and which had been analyzed previously by the interviewer. The responses solicited were requested in a fixed-alternative and open-ended format. The non-directive component of the interviews in-
cluded no set questions, and the interviewer allowed the course of the interviews to be guided by the subjects.

Methods of Data Analysis

Data from all of the subjects' journals, portfolios, calendars, questionnaires, videotapes, and personal interviews were explored qualitatively. In the initial review of the data sources, information that could be extracted from the data sources which pertained to teacher behaviors or characteristics was denoted as a possible element for further study. Patterns constructed from the data during the initial review of one data source were corroborated by identifying the same element in at least two additional data sources. When discrepancies occurred between the various data sources, the daily calendar, as the most comprehensive source available, was used to arrive at decisions concerning deletion or retention of the data.

Teachers in the TOMTOMS project had recorded predetermined items in their calendars during the year, including the types of manipulatives used, classroom organization, and activity objectives (Appendix F). Moreover, teacher journals contained a wide variety of information concerning the classroom environment. Interview questions were predetermined by the investigator and were structured to verify elements from other data sources (Appendix G). The teacher questionnaires also elicited predetermined
information (Appendix A). Portfolios and videotapes revealed additional information about lessons and activities, as well as teacher actions in the classroom.

Triangulation was used for all of the elements of consideration which emerged from the raw data. Cohen and Manion (1989) suggested that triangular techniques are particularly appropriate when a holistic view of education outcomes is sought. Since multiple checks do not ensure the accuracy of observations, the investigator was ultimately required to formulate decisions as to what behaviors and/or characteristics constituted a pattern (Feiman-Nemser & Floden, 1989). If an element was evident in three or more sources, it was considered to constitute a pattern. However, the use of methods of multiple data collection and pairwise comparisons of the data served to minimize the possibility of bias and distortion.

Once elements from the raw data judged worthy of consideration had been triangulated, the behaviors and characteristics of Groups A and B were compared to identify differences between the groups. If groups were found to exhibit an element to the same degree over 60 percent of the time (that is, less than 15 of 25 comparisons with no substantial difference), the variable was not retained as a potential difference. Approximately 3,650 pairwise comparisons were conducted for 41 elements within the six data sources. Only 19 of these elements were verified from
three separate sources. The remaining 22 elements (Appendix H) were found either in two sources, or were clearly apparent from a single source, but were not considered as variables since they could not be triangulated from three sources. The elements remaining following triangulation and pairwise comparison were denoted as the variables which may have affected student performance as determined by administration of the evaluation instrument and were thus considered as potential group behaviors or characteristics. To avoid the possibility of bias, the exploratory character of the present qualitative research precluded the determination of categories or patterns of behaviors and characteristics prior to the review of data sources.

All variables which then remain were again analyzed with the aid of matrices to generate group profiles. A 5 x 5 matrix was constructed for each potential group variable. The five teachers from Group A comprised the horizontal axis and the Group B teachers were distributed along the vertical axis. Comparisons of behaviors and characteristics were made between each teacher for each group, and a determination was made whether or not there were apparent differences between any two teachers. For example, Karla and Maria from Group A assigned homework on a daily basis, whereas Ed, Tracy, and Jean assigned homework less than three times each week; from Group B, only Tony assigned homework daily and Denny, John, Stephanie, and Megan as-
signed homework less than three times each week. For the pairwise comparisons, Group A evidenced daily homework more than Group B for eight pairings (i.e., Karla to Denny, Karla to John, Karla to Stephanie, Karla to Megan, Maria to Denny, Maria to John, Maria to Stephanie, and Maria to Megan); Group B evidenced daily homework more than Group A for three pairings (i.e., Tony to Jean, Tony to Ed, and Tony to Tracy). In the remaining 14 pairwise comparisons, Groups A and B exhibited identical levels of homework assignments.

To retain subtle differences, but to delete differences which may have been present for only one out of five group members, it was determined to require a minimum of 10 of 25 differences in one direction for retention of the characteristic and/or behavior. For example, if two subjects in Group A were positive for one variable and all others were negative, then there would have been no differences in 15 matrix cells, 10 positive differences for Group A, and 0 positive differences for Group B. However, differences between groups were rarely so precisely defined and group characteristics often crossed group dimensions. Differences of 10 or more between groups were apparent for 11 of the variables. If a difference occurred between teachers from different groups 10 times or more within a matrix, then the variable was accepted as a group characteristic. For the homework example given previously, the
groups did not differ more than 10 times within the matrix, thus the variable was not included as a group characteristic.

The use of pairwise comparisons to identify variables and again to generate group profiles resulted in the identification of teacher behaviors and/or characteristics which constituted differences between the two groups. Making pairwise comparisons for each data set to generate group profiles, rather than comparing teacher profiles, precluded the possible loss of data inherent in the method of preparing a summary. Moreover, though the data sources considered for the present study consisted of teacher self-reports and teacher-selected videotaped lessons, reliance was placed on the availability of different types of reports to create a valid representation of classroom practices.

The variables which differed in 10 or more comparisons were analyzed individually to gather additional information about the specific characteristics of differences with regard to group members. Eleven variables were thus analyzed. After review of all appropriate data, triangulation of the variables, the conduct of pairwise comparisons, analysis of the variables which were considered to indicate differences, and compiling group and individual profiles, group rankings were provided to the researcher. The identify of the groups did not affect the results of the study.
CHAPTER 4
ANALYSIS OF DATA

Introduction

Individual teacher behaviors and characteristics evidenced in the data sources were compared for the purpose of identifying the variables from which Group A and Group B profiles could be constructed. The two groups of middle school teachers selected for the study sample were those whose students' converted pretest and posttest mean gain scores for their classrooms placed them in either the top or the bottom 25 percent of a rank-ordered continuum of participants in the TOMTOMS Curriculum Development Project. To ensure that characteristics/behaviors were indicative of the groups, and were not the results of individual teacher attributes, five teachers were included in each group. Since the top and bottom classes were separated by almost three and one-half standard deviations, true differences between student performances were assured. Subtle variations in group behaviors were distinguished by the inclusion of five (25%) subjects within each group and by analyses of the variables based upon the use of matrices.
As an option to consideration of predetermined behavior/characteristic differences between the two groups, 25 comparisons for each variable from each separate data source were conducted to determine group differences. The use of multiple sources of data served to enhance the potential to acquire in-depth knowledge of the composite characteristics of each group. Lederman (1986) described such generic variables as "a network of factors which interact to create the instructional milieu of each classroom" (p. 13). Since the two groups were structured on the basis of differences among class mean gain scores on a test of critical thinking, it was hypothesized that common group variables may have been instrumental in the development of student critical thinking skills.

Following triangulation, 19 potential group characteristic variables remained, and were subsequently used for pairwise comparisons to determine the magnitude of the differences between Groups A and B. To assure that the variables included in the group profiles were indicative of the behavioral characteristics of each group, pairwise differences of 10 or more between groups were required for retention as indicators of differences.

Identification of the Variables

After each variable suggested from initial data analysis was validated from at least three data sources and
determined to have at least 10 pairwise comparative differences in pairwise comparisons, a total of 19 behaviors and/or characteristics were retained for further analysis. Following resolution of discrepancies among data sources, the 19 variables were again placed in a $5 \times 5$ matrix, with Group A members placed along the horizontal axis and Group B members placed along the vertical axis. To further determine differences between individual teachers for the purpose of generating group characteristics, 25 cells were used to compare the dimensions of the variables (e.g., assigned homework once each day, made at least two transitions per day, used warmups daily). If no differences were found between two teachers from opposite groups, then the comparison was placed in the column labeled "No Diff." To negate the possibility of including those attributes reflected by two or fewer of the members of a group, it was determined that those characteristics/behaviors which did not differ among 10 or more comparisons should be deleted. The variables which differed for 10 or more comparisons of the total of 25 were considered to be indicative of group characteristics, and were thus included in the group profiles.

Following completion of data analysis, the investigator was informed of the class mean gain score rankings for Groups A and B by the TOMTOMS project directors. Based upon these scores, Group A comprised the top 25 percent of
the TOMTOMS participants, whereas Group B comprised the bottom 25 percent. The two groups were separated by almost one (.964) standard deviation for the Z-scores.

**Group A Profile**

Pairwise comparisons had resulted in the characterization of Group A as teachers who provided students with three or more opportunities per week to complete work in small groups, specifically designed lessons or activities for teaching critical thinking skills more than 20 times during the year, used math manipulatives more than twice each week, provided transitions between learning modes at least twice each day, used math warmups more than half of the time, and created opportunities for students to apply their mathematical knowledge more than twice as often as Group B teachers.

Additional demographic information disclosed that three of the five teachers in Group A had elementary training, one held an advanced mathematics certificate, and one held an integrated science certificate. Four females and one male made up the group. In comparison to Group B, Group A teachers had more experience teaching middle school, more overall teaching experience, and more involvement in professional development during their careers. The only teacher of a self-contained classroom was assigned to this
group. Three of the teachers in this group required their students to maintain math journals.

Ed

Ed was the only male in Group A. Ed taught math, science, health, physical education, and art to students in grades five through eight at a school located in an isolated rural community. His target class was composed of all of the seventh- and eighth-grade students in the school, and varied in size from 28 to more than 30 students during the year.

During his college teacher preparation, Ed concentrated on science. He held an integrated science and combined math certificate for grades five through nine. All of Ed's college elective courses were in computer science, which had provided the basis for his combined math endorsement. Calculus and linear algebra were the highest levels of math which Ed chose to take in college.

Ed did not use a textbook in his target class. His decision to discontinue textbook use was based upon his determination to focus on building critical thinking skills among his students. Slightly more than half of his classroom activities were for the purpose of applying skills or developing problem solving skills than practicing or maintaining skills. All of the tasks which he assigned to his students were projects, computer activities involving problem solving or spreadsheet lessons, concept-building activ-
ities with supplementary materials, laboratory exploratory exercises, or teacher-made worksheets. The students in the target class were involved in small group, paired, or cooperative learning activities approximately 50 percent of the time. The year previous to the period during which the data for the present study was acquired, Ed's supervisor had discussed a philosophy of decreased teacher-talk and more kid-talk. Consequently, Ed was aware of the need to de-emphasize his own speaking role in the classroom and to reduce the amount of individual seatwork. Therefore, Ed's class time was distributed equitably between small group work (projects, pairs, cooperative learning groups), teacher instruction, and individual study. The students in Ed's math class were also in his science class, and assignments tended to overlap between the two subject areas.

No strict time limits were placed on the mathematics class. If students were involved in an activity, then they would continue to work until an appropriate stopping-point had been reached. During the second semester, Ed began to utilize warmups. The warmups served the purpose of checking for prerequisite skills and/or establishing an anticipatory set among the students. Students also used calculators at Ed's direction. A classroom set of four-function calculators was available, but Ed did not incorporate calculator use into daily activities. Rather, he preferred to
use calculators with materials that were specifically designed for calculators.

A computer lab was situated in the back of the classroom, and students were comfortable using the computers throughout the day. Students prepared reports for their target class on the computers and utilized the computers for math lessons approximately once every nine weeks. Combined science and math lessons also utilized the computer. Math activities were specifically designed to include the use of spreadsheets and databases. Ed's students "played" Fraction Factory and Number Muncher (a commercially available computer program) on their lunch hours, but these activities were not built into the math class since Ed felt that student involvement with the computer programs would consume too much available time during the math period.

Homework was not assigned as a separate task. Students were responsible for compiling notes on each day's class discussion. If the written notes were incomplete, then the writing assignments became homework. At other times, a major assignment for the week was given on Monday to be due on Friday. If class time was insufficient to complete the assignment, students were expected to complete the work at home. Ed explained his philosophy of homework as follows:

A lot of them don't have any motivation to do homework. I could start prying on them and beating on them with threats of grades and points and this and that, but what I have noticed is that there are kids
who will do it and kids that won't, and no matter how much I affect their grade, the kids that won't, won't. And then you end up failing a kid for his behavior pattern, which is something, you know, that I can change.

A major factor in homework policy was Ed's resolve to foster positive self-concepts among his students. He received little support from parents for academic work, and consequently found that students became quickly frustrated if they were required to complete homework that could not be easily accomplished. Six percent of his classroom activities were designed to develop positive attitudes toward mathematics. Tests or quizzes were administered to students approximately once every nine weeks. The major components of assessments of student progress were projects, class presentations, and group performances.

Most of the manipulatives which Ed listed on his calendar were non-commercial materials usually found in a science laboratory. Although Ed intended to use more instructional aids to "bridge from the concrete to the abstract," he was surprised when he reviewed the year's calendar to find that he had used comparatively few. Prior to his involvement with the TOMTOMS project, Ed had not acquired experience in the use of math instructional aids.

Jean

Jean had the least teaching experience of all of the Group A teachers. She had taught for nine years, one and one-half of which were in middle school. Her preservice
teacher preparation was for elementary school teaching and she held a Basic Elementary Certificate with a mathematics endorsement. She completed a math minor for her Bachelor’s degree and a math concentration for her Master’s degree. The most advanced level of mathematics which she had elected to take in college was calculus. Jean had always been interested in mathematics, but not always with success. Her college mathematics courses had proved to be very difficult for her.

Jean was also the only person in either group who taught in a self-contained classroom situation. Her target class in a small rural school devoted 45 minutes each day to mathematics. The rest of the day Jean taught reading, history, language, health, science, physical education, and computer use. Students in Jean’s school were assigned to math groups within the target class according to their ability. The 15 students thus assigned to the target class were divided into three groups, each working on different subjects: a) seven students working on seventh-grade math, b) four students working on eighth-grade math, and c) four students enrolled in Algebra I.

The most prevalent mode of instruction in Jean’s class was teacher instruction. Although the students were divided into subject matter groups, they worked individually after Jean gave instructions to each group, but were allowed to interact within their groups. Students frequently
worked problems on the board. Supplementary materials were extensively used. As shown by the videotaped lessons submitted for the TOMTOMS project, Jean lectured and directed students for the entire class period. Overall, the mode of instruction was changed during her target classes only six percent of the time and cooperative learning groups were utilized only five percent of the time. However, Jean mentioned the use of math cooperative learning activities during her other subject matter time slots and indicated that critical thinking techniques were focused upon in her reading class.

Students were required to provide calculators in the target class. When asked if these calculators had to have scientific capacities, Jean replied "I don't even really look." However, she noted that her students "hardly ever come to math without a calculator." None of the math lessons during the school year were structured to use computers. Computers were available, but were used for word processing, keyboarding practice, and to publish a school newspaper.

Jean's math class was given homework once or twice each week. The homework assignments consisted of skill practice problems. Warmup problems were not utilized, and none of the data suggested that provisions were made to establish an anticipatory set among students. Jean's students did not maintain math journals, but were required to
keep a school journal which included mathematics since Jean was teaching in a self-contained classroom. Students prepared weekly or daily entries, or included lesson summaries for insertion into their portfolios.

Instructional aids were used to develop math concepts on only three occasions during the school year. Jean pointed out that this limited use of concrete materials was still twice the use of instructional aids with respect to the previous year. Jean has had course training in the use of Math Their Way and Math in the Mind's Eye, but most of her training in the use of manipulatives was in relation to primary grade levels. Assessments for the target class were based on unannounced quizzes, tests, portfolios, and school journals. Quizzes and tests were administered approximately once every two weeks.

Jean planned ahead for classes in three-week blocks, working on one subject each day during her preparation period. Her yearly curriculum plan directed the planning efforts and most of her preparation time was spent:

Pulling the stuff that I need to have run off . . . . I’ll skim through the chapters coming up and if I’m going to skip a section or if I’m going to use supplemental materials, I’ll, you know, get that stuff out and run [sic] off. So even though I don’t know specifically what lesson is taught, I know generally where we’re going.

Jean estimated that she spent approximately 30 minutes per week planning for the activities of the target class.
Karla

Karla had spent her entire teaching career of 15 years with middle school students. Her preservice teacher preparation program was in secondary mathematics and the highest level of college mathematics taken was abstract geometry. Though Karla expressed the opinion "math classes that were the most abstract were extremely difficult and I took several of them more than one time," she continued to take at least two math classes each quarter during four years of college.

Three different levels of seventh-grade mathematics were offered at Karla's suburban school and student placement was dependent upon performance on a district math test. Approximately the top one-third of the students were placed in seventh-grade advanced mathematics. Thus, Karla taught three seventh-grade advanced math classes, two seventh-grade basic math classes, and one eighth- to ninth-grade pre-algebra class. Karla's target class of advanced students was composed of approximately 22 students.

Karla described her target class as content-oriented and teacher-driven. On her questionnaire, she estimated that 60 percent of the class time was spent in large group discussions and during 20 percent of the class time the students worked independently. However, her calendar, journal, interview, and portfolio indicated that students spent most of their time working independently or listening
to teacher instruction. Karla described a typical class period as follows:

They [her students] know that immediately after we do the warmup and go through the answers to it that we are going to correct the assignment. And immediately after that we're going to take notes, and immediately after that they're going to do some practicing of some sort, whether it's by themselves or in a group or whatever. And then immediately after that they're going to have a chance to ask their questions and go through that and then they're going to get their assignment. And at the very end of class, we do the critical thinking problem that has been on the board.

The students worked as partners or in small groups approximately once every two weeks during the school year.

Written tests or quizzes were administered approximately once each week, and assignments from the text were given daily. Karla estimated that the students were able to finish approximately one-third of their daily textbook assignments during the class period, with the remainder to be done as homework. Assessments of student progress was based upon student daily homework grades, quiz scores, and test scores. Once each quarter, Karla conducted an observation of her students as they worked in groups and also graded them on oral responses to math problems.

Calculators were used every day. Students purchased their own and were able to use them on assigned problems, unless the warmup or assignment involved basic arithmetic facts. If basic facts were used, the students were told not to use their calculators. Computers were used in the target classroom approximately six times during the school
year. Instructional aids were used once during the year. Activities which provided opportunities for divergent thinking and problem solving were intentionally assigned. Supplementary materials focused on problem solving and on the applications of skills. Warmups were given each day, focusing upon review or skill practice.

Karla did not consider it necessary to assign tasks which would assist students in the development of positive attitudes toward mathematics. She felt that her students were highly inclined toward mathematics and did not require additional encouragement to continue their math studies.

According to information provided on her questionnaire, Karla estimated that she spent four hours per week preparing for the target class. When asked if she considered herself a moderately heavy planner, Karla responded, "I wouldn’t use the word ‘moderately.’ I do plan a lot. I need, personally, to be very organized." Conversely, though her classroom was highly structured, she felt that she was reasonably flexible. As an example of her flexibility, she stated that "I think the students feel that I’m fairly flexible in that if the overhead goes out, it’s no big deal. I can write on the chalkboard."

Maria

Maria had been teaching school for 20 years, eight of which had been middle school mathematics. She held a Basic Elementary Certificate with a math endorsement and during
the year the present study was conducted taught only mathematics courses. Although she studied advanced mathematics in high school, Maria avoided mathematics during her college undergraduate work. Her undergraduate coursework in math consisted of one term of math preparation for elementary teachers. Maria began to enjoy mathematics only after she began to teach, and her graduate work included courses in calculus, advanced algebraic structures, the history of math, statistics, probability, and logic.

The seventh-grade students at Maria’s inner-city school were assigned to average/low, average/high, pre-algebra, and algebra groups, based upon test scores and teacher recommendations. Students were then randomly selected from the average/low and average/high groups to make up Maria’s target seventh-grade math class. The size of the target class varied from 26 to 35 students, who were seated at round tables in groups of four. The seating configuration encouraged small group work, pairs, or cooperative learning modes. Maria’s class was involved in interactive learning 41 percent of the time, whereas the students were engaged in individual seatwork less than half as often (15 percent). Every 10 days, Maria changed the group seating arrangement on a random basis.

Warmups were routinely used at the beginning of the class periods. These warmups sometimes served as anticipatory sets for daily activities. The establishment of an
anticipatory set involved preparing students for the developments which would take place in the classroom during the class period. At other times, warmup emphasis was placed upon critical thinking skills. Except for Fridays, homework was routinely assigned. Class time was not used for the homework assignment, but was related to the daily lesson. The homework often consisted of a review or the application of what had been learned in class. Maria had a classroom set of four-function calculators available for student use, but students did not have access to them while completing homework. Computers were used for classroom work five times during the school year.

The variety and quantity of manipulatives used in Maria's classroom were among the highest of all 10 teachers included in the sample. She had taken courses which encouraged the use of manipulatives and was comfortable developing concepts with concrete materials as well as using them to reinforce skills. Square tiles were used when teaching concepts such as "lowest common multiple, and rectangular [numbers], finding factors and primes." Tiles in individual bags were stored in boxes in the classroom and Maria observed that

a lot of times when we are doing warmups like doing logic or something, the kids will say, "this would be easier to do using this," or something. And they [manipulatives] are always available for kids.

The students in Maria's target class maintained journals, which provided Maria with a method of giving positive
feedback to the students about their performances. She mentioned that she also writes something personal on each of their tests, and makes an effort to talk to students while they are working during the class period. Twenty-three percent of Maria's student activities were designed for the practice or maintenance of skills, whereas only five percent of the activities were specifically designed to develop problem solving skills or patternning and predicting skills. Maria stated, "I try to [plan activities that will develop critical thinking skills], but it's hard to tell if you are. But I am aware and I need to be more aware". Four extended student projects were assigned during the school year. Maria also incorporated selected activities to develop positive attitudes toward mathematics among her students, but this took place fewer than 10 times during the school year.

For the target class students, two separate activities usually took place during single class periods. Maria used a game format approximately twice a month, and three times as many activity sheets were drawn from resource materials as were from the adopted curriculum. Assignments from the textbook were given approximately twice each week, and all other assignments were drawn from resource materials. Tests were given two or three times each quarter.

Maria described herself as an extensive planner. She estimated that she spent one to two hours per week planning
for the target class. She felt that she needed to know exactly what she was going to do during each activity since the students would be working and the noise level might be high. To be flexible during class periods, Maria needed to be aware of the overall structure of each lesson.

Tracy

Tracy had been teaching middle school mathematics for six of her 10 years of teaching experience. She had an extensive mathematics background and a Secondary Advanced Mathematics Teaching Certificate. The mathematics courses she completed in college included calculus, linear algebra, and Euclidean and non-Euclidian geometries. Tracy had not received training in the use of math manipulatives. The approximately 25 students enrolled in the target class had scored below the seventh percentile on a standardized test. Tracy also taught six other sections of mathematics, ranging from a math tutorial to algebra. The school was located in a mid-sized town within easy driving distance of a large urban community.

Tracy’s students spent more time in cooperative groups or working in pairs than in any other instructional mode. A teacher-directed mode of instruction was used only when instructions were given for the beginning of the daily activities. If a concept required review or amplification, then students used the overhead to provide explanations to the rest of the class, or large group discussions, in which
some students presented ideas and others reacted, took place. Warmups and tests were the only individual activities scheduled, and they were occasionally completed as groups. Three or more different activities took place each day and the instructional mode was changed as the activities were changed. Though the composition of the groups was changed daily, students were adept at moving from small groups to pairs to large groups. Teacher-talk was minimal.

Warmup activities were used daily to enhance critical-thinking skills. Often, an additional activity focusing on review of a learned concept or foreshadowing a coming development followed the warmup. Students worked as partners or in cooperative groups during the principal activity of the day. Many of their assignments were carried over from one day to the next. For instance, during one week Tracy's journal recounts:

Lab lessons on Tuesday using bicycles (Get in Gear) and metric tapes (All About You). Students liked bringing bikes down the hall to math class. Wednesday students created ratio, proportion stories in math journal and illustrated it [sic]... Used rate-pattern warmup. It was fun to see rate increase for students.

Students brought their own calculators to the target math class, but classroom calculators were available for students who had forgotten to bring their own. Some students used scientific calculators and some used basic four-function calculators. Except during mental math warmups,
students had free access to calculator use. Computers were not used at all in this class.

Textbook assignments were given on approximately a weekly basis. Of the assignments included in Tracy's portfolio, the most common tasks (91%) were focused on such problem solving skills as extending sequences, analyzing patterns, or making logical arguments; in contrast, 15 percent of the assignments involved the application of concepts. Homework activities, when assigned, usually focused on enrichment, the solution for a single problem, or data gathering. If the work did not need to be completed in a cooperative group, a typical homework assignment would be to finish classroom work. No homework was given on Fridays, nor did Tracy have a set procedure for collecting homework since completed homework was often was the nucleus for large group discussions. Students maintained portfolios in which they recorded on-going classroom work, past projects, and/or assignments. Whereas student portfolios and journals were used for assessment purposes during the second semester, written tests were otherwise administered approximately once every three weeks.

Throughout the school year, Tracy used concrete materials for an activity on an average of once each day. The most frequently used concrete materials were dice, spinners, or other random number generators. Other frequently-used manipulatives included measurement devices, geometric
figures, geoboards, and fraction bars. To encourage students to think critically, Tracy intentionally structured her lessons toward concept attainment, rather than toward the mastery of skills. She felt that she had consciously diversified the types of questions which she asked, and provided students with frequent opportunities to develop critical thinking.

During the first quarter of the school year, and only during that quarter, specific activities were planned which focused upon the development of positive attitudes toward mathematics. From the pairwise comparison of variables, Tracy was categorized as a heavy planner. She estimated that she spent five hours per week planning only for her target class. Once each week, a parent volunteer came to her classroom to organize activities and to arrange math manipulatives for use in the classroom.

Group B Profiles

The students of the Group B teachers had an average mean gain score of 2.98, compared to an average mean gain score of 9.91 for the Group A teachers, almost one standard deviation of difference. The teachers in Group B relied more heavily upon individual student seatwork, tended to structure their lessons more thoroughly, used computers more often, directed student learning activities, and spent more time teaching lessons from textbooks. In contrast to
two out of five teachers in Group A whose classes were set by rigorous student ability level grouping, all five Group B teachers instructed in homogeneous classrooms determined by rigorous ability level grouping.

Three of the five teachers in Group B had secondary training and most had less than 10 years of teaching experience. Three Group B teachers were male and two were female. Most of the Group B teachers had been successful in mathematics courses from an early age. Student use of scientific calculators was more prevalent among Group B teachers, although all of the teachers of both groups allowed students unrestricted use of calculators. Only one teacher in Group B asked students to maintain a journal for the entire school year, but two others initiated the practice during the fourth quarter. The Group B teachers also relied more often on teacher-made worksheets for students than they did on commercially-prepared activities.

Denny

Denny, who had taught for 24 years, 21 of them as a middle school teacher, was one of the three males in Group B. Denny has a Bachelor of Science in mathematics, but had received no training in educational pedagogy until after he had taught for four years. He held an Oregon Standard Advanced Mathematics Certificate. Denny feels that he gravitated toward mathematics as a student because he had never been taught good study skills. Consequently, he "majored
in math because it's the class I got the best grades in with the least amount of work."

Students in Denny's school were assigned to math courses according to their scores on the Comprehensive Tests of Basic Skills (CTBS), a nationally-normed standardized test. The approximately 25 students in his seventh-grade target class scored between the 15th and 90th percentile on the CTBS. Denny taught general math four periods each day and also offered two computer classes. Denny's school was located in a mid-sized town, located at a considerable distance from any large urban areas.

When asked what mode of instruction he used most often, Denny responded, "generally classroom discussion." However, when asked if students were able to ask questions of other students during these discussions, Denny replied: "[The] questions or responses that I am looking for would be directed from me to them and then from them to me." In the five videotapes submitted, there was no evidence of large group discussions. The only large group activity that took place was teacher instruction, followed by individual questioning with individual responses directed to the teacher. In one activity, after asking students for suggestions, Denny evaluated their suggestion, explained why it could not be "right," and then gave them the right answer.
A large amount of teacher talk took place even while students were working individually. According to Denny's calendar, the majority of class assignments were textbook questions completed individually. No journals were maintained by students. When Denny was asked the question, "what percent of the available time in this class do students spend in cooperative small groups?", he replied, "fifty percent." However, only one activity on the teacher calendar was designated as small group work. Small group work which took place during the videotaped lessons consisted of students moving their desks into groups of four for approximately five minutes to fill out individual worksheets following an extensive teacher presentation. Students then returned their desks to the usual row-column configuration, and more teacher direction took place. According to Denny's calendar, during class periods transitions were made from one mode of instruction to another in approximately 35 percent of the classes taught. In the majority of Denny's target classes during the year, the same mode of instruction prevailed from the beginning of the class until the end. Students changed from one activity to another during a class period only one-fifth of the time. Most of the classes involved one activity in a single mode of instruction, lasting the entire class period.
A classroom set of scientific calculators was available for student use during class time. Denny stated:

We won’t let them take them home or we won’t get them back, or we’ll lose them . . . , but they do have a calculator at home because on the homework I give them, there will be specific instructions on how the calculators are to be utilized, too.

On one of Denny’s videotapes, it was noted that he told students when to leave their seats to get a calculator to "check their answers," and then when to return the calculators to the storage area.

Homework was assigned twice each week (Tuesdays and Thursdays) in the target class, and no time was allowed in class for homework. Homework assignments always involved practice of an arithmetic skill. Homework problems were collected at the beginning of the class period on the day following the assignment. Quizzes last from 5 to 10 minutes were given once each week and always involved an arithmetic skill. At the end of each test chapter, tests drawn from the publisher materials which accompanied the adopted textbook were given. To evaluate student progress in the class, portfolios were maintained by the students. The learning groups were also assessed subjectively, according to Denny’s judgment as to whether or not students were on task and working well together.

When asked what provisions were made for teaching critical thinking skills, Denny replied "questioning skills." This was followed by the comment that
I organized my week so that every Friday was set aside for project day, and usually as much as possible, that project, in some way, reflects what we have been doing during the week in the classroom.

According to the portfolio of classroom materials compiled by Denny, the Friday "projects" were a 45 to 50 minutes activity directed by a written worksheet. The project may have been a game or a logic problem. Approximately 94 percent of the daily assignments were from textbook practice problems. Of the 12 non-textbook assignments included in Denny's teacher portfolio, six were considered by the researcher to be problem solving in nature and one was a long-term student project. Consequently, those activities which Denny considered as oriented toward the development of critical thinking skills tended to focus lower level skills similar to textbook exercises.

One activity during the year was designed to develop positive attitudes, compared to 27 designed to practice and maintain skills. The most common purposes for activities were warmups (on the average, once per week), developing understanding, problem solving, and applying concepts. Denny suggested that the warmups in his class were used to establish an anticipatory set for students whenever possible. Warmups were used an average of once each week. Denny also said that he made attempts to effect closure, but often was frustrated in these attempts.

Calculators were utilized in approximately six percent of the target class assignments, whereas computers were
utilized for approximately 16 percent of the assignments. At the teacher’s discretion, a complete computer lab was available to the class. Two of the videotaped lessons submitted were recorded while students worked in the school computer lab. During these lessons, Denny directed each keystroke. During most of the class periods students spent most of their time waiting while Denny checked each computer to determine that the correct keys had been pressed. Each keying segment was followed by individual instruction to each student describing exactly what should be inputted. At the end of the lesson, students were instructed what to name their file, where to place their disks, and exactly when to turn off their computers. There was no evidence of exploration or the discovery of mathematical principles.

Instructional aids other than calculators and computers were used during 20 percent of the class periods. However, until he became involved with the TOMTOMS research project, Denny had undertaken no training in the use of manipulatives for concept development. Playing cards, dice, and spinners were the most frequently cited manipulatives used. In a videotaped lesson, the spinners and disks were used on the overhead by the teacher, but not by the students. Denny’s class was highly structured. In his questionnaire responses, Denny estimated that he spent 20 hours per week planning for classes, grading papers, and
making and grading tests. However, in the interview he stated that he did not write his plans down, but did his planning "up in here," referring to his mind.

**Megan**

Megan had taught for four years, all of which were spent in teaching middle school math and computers. Her college teaching preparation consisted of elementary education courses with an emphasis in mathematics. A course in calculus for teachers was the highest level of college mathematics completed by Megan. Megan noted that she decided to be a high school math teacher when she was in the fourth-grade, offering the feeling that she cared about students, and wanted to help them develop positive attitudes toward mathematics. Of the activities in her target classroom, 19 were generated specifically to develop positive attitudes.

At Megan's school, located in a mid-sized town easily accessible to a nearby large urban area, students were assigned to math classes based upon previous test scores and teacher recommendations. Seventh-grade classes were divided into four levels (i.e., from level I through advanced math), and Megan's target class was a level III class. In this class, a wide variety of instructional modes were utilized. She estimated that her students spent more time (40%) in cooperative small groups than they did in independent work (20%). Megan used small groups to a greater
extent that any of the others in Group B. However, according to her calendar, she used individual instruction almost twice as often as small group instruction.

Students were given a broad variety of assignments consisting of textbook problems and supplementary materials. In Megan’s portfolio, five times as many classroom assignments were taken from alternative sources as from materials related to the adopted text. Unless students were working on an extended project, at least two transitions (i.e., moving from one activity to another) took place each day. Warmup problems were used for review or motivation, and to preview upcoming concepts. Occasionally, warmup problems were used to establish an anticipatory set for the daily activities. Establishing an anticipatory set was a specific teaching strategy used by Megan. In turn, homework was not given as specific assignments. Students completed work at home only when the classroom work had not been completed.

Conscious provision was made to teach critical thinking skills and problem solving. This was reflected in the types of class assignments, including logic problems, extending concepts, looking for patterns from which to develop algorithms, and transferring learned concepts to unfamiliar situations. After students proved their competence with basic arithmetic facts, calculators were made available. According to Megan’s calendar, calculators were used
in her class for more than one-third of the assignments throughout the year. A classroom set of computers was also available for student use, and computer activities took place during nine percent of the classes.

Megan used her planning time to assure that she had the manipulatives and worksheets she needed and that her objectives were clear. At times she wrote down "word for word, the questions that I want to ask." Also, if something did not work effectively, she tried to "sort of have an idea in my head about what I should do or where I should go at this point if the lesson isn't working." On her questionnaire, Megan noted she spent more time preparing for classes than she did in actual teaching. Megan revealed that at the beginning of the year she spent considerable time teaching her students routines and classroom procedures. Her highly-structured classroom was evident in the videotapes she submitted and in her journal.

Though in her interview Megan had stated that she felt she used math manipulatives when they fit with the topic under development, her calendar, journal, and portfolio indicated little utilization of manipulatives. Her elementary coursework included training in the use of manipulatives, and she had also taken Math In the Mind's Eye, which emphasizes the use of manipulatives in the mathematics classroom. However, she also indicated that manipulatives had only recently become available in her school.
Megan's students maintained journals as a component of their math grades for the course. She also graded their work in cooperative groups, on tests, and on assignments. Testing took place approximately every two weeks. Project work was not assigned.

**Stephanie and John**

Until the final quarter of the school year, two members of Group B taught their two target classes as a team. Stephanie was one member of the team. She held a Secondary Teaching Certificate for advanced mathematics. Stephanie had been interested in math since early in her own elementary education. Prior to teaching two years at the middle school, she had taught mathematics for two years in a high school.

John, a second-year teacher, also held a Secondary Teaching Certificate for advanced mathematics. He had studied calculus in high school and advanced calculus in college. Math was his favorite subject and he had always been successful at it. Though he wanted to teach calculus, during his first two years of teaching he taught middle school math.

At this school, 10 different levels of mathematics were available, ranging from first level arithmetic skills to geometry. All students were placed in a particular level according to teacher recommendations. The target classes consisted of students considered one level below
pre-algebra. Both target classes were taught using the same materials, activities, teaching strategies, and teaching techniques. The class period which was selected as part of the sample was not designated.

The prevalent mode of instruction in the target classes was teacher instruction, followed by individual practice (69 percent of the time, versus 22 percent for small group and pairs). Students at this school were allowed to schedule their classes to a limited extent. Stephanie attributed the emphasis on teacher instruction to the large class sizes, in turn attributed to student interest in the team taught classes. John attributed the emphasis on teacher-directed learning to ease of instruction and lack of planning time. In two of the four videotapes submitted, following detailed instructions the students worked individually while the teacher demonstrated the steps on an overhead. Individual seatwork continued for the remainder of the class period. Once an instructional mode had been entered at the start of class, no further change of instructional mode took place during the class period. However, in approximately 50 percent of the classes, students were involved in two separate activities during class times. Transitions for the students were preplanned and were emphasized.

Once each week the target classes worked in a math lab, where students worked in groups of four to five at one of
eight different lab setups. Math labs consisted of hands-on activities focusing on probability, measurement, logic, geometry, and other areas of mathematics. Students rotated from one lab to another each week so that no two groups were involved in the same lab during the same class period. During laboratory times, both teachers circulated from group to group, interacting with students, assisting, and questioning.

Occasionally, students worked in groups when involved with projects. Students in these target classes were engaged in more project work (e.g., enlarging comic strips, the mathematics of motion, map drawing, statistics projects) than any other of the target classes. Routines were important and students were specifically trained in the techniques for storing calculators, forming small groups, and moving into and out of laboratory situations. John and Stephanie felt that they did extensive planning and, for reason of their desire to teach as a team, enforced a highly structured classroom.

Stephanie and John created many of their own lessons and emphasized games and cooperative learning structures. Of the worksheets completed by students, 40 percent were teacher-made. During the year only one worksheet was drawn from the adopted curriculum materials. Neither Stephanie nor John felt that they did a good job of focusing upon critical thinking skills. Less than two percent of their
classroom activities focused on developing problem solving skills, in comparison to 33 percent focused on the practice and maintenance of skills. Conscious emphasis was also placed on the development of positive attitudes toward mathematics. Specific activities were designed to enhance student perceptions of math and to make the classroom comfortable. John was proud of his teaching style, reportedly "full of humor." He felt that the rapport he had with his class was important. Stephanie stated that "sometimes when I see someone slipping away, I will try to target in on relating or trying to teach something I know that [particular] kid enjoys."

Warmups were not used and nothing was present in the data submitted which indicated that provision had been made for establishing an anticipatory set or providing closure. However, John and Stephanie both felt the journals which the students maintained during the fourth quarter of the school year provided a considerable contribution toward the sense of completion of activities. Homework was assigned once or twice each week, and as a separate activity. Quizzes and tests were also teacher-constructed and were given approximately once every three weeks. Daily class assignments, quizzes, and tests were used to assess student progress.

A classroom set of scientific calculators was available for student use at all times. With the exception of
one test on estimation, use was unrestricted. However, students used computers only during the math labs. One of the eight lab activities was a computer activity and one group was assigned each week to the computer lab. A wide variety of other instructional aids were used in the target classes. Once each week during the math lab, instructional aids were used by almost all of the students. Compasses, protractors, geoboards, integer tiles, measurement devices, pattern blocks, dies, spinners, cards, base-10 blocks, and coins, were used infrequently during non-lab classes throughout the year.

**Tony**

Tony's college preparation was for elementary school teaching, with emphasis in physical education and mathematics. The highest level of mathematics he had completed was introductory calculus. Tony did not become interested in mathematics until after he had left high school, thus he entered college with only one secondary credit in mathematics.

All of Tony's eight years of teaching were at middle schools. During the project year, Tony's school was located in a mid-sized town. Tony felt that his supervising teacher had strongly influence his own teaching style, which he described as "a good traditional teacher where the text was the main portion of instruction." Although Tony felt that his teaching style had changed in the prior two
years, he stated that "I don't like working in groups because I'm not comfortable with that interaction yet."

In Tony's classroom, individual student desks were configured in rows and columns, but were moved into groups of four for small group work. The target class enrolled approximately 23 students. Tony's class was highly structured, with specific directions provided for procedures, expectations clearly spelled out, and directions given on how to work or how to divide up the work if students were working in pairs. In the videotaped lessons, students completed individual worksheets even when they were working in pairs.

Tony's teaching schedule consisted of five math classes and one physical education class. His target class was made up of seventh- and eighth-grade students assigned according to scores on a placement test. Students scoring high on the placement test were placed in pre-algebra classes. Tony's target class consisted of seventh-grade students who did not take pre-algebra and eighth-grade students who had either failed seventh-grade math or who did poorly on the placement test.

The most frequently used instructional modes for the class were individual seatwork (44%) and teacher instruction (35%). Teacher instruction involved interaction between students and Tony. Students seemed to feel comfortable providing input for examples worked out on the board.
Small group work was used 10 percent of the time during the school year and student pairs were used 7 percent of the time. Tony estimated the amount of time spent in small groups to be from 20 to 30 percent.

A change in instructional mode took place on an average of 2.3 times each class period. It was Tony's intention to engage in a transition between modes of instruction three times each day, and these transitions were evident in his journal. Concepts were usually introduced with an activity and textbook assignments were used to practice the concepts; 60 percent of the activities were non-text. The tasks in which students were involved varied in number, but averaged 1.3 activities per class period.

According to Tony, provisions for teaching critical thinking skills and problem solving were not consciously undertaken. Questioned about this, he responded:

That's tough. That probably works more when we are doing the activity-based activities. It leads more into that working cooperatively, not giving answers, helping them come up with those answers themselves.

None of the assignments given to his class were designed to develop a problem solving skill. However, Tony felt that he devoted 15 percent of his class time to problem solving activities and 10 percent to open-ended investigation. The other 75 percent of the class time was utilized for the development, maintenance, and application of concepts and skills.
Warmups were utilized for 11 out of 180 class periods. The warmups were constructed to be an activity within themselves, or to tie into the daily activity. Homework was not assigned regularly.

Students used the classroom set of four-function calculators at their own discretion during the target class. However, they were not allowed to use them until after they had covered the first unit of the year covering whole number operations. According to Tony’s journal, students began to use calculators during the second quarter of the school year. Computers were used for a classroom activity three times during the school year, and access to computers for students during math classes was limited.

The most commonly used instructional aids were algebra tiles, followed by geometric figures, cards, newspapers, and random number generators. Instructional aids, other than calculators and computers, were used for approximately 10 percent of the class assignments. During his undergraduate work, Tony had been trained in the use of math manipulatives in the classroom. Daily work, tests, and portfolios were used to assign student grades. Unit tests were given approximately once every 10 class periods. Journals were not used and projects were not assigned.
Group Differences

Differences between the two groups of teachers are listed in Table 4. The numbers indicate the pairwise comparisons in which a teacher from one group evidenced more or less of a variable than a teacher from the group occupying the opposite axis. For instance, in four of 25 pairwise comparisons, the teacher from Group A gave students tests once a week or more, whereas the teacher from Group B tested students less often. In four of 25 comparisons, the Group B teacher tested students once a week or more frequently, and the Group A teacher tested students less often. In 17 comparisons, teachers from either Group A or Group B tested less than once each week. Thus, no differences were apparent. Differences which were determined to be definitive of the groups were teacher-directed instruction, small group work, student individual work, use of computers, structured classes, provisions for higher-order thinking skills, use of math manipulatives, transitions for students, student warmup activities, activities designed for applications of concepts, and textbook-driven instruction. Other variables may also have contributed to the differences in student performances. However, for reason of the exclusion of variables which could not be triangulated or were not otherwise sufficiently distinctive to be
Table 4. Triangulated Group Differences.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Occurrences</th>
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<tbody>
<tr>
<td></td>
<td>Group A</td>
<td>Group B</td>
<td>No Diff</td>
</tr>
<tr>
<td>1. Teacher directed instruction*</td>
<td>2</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>2. Small group work*</td>
<td>12</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>3. Student individual work*</td>
<td>2</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>4. Extent of planning</td>
<td>3</td>
<td>8</td>
<td>14</td>
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<tr>
<td>5. Frequency of testing</td>
<td>4</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>6. Frequency of use of calculators</td>
<td>6</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>7. Use of computers*</td>
<td>0</td>
<td>20</td>
<td>5</td>
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<tr>
<td>8. Structured classes*</td>
<td>0</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>9. Provisions for teaching higher-order thinking skills*</td>
<td>16</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>10. Use of math manipulatives*</td>
<td>10</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>11. Frequency of homework</td>
<td>8</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>12. Transitions for students*</td>
<td>12</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>13. Student warmup activities*</td>
<td>16</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>14. Use of alternative assessment tools</td>
<td>0</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>15. Class discussions</td>
<td>6</td>
<td>6</td>
<td>13</td>
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<tr>
<td>16. Activities designed to develop a positive attitude</td>
<td>4</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>17. Activities designed for application of concepts*</td>
<td>12</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>18. Textbook-driven instruction*</td>
<td>2</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>19. Student project work</td>
<td>6</td>
<td>6</td>
<td>13</td>
</tr>
</tbody>
</table>

* Denotes variables in which one group evidenced more variation than the second group for 10 or more of the total of 25 comparisons.
included, increased confidence can be placed in the limited number of variables retained.

**Teacher-Directed Instruction**

Teachers from Group B relied almost exclusively on teacher-directed instruction as a teaching strategy, giving step-by-step instructions to students as they completed their lessons. Teachers from Group A tended to rely more upon small group work, discussions, and cooperative learning.

**Small Group Work**

Average use of a small group instructional mode in Group A was more than double the average of use by Group B teachers. Also, twice as many Group A teachers as Group B teachers used small group work on more than 20 occasions during the nine-month school year. During interviews, two Group A teachers described their classes as predominantly teacher-directed rather than group-oriented. All five Group B teachers described their class structure as predominantly teacher instruction, followed by individual student practice, rather than small group work.

**Student Individual Work**

Group B teachers used individual seatwork twice as frequently throughout the year as did Group A teachers.
Furthermore, the videotapes of Group B teachers indicated that students worked individually even when they were paired or assigned to small groups. For example, some teachers handed out assignments and asked students to form learning groups to work on the assignments. However, once students formed their groups, very little interaction took place between the students as they worked singly to finish their individual assignments.

Use of Computers

All five of the Group B teachers took advantage of the availability of classroom sets of computers for instruction at least once each week. Only one teacher in Group A had access to a classroom set of computers, which was then used only upon occasion for math work; the students used the computers often for projects and games outside of the math period. However, it is important to note that the computer activities of Group B students were often intensely teacher-led and were focused on the recall of arithmetic facts.

Structured Classes

Establishing and maintaining a non-varying routine occurred in more than twice as many Group B classrooms as Group A classrooms. Group B teachers also spent more time planning for their classes than did Group A teachers. The
classrooms of all five Group B teachers were considered to be highly structured. In addition, four Group B teachers rated themselves as heavy planners.

**Provisions for Higher-Order Thinking Skills**

A conscious effort to promote critical thinking skills was found among Group A teachers. Assignments were given which specifically focused upon problem solving strategies and supplementary materials were used to provide students with opportunities to develop higher-order thinking skills.

During interviews, teachers were asked what provisions they made for developing critical thinking skills among their students. Only one teacher from Group B described undertaking a conscious effort to develop higher-order thinking skills. However, analysis of the videotapes of this teacher during the sample lesson served to contradict this assertion. Calendar data was then used to make a determination concerning the amount of effort. The ratio of assignments used to develop problem solving skills from Groups A and B was, respectively, 99 to 57. The average number of portfolio problem solving materials for Groups A and B were, respectively, 56 and 31.

**Use of Math Manipulatives**

Group A teachers used math manipulatives to teach math concepts more frequently and used a greater variety of math
manipulatives than did Group B teachers. The mean weekly use of math manipulatives for Group A was 1.8, compared to a mean weekly use of 1.1 for Group B. Three teachers from Group A and two from Group B had taken coursework designed to enhance teachers' use of manipulatives for the development of math concepts.

Transitions for Students

Traditional classes often consisted of one activity per class period. Homework was reviewed, new material was discussed, and students practiced the new concept. During classes in which three transitions occurred, students may have begun by working cooperatively on a logic problem, worked in pairs to complete a probability investigation, and then listened to presentations on student projects. Group B teachers tended to have students work on one activity for the entire class period, whereas Group A teachers often presented students with the opportunity to work on as many as three different activities during math class. Three of the Group A teachers averaged two or more changes of mode during class periods. Only one of the Group B teachers had a similar average. The ratio of changes in instructional mode for Group A to Group B was approximately 1.4 to 1, respectively.
Student Warmup Activities

The majority of Group A teachers (4 of 5) used warmups at least half of the time. Only one Group B teacher regularly used warmups. The types of warmup activities included reviews, establishing anticipatory sets, checking prerequisite skills, developing critical thinking skills, and generating positive attitudes toward mathematics.

Activities Designed for Application of Concepts

Group A teachers provided twice as many assignments designed to enhance student applications of mathematical concepts as did the Group B teachers. Application activities could take the form of data gathering activities from which to make predictions about students’ food preferences, measuring activities to determine the area of school playing fields for the purpose of calculating the quantity of grass seed required, or written problems containing realistic situations.

Textbook-Driven Instruction

Group B teachers relied more heavily upon textbook assignments than did Group A teachers. Analysis of the teacher data sources indicated that only two teachers from Group B utilized activities and supplemental materials more often than textbook assignments. Conversely, only one Group A
teacher used a textbook as the primary source of instructional materials.

Summary

It is important to note that if a variable was not identified as a difference between groups, it was present to a lesser or greater extent within both groups. Both groups of teachers had been given extensive training in the use of alternative teaching strategies, technologies, supplementary activities, and the use of manipulative materials. The behaviors and characteristics which differentiated individual teachers from the larger population from which they were selected may have grown out of previous training experienced within the larger group. However, in general, teachers whose students were more successful on tests of critical thinking skills were less rigid in their classroom structures. Group A teachers were more likely to begin classes with a short warmup exercise, used more varied teaching strategies and materials, often involved their students in small group work activities, planned to provide students with opportunities to apply learned concepts, and varied the activities students were involved in during class periods.

The teachers whose students were less successful on tests of critical thinking skills were more likely to create a more traditional, highly structured mathematics
environment, and most frequently provided direct instruction followed by individual student work. Group B teachers used computers and textbook assignments more often than did Group A teachers and usually planned for one activity per day for their classes.
CHAPTER 5

RESULTS

Introduction

The identification of variables in a causal-comparative study is not of itself adequate for the establishment of causal relationships among independent and dependent variables. However, insofar as the variables provide a focus for subsequent research, it is a first step toward the establishment of causal relationships (Cohen & Manion, 1989). Consequently, this study was considered to be a source of hypotheses to be tested by experimental means in future research.

A clear representation of the two groups of teachers, differentiated on the basis of student performances, was enabled by the use of the variables identified in this study. From a sample of 21 classes, as based upon student performance, the five top-ranked teachers were identified as Group A and the five lowest ranked teachers were identified as Group B. Group A teachers were distinguished from Group B teachers by greater use of small group instruction, math manipulatives, and warmup activities; by increased provision for teaching higher-order thinking skills, fre-
quent transitions between activities for students, and by the use of more activities requiring the application of concepts. Group B teachers were characterized by a greater frequency of teacher-directed instruction, computer usage, and individual student work. Group B teachers also provided more highly structured classes and utilized textbooks for instruction to a greater degree than did Group A teachers.

Teacher lectures, questions directed by a teacher to individual students during whole group situations, and student work completed at the explicit and continuous direction of the teacher were categorized as teacher-directed instruction. Though teachers had been asked to distinguish between small group work and cooperative learning, small group work may have included structured cooperative learning activities. If students worked on exercises individually, whether seated in groups or at single desks, the work was categorized as student individual work.

The computer variable did not distinguish among types of computer usage, but focused upon the number of times computers were used during the course of the school year. Consequently, computer use may have extended teacher-directed instruction, small group or individual work applications, or higher-order thinking skills, dependent upon the specific computer activity and the individual teacher's utilization of the technology.
Classes in which the students were expected to follow an established routine were considered as structured classes. A determination of the extent to which higher-order thinking skills were taught, math manipulation and warm-ups were used, application activities were utilized, and transitions took place was based upon the number of occurrences of each of these variables during the school year.

Finally, teachers who assigned exercises directly from the text more than one-half the time were considered to be dependent upon the textbook for classroom activities.

Interpretation and Discussion of the Results

Students in the classes of the Group A teachers spent more time working in small groups than did students taught by Group B teachers. In contrast, students of the Group B teachers spent more time in teacher-directed instructional situations or at individual seatwork. Although an overview of research on the effect of small group versus traditional methods of mathematics instruction found that less than half of the studies reviewed indicated significant differences in student achievement, in those studies which did demonstrate significant differences, the small-group approach almost always scored higher (Davidson & Kroll, 1991). A significant relationship between student achievement and small group work in mathematics classrooms was also found by Chambers and Abrami (1991). For the present
student, classes with better students may have been more likely to use small group structures. However, the use of class mean gain scores to determine teacher rankings minimized the possibility that the teachers with better students would be ranked in the top 25 percent.

Recently, Good, Mulryan, and McCaslin (1992) concluded that the general consistency of gains in student mastery of mathematical skills and concepts during small group work was impressive. It had been argued that the quality of planning and instruction was more important than whether individualized instruction, small group instruction, or discovery learning was emphasized. However, the research on which this argument was based did not involve measures of critical thinking. In contrast, Johnson and Johnson (1975) asserted that while lower-level skills were acquired as readily during individual work as cooperatively, more complex thinking was encouraged during cooperative work efforts. Good et al. called for this type of research, stating:

Yet to be demonstrated is whether small-group instruction influences the development of critical thinking, students' views of mathematics content and problem solving, students' ability to reason mathematically, and their developing social intelligence. (p. 167)

For the present study, between Groups A and B, the hypothesis that differences in student achievement during small group work tend to exist in relation to the level of thinking skills promoted was supported.
However, the possibility remains that the quality of planning and instruction is a factor in the attainment of critical thinking skills as well as basic skills. The organization of small group work differed between the two groups. Group B teachers tended to use the same types of activities with small groups as they did with larger groups. Consequently, the extensive planning conducted by Group B teachers may have been inappropriate for small group work.

When the differences between Groups A and B with respect to the types of instructional modes used are viewed in the context of differences in student performance, the possibility that increased time spent in small group situations positively affected student critical-thinking skills is supported. Conversely, it may be stated that the preclusion of small group working time resulting from greater utilization of teacher-directed and individualized learning modes by Group B teacher may have served to hinder the development of student critical thinking skills. Stodalsky (1985) found that when students are taught mathematics by teacher explanation and self-paced practice, they are led to rely upon being told what to do. The development of the ability to analyze, synthesize, and/or evaluate is reliant upon independence of thought. Excessive reliance upon teacher input may actually hinder the development of critical thinking skills.
It would be useful to find an optimum balance between small group work, individualized seatwork, and teacher-directed instruction. Group A teachers changed instructional modes (transitions for students) almost twice as frequently as Group B teachers. Within Group A classrooms, the changes in instructional modes which took place were movements from large group discussions to small group work, or to work with math manipulatives. The characterization of Group A classrooms suggested by the frequent transitions is that of a more active and interactive situation for students. The Teaching Standards (NCTM, 1991) contended that no single classroom arrangement (i.e., independent work, pairs, small groups, or whole-class discussions) works at all times. However, for students to be successful mathematical thinkers, the possibility of enhanced growth by Group A students was supported by the Teaching Standards' advocacy of flexible classroom arrangements. The short attention span of adolescent students may have increased the importance of transitions in this study. Thus, if the study had been conducted among student in other age groups, frequent transitions may not have emerged as a potential variable.

Good, Biddle, and Brophy (1975) found that the use of models, objects, and visual aids provoked imagery in students and focused student attention upon problem solving situations. The expanded use of concrete materials by
Group A teachers may have assisted students in the development and incorporation of problem solving strategies into their mathematical experiences, as well as have allowed students exposed to more varied learning styles to become involved in classroom tasks.

Group A teachers expressed an interest in providing students with experiences designed to enhance critical thinking skills. According to the Teaching Standards (NCTM, 1991), comparing, experimenting, inquiring, examining, investigating, probing, and inspecting are all activities which are representative of higher levels of critical thinking. Previous research has demonstrated improved achievement on standardized mathematics tests using process-oriented teaching strategies (Harrison et al., 1989). For students to become proficient at these activities, opportunities must be provided for such activities to take place.

An emphasis on activities designed for the application of concepts was found among Group A teachers more often than among Group B teachers. Cobb et al. (1991) suggested that a mathematically meaningful problem-centered instructional approach will lead to higher levels of conceptual understanding. Nunes (1992) discriminated between those math concepts used as tools and those studied as objects. Using mathematical concepts as tools in everyday life requires an understanding of mathematical relations in-
olved in particular situations, whereas studying concepts as objects in the classroom simply requires replication without understanding. For example, drawing a blueprint for a senior citizens' center requires understanding of measurement relationships, whereas substituting numbers into a given area formula requires repetition. The Cobb group presented teachers' roles in mathematics instruction from a constructivist point of view, or one of initiating and guiding mathematical activities to provide students with opportunities to exercise individual thinking. Consequently, the increased emphasis on the application of concepts by the Group A teachers may have had a positive effect upon the students' critical thinking skills.

Extensive computer use by Group B teachers in comparison to the Group A teachers seemingly is a refutation of previous research on computer use. Ball (1988) found improved performance by fourth-grade students after using manipulatives and computers to study fractions. However, Mullis, Dossey, Owen, and Phillips (1991) found no relationship between the availability of computers and student performance, with the possible exception of low-ability classes in which students with available computers performed less well than other low-ability students in an analysis of the performances of more than 26,000 eighth-grade students for the National Assessment for Educational Progress (NAEP).
The NAEP was designed to measure mathematics proficiency in six content areas: numbers and operations, estimation, measurement, geometry, data analysis, statistics, and probability. If computers were not used to investigate mathematical concepts, test hypotheses, or construct mathematical thinking, their use may not have varied from individual algorithmic practice in the traditional classroom. Mullis et al. (1991) suggested that the absence of a relationship between the availability of computers and student performances may have been due to the role of computers in the mathematics classroom. Thus, a reduction in the use of computers as substitutes for paper and pencil exercises, as well as an increase in the use of computers to develop understanding of processes and reasoning abilities, was supported.

Computer activities in Group B classrooms tended to involve teacher-directed inputs and/or individualized algorithmic practice. Computer use by Group B teachers was not consistent with that described in Teaching Standards (NCTM, 1991). The preponderance of teacher-directed instruction evident among Group B teachers during classroom activities was also evident during computer activities. In light of research cited, the high frequency of computer use by Group B students and their lower level of student performance may be indicative of a negative effect upon critical thinking skills, in addition to a neutral effect upon lower level
thinking skills. In addition, class time spent on the computer may have decreased the amount of time students could spend on other, and perhaps more meaningful, tasks.

A high level of structure in Group B classrooms was identified by the large amounts of time spent planning and preparing for class as well as the reluctance of Group B teachers to deviate from planned activities. Ongoing assessment of students' thinking and adjustment to their needs is an integral part of effective mathematics teaching (NCTM, 1991). To carry out these adjustments, flexibility on the part of teachers is requisite. In the absence of teacher flexibility, alternative activities that permit students to build on their experiences will not be readily available to them. Since it has been frequently assumed that students learn by connecting new knowledge to previous knowledge, the linkage of experiences may be an essential element in the development of critical thinking skills.

The transition stage of middle school students through early adolescent years creates a particular need for efficient management tools for the creation of learning environments in which students can draw advantage from mathematical opportunities. Though the Group B teachers were found to be more highly structured, they were also distinguished from the Group A teachers with respect to the lack of the only classroom management technique that could be triangulated: warmup activities. Group A teachers used
warmups in a variety of ways (e.g., for review, creating mental sets, developing problem solving strategies, and for practice). The use of warmups has been advocated by educational researchers to increase the possibilities for active student participation in lessons (Cummings, 1990). Hamilton (1985) also provided evidence that retention of information was increased if pre-questions and objectives were provided. Increased retention could also assist students in the linkage of the experiences discussed above. It is probable that the positive effect of the warmups upon student achievements was related more to effective classroom management than to the math content covered. In addition, it is possible that some variables are necessary for any level of learning to take place, whether these variables are lower-level algorithmic skills or higher-level critical thinking skills.

Moreover, the Group B teachers relied more heavily upon textbook exercises and emphasized the application of learned skills to a lesser degree than the Group A teachers. The consequent lack of real life problem solving opportunities may have contributed to the Group B teachers' lower student performances.

The variables identified as differences between Groups A and B are possible candidates for further research. Deleting the variables which were found in both groups may have caused some variables which affected student perfor-
mances to be dropped. However, deletion strengthened the probability that the remaining variables had a relationship to the dependent variable, student performance. The triangulation of data sources made it more likely that differences which were true differences were dropped than that differences were retained which were not true differences.

Limitations of the Study

Information from journals, calendars, portfolios, questionnaires, and interviews may have been partially dependent on teacher's interpretations of their own behaviors and intents. Teachers' statements during the interviews occasionally contradicted information gathered from other sources. If the information was available from fewer than three sources, then the contradicted information could not be triangulated and was deleted from the study. It is possible that attributes deleted in this manner interacted with remaining variables to affect student performance. In that case, the absence of the dropped attributes may render another variable impotent in isolation.

However, the existence of contradictions between the longitudinal data (i.e., journals, calendars, and portfolios) and the interview data confers additional legitimacy upon the longitudinal data and increases confidence in the results of this study. Since the interviews consisted of necessarily personal interpretations of behaviors and
intentions, the fact that personal interpretations sometimes contradicted information in the longitudinal data indicates that the longitudinal data was not heavily influenced by teachers' perceptions. The longitudinal data was systematically maintained and may be regarded as a true reflection of the classroom milieu.

Differentiation between teachers was limited to the ability of the testing instrument to discriminate between student performances. Teachers were ranked according to student performances on a test constructed by the project staff. Although every attempt was made to construct a valid and reliable instrument and to administer the test equitably, no criterion variables have been identified against which critical thinking skills among seventh-grade students may be measured. For example, no demonstrable performance instrument has been identified for differentiation between adult critical thinkers and non-critical thinkers. Consequently, correlations between tests which measure critical thinking skills and truly critical thinkers have not been established.

All of the teachers included in this study were aware that a posttest would be administered to their students. Thus, to enhance test results, some of the teachers may have consciously taught critical thinking skills to their students. However, if the test was valued and these types of behaviors raised student test scores, the variable
identified in the present study would nonetheless provide potential candidates for those teacher attributes related to critical thinking skills.

For reason of the nature of this research investigation, the variables identified in this study cannot be generalized. In previous studies dimensions were found which were apparently subject specific (Berliner & Tikunoff, 1976). For instance, at some grade levels, teachers teach mathematics differently from the way they teach reading. Consequently, teacher behaviors/characteristics which may be related to higher-order cognition in seventh-grade mathematics classes taught by a select group of Oregon teachers may not produce similar results in other levels or types of mathematics classes in other locations. The variables must be subject to further study in isolation and in combination prior to generalization from results obtained from their consideration.

The variables generated may also have been affected by teacher personalities intrinsic to the group of teachers from which the sample was selected. Teachers participating in the TOMTOMS project were predetermined to be a select set of educators. Other teachers without the same interests and training may not have generated the same group profiles and, consequently, may have contributed to the extraction of different variables.
The possibility must be considered that student performances could have affected group behaviors/characteristics. This possibility was diminished, but not eliminated, by a measure of control which was built into the research: the homogeneity of teachers with respect to their familiarity with a wide variety of teaching techniques and strategies. All of the teachers had received in-depth training in alternative teaching strategies and techniques during an eight-week summer session in 1990. Considerable similarities in teaching behaviors were found which may have resulted from the training. The homogeneity of the group decreased the likelihood that the dependent variable exercised an effect upon the independent variable (Cohen & Manion, 1989). The similarities decreased the number of differences between teachers, but may also have served to validate the differences which were identified.

Although every effort was undertaken to eliminate researcher bias, value judgments were necessarily exercised in the course of this investigation. In a discussion of ethnographic procedures, Biddle and Anderson (1986) reasoned that investigators inevitably come to case studies with unique backgrounds that include related experiences, ideological commitments, and interests in certain issues and concepts which make it impossible not to make assumptions or to exercise choices. Consequently, the researcher must be aware of the assumptions that govern his or her
decisions and make these explicit in the report. Objectivity must be of concern to both qualitative and to quantitative research (Eisner & Peshkin, 1990). The procedures and methods outlined in Chapter 3 are the assurance of confidence in the results considered in the current study.

For this study, a decision was made to include variables if there were 10 or more pairwise differences among 25 possible differences between Groups A and B. The decision was made in order to assure that differences between the groups were true differences. However, a smaller number (e.g., less than 10) may have allowed critical variables to be targeted, whereas a larger number of pairwise differences (e.g., more than 10) may have eliminated some of the weaker variables. The ideological commitments of the researcher may also have influenced the identification of variables from each independent source, possibly eliminating a potential variable. Judgments were also made on the inclusion of specific questions in both the interviews and the questionnaire, as well as the data requirements for calendar recordings.

Unidentified characteristics present in all of the classrooms may have affected outcomes, or specific combinations of variables may have contributed to their effectiveness. The relative importance of each variable or of possible combinations of variables complicated relationships between the variables and student outcomes, and may have
affected the identification of variables. Alternative hypotheses which might provide plausible explanations for the outcomes of this study may need to be tested.

Recommendations

The intent of the study was to generate possible variables which should be subject to closer examination in future research. It is recommended that the teacher behaviors and characteristics identified in the current study be subject to further examination, using experimental and control groups to determine whether they are factors which contribute to higher level thinking skills among middle school students. This type of research undertaking should also distinguish which, if any, of the variables are pivotal and/or which combinations of variables are the most effective. For example, the small group structure variable may have been a single overpowering variable, which either made all others superfluous or without which none of the others would have been productive.

Skemp (1987) distinguished between lower- and higher-order cognition, using the terms "instrumental" and "relational" mathematics. He contended that students wishing to learn relational mathematics must be taught in a manner which allows for relational understanding, or the conceptual whole of mathematics. However, students wishing to learn instrumental mathematics (i.e., skill mastery) could
be successful whether taught in a relational or instrumental manner. Consequently, the variable of small group work may have been a pivotal variable, creating a bridge from instrumental to relational learning, and its presence alone may have ensured relational learning. As an alternative, the absence of this variable may have negated the effect of the other variables.

The possibility that successful student performance on tests of critical thinking may require different student experiences than those necessary for success on tests of basic skills suggests that different teacher behaviors and characteristics may also be related to the successful development of student critical thinking skills. Future qualitative research should be conducted to compare behaviors and characteristics among groups of teachers whose students demonstrate improved performances on both basic skills and critical thinking, groups of teachers whose students demonstrate improved performances on only basic skills, and groups of teachers whose students demonstrate improved performances only for critical thinking.

Johnston and Markle (1986) advocated distrust for reports which advocate specific teacher behaviors in isolation. They considered clusters of teacher behaviors to be useful in influencing middle school student performances. In addition to analyzing the variables generated for this study in isolation, and in combinations at the middle
school level, it may also be worthwhile to study the effect of the variables upon students in other grade levels to determine if this set of behaviors and characteristics will have an effect upon the critical thinking skills of students across grade levels.

To determine if other variables will emerge that are common to teachers of other age groups, it is also recommended that research on the behaviors and characteristics of math teachers at other grade levels be conducted using instruments which focus upon higher-order thinking skills.

Implications of the Investigation

Transcendence is a term which has been used to describe the stage of development beginning before puberty and continuing through early adolescence (George & Lawrence, 1982). Middle level students are in the process of developmentally changing from children into adults, both mentally and physically. George and Lawrence suggested that hormonal changes, physical changes, and awakening sexual interests may contribute to middle level students' relatively short attention spans. The physical needs of transitioning students point to variety and to change of pace as vital components of the classroom. Middle level teachers should be aware of the importance of variety on the cognitive development of students, as distinct from
achievements measured by the learning of specific information or skills.

Transitioning students are considered to be moving from concrete into the direction of abstract thought and the development of their reasoning abilities (Johnston & Markle, 1986). Throughout this transition, experiences with concrete materials allow students to construct bridges to abstract ideas. Cognitive development is the building of general structures for learning rather than the mastery of a task. School experiences which emphasize higher-order thinking skills, utilize small group instruction, use concrete representations of mathematical concepts, and which include more transitions between instructional modes during class periods may be particularly linked to enhanced cognitive development among middle school students. Other middle level teachers may wish to accommodate middle level students' physical needs and support their cognitive development by increasing the amount of time these students spend building concepts through concrete representations.

The teacher behaviors and characteristics identified in this study should be considered and utilized by institutions and/or individuals designing inservice education programs for practicing middle level teachers or preservice teachers. The professional development asked of teachers by the NCTM (1991) to improve the teaching of mathematics must be guided by a continuing reexamination and revision
of the assumptions upon which mathematics instruction is based. In view of the differences in student performances for teachers from Groups A and B, the present study provides information which should be further analyzed and evaluated.

It is likely that the preservice training of most teachers of elementary students has been focused upon pedagogy, rather than upon math content, whereas preservice training for most secondary school teachers has been increasingly focused to a greater degree upon math content than upon pedagogy. The preservice training of the elementary and secondary teachers in Groups A and B was consistent with traditional training for pedagogy and content for elementary and secondary teachers. To ensure that middle school teachers are well grounded in pedagogy as well as content, the results of this study may be interpreted to reinforce the need for a reevaluation of middle level mathematics teacher preparation. Subsequent research on the identified variables may suggest that middle level teachers should be skilled in the variance of their teaching styles, in the use of a variety of instructional tools, in the management of small groups, in the creation of opportunities for students to develop critical thinking skills, and in providing students meaningful problems with which to apply their mathematical skills. If the research supports these suggestions, the teachers of transitioning middle level
students may need to teach in a manner which bridges the traditional roles of elementary and secondary teachers.

It may be that the skills which are required for middle level mathematics teaching cannot be adequately measured by such teacher evaluation tools as the National Teacher Exam (NTE), which focuses on math content skills. Moreover, since the development of critical thinking skills is a desirable student outcome in other content areas, teacher certification specialists may need to devise a tool for teacher evaluation which focuses on pedagogical skills for middle level teachers.
REFERENCES


Appendix A

Teacher Questionnaire

(Pretest)
TEACHER QUESTIONNAIRE

Name ____________________________  Demographic Data:

Date ____________________________  Sex:  F  M

Circle:  Participant  Leader

Teacher workload:
If your school, principal, home address or phone numbers have changed since last January, please make the changes on the back of this page and mark here so we can update our database.

1. How many years have you been teaching?  1. _____
2. How many years have you been teaching middle school math?  2. _____
3. What teaching certificates/endorsements do you have?  ____________________________

4. Please complete the following chart regarding your teaching assignment for next year.
   (if you do not know next year's assignment use this year just completed)

<table>
<thead>
<tr>
<th>Period</th>
<th>Class Name</th>
<th>Approximate Time</th>
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5. Describe the availability of calculators, computers, software, manipulatives in your school.
Then discuss your use of these technologies/manipulatives.

   calculators -  computers -

   software -  manipulatives -
6. Describe how students are assigned to classes in your school. Include the different levels of math available for students in your school.

7. Approximately how much time do you spend each week on the following activities:
   a. preparing for classes
   b. grading homework
   c. making and grading tests
   d. teaching
   e. other school responsibilities

Describe:

Choose a typical regular 7th grade class from this year when reflecting about and answering these questions.
Which class are you describing?______________________________________________________

(Circle the appropriate answer - feel free to comment in the space provided)

8. How much time do you have available on a weekly basis during your school day to spend preparing alternative assignments, projects, problem solving activities for your classes in addition to the basic course requirements?

1 2 3 4 5
none some a lot
9. To what extent is it necessary to use materials in addition to your textbook to teach your class?

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<td>a lot</td>
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10. How much flexibility do you have to include additional or alternative activities in the curriculum you teach?

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11. How much encouragement does your school district give you for using course materials other than your text?

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12. Estimate the percent of available time you spend in a typical week on each of the following activities in this class:

a. development/maintenance of concepts/skills  
   a._____

b. applications of concepts/skills  
   b._____

c. problem solving  
   c._____

d. open-ended investigation  
   d._____

e. other  
   e._____

13. What percentage of students in your class are competent at the following activities?
   a. development/maintenance of concepts/skills
   b. applications of concepts/skills
   c. problem solving
   d. open-ended investigation
   e. other

14. What percent of the available time in this class do students spend in:
   a. large group discussion
   b. cooperative small groups
   c. independent work
   d. other
   e. total 100%

15. About how much time per week do you provide in-class time for homework? 15.

16. Do you use calculators in this class?
   How often? 16.
   For what purpose?

17. Do you use computers in this class?
   How often? 17.
   For what purpose?

18. Do you teach estimation and mental math skills in this class?
   How often? 18.
   For what purpose?
19. Approximately how many weeks each year do you spend teaching the following:

a. Probability
b. Statistics
c. Geometry
d. Measurement
e. Algebra
f. Problem Solving
g. Numbers/Computation
h. Graphing, patterns, relationships
i. Integrated units
describe please:

j. other
describe please:
Teacher Questionnaire
(Posttest)
Teacher Questionnaire

Name _________________________________

Date _________________________________

1. If your school, principal, home address, or phone numbers have changed since last summer, please include the correct information on the back of this page.
   Check here if changed. ______

2. If your teaching certification/endorsements have changed since last summer, please list the changes here.

3. Please complete the following chart regarding your teaching assignment for this year.

<table>
<thead>
<tr>
<th>Period</th>
<th>Class Name</th>
<th>Approximate Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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<td>3</td>
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<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Describe how students were assigned to your target class. Include the different levels of math available for those students.
5. Describe the availability of calculators, computers, software, and manipulatives for your target class. Discuss your use of these technologies/manipulatives this year.

6. Approximately how much time did you spend each week on the following activities for the target class?

   a. preparing for classes  
   b. grading homework  
   c. making and grading tests  
   d. teaching  
   e. other school responsibilities

Describe other responsibilities:

Please answer the following questions about your target class. (Circle the appropriate answer. Feel free to comment.)

7. How much time did you have to spend preparing alternative assignments, projects, and problem solving activities in addition to the basic course requirements?

   1  2  3  4  5
   None  Some  A lot
8. To what extent was it necessary to use materials in addition to your textbook to teach your class?

1   2   3   4   5
   None  Some  A lot

9. How much flexibility did you have in the curriculum to include additional or alternative activities?

1   2   3   4   5
   None  Some  A lot

10. How much encouragement did your department give you for using course materials other than your text?

1   2   3   4   5
   None  Some  A lot

11. Estimate the percent of available time that you spent in a typical week on the following activities in your target class.

   a. development/maintenance of concepts/skills
   b. applications of concepts/skills
   c. problem solving
   d. open-ended investigation
   e. other

12. What percentage of students in your class were competent at the following activities?

   a. development/maintenance of concepts/skills
   b. applications of concepts/skills
   c. problem solving
   d. open-ended investigation
   e. other
13. What percent of the available time in this class did students spend in:
   a. large group discussions
   b. cooperative small groups
   c. independent work
   d. other

14. About how much in-class time per week did you provide for homework?

15. How would you categorize student use of calculators in this class? Check one.
   - Free access by students
   - Teacher determined access
   - No calculator use
   - Free access except on tests

16. Did you use computers in this class?
    How often?  _____  For what purpose?

17. Did you teach estimation and mental math skills in this class?
18. Approximately how many weeks this year did you spend teaching the following:

a. Probability
b. Statistics
c. Geometry
d. Measurement
e. Algebra
f. Problem Solving
g. Numbers/Computation
h. Graphing, patterns, relationship
i. Integrated Units
   Please describe the integrated units below:

j. Other
   Please describe the other units below:
Appendix B

TOMTOMS Project (Pretest)
TOMTOMS Project

1. Name_________________________

2. Teacher______________________  3. Period____

4. Grade ________________________

5. School_______________________

6. School's City_________________

7. Circle: Female  Male

8. Birthdate_____________________

Try your best on this test, we want to find out what 7th graders know about math when they come to school in the fall. Some problems you may not be able to answer, but make a reasonable estimate if you can. This test will also ask you the kinds of math problems you like to work on and how interested you are in the problems you try.
Try your best on these problems. Some problems you may not be able to answer, but make a reasonable estimate if you can. If you want you may skip over a problem and come back to it after you have done the other problems. Feel free to make comments about ideas you have on solving problems even if you can't get an exact answer.

1. What number times 35 is 140?

2. \(10^4 = \)

3. Find \(-14 + 9\)

4. Find 30% of 50

5. Find \(0.2 \div 0.014\)

6. If \(x = 3\) and \(y = 1\) find \(2x - y\)

7. Find \(3 + 2(12 - 7)\)

8. About how many centimeters long is this line?

9. Grandma left Corvallis at 10:45 am. Her trip to Ashland took 4 hours and 20 minutes. What time did she get to Ashland?
10. a. Shade in 65% of the square:  
   ![Shaded Square](image1)

   b. Shade in $\frac{3}{5}$ of the square:  
   ![Shaded Square](image2)

   c. Which shaded part is bigger?  
   10c. __________

11. Jane makes 2 out of every 3 baskets she shoots at the free throw line. If Jane shoots 42 times, how many baskets would she expect to make?  
Show your work.  
11. __________

12. Suppose you have a strip of wood 10 inches long. You need to cut the strip into $\frac{3}{4}$ inch pieces.  
   a. How many $\frac{3}{4}$ inch pieces will you get?  
   12a. __________

   b. Is there any wood leftover?  
   Explain how you got your answer.  
   12b. __________

13. Which letter corresponds to the section of the graph where you would expect to find the difference between $7\frac{1}{2}$ and $3\frac{2}{3}$?  
13. __________

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
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<tbody>
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<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
</tbody>
</table>
14. Draw as many isosceles triangles as you can with AB as one side and a point of the grid as the third vertex.

How many isosceles triangles did you draw? 14.

15. Jay knows that half the students from his school play the piano. Also, half of the students play soccer. Jay thinks this adds up to 100% of the students. Jay may be wrong. Explain why you think Jay is right or wrong. If possible, draw a picture to explain your thinking.

16. Using each of the numbers 1, 2, 3, 4, 5, 6 once, fill in the boxes at the right to get the largest possible answer. Show below as many other ways as you can find to get your answer.

\[ C = \square \]
17. The following picture shows you my garden. Each square is one square yard

   a. How much fence will I have to buy to protect it?  
      17a.________________  

   b. How many scoops of flower seed will I have 
      to buy (1 scoop covers one square yard)?  
      17b.________________  

18. Cascade Breakfast Cereal Company wants to find out the favorite breakfast cereal of Middle School aged students in Medford and are willing to pay someone $5 per hour to find an approximate answer. Cascade will hire the person who will most likely find the right answer, but for the least amount of money. Make a plan for finding out the answer.
19. Toothpicks:
   a. Make a square with 4 toothpicks.
      \[
      \begin{array}{c}
      \hline
      |   |
      |   |
      \hline
      \end{array}
      \]
   b. Next make another square using one side of the first square.
      \[
      \begin{array}{c}
      \hline
      |   |
      |   |
      \hline
      |   |
      |   |
      \hline
      \end{array}
      \]
   How many toothpicks do you have now?
   c. Make a third square in the same line.
   How many toothpicks do you have now?
   d. Complete the chart at the right, adding squares in the same line.

<table>
<thead>
<tr>
<th>Squares</th>
<th>Toothpicks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td></td>
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<td>3</td>
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<tr>
<td>5</td>
<td></td>
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<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

   e. If you made 10 squares in a line, how many toothpicks would you need? 18e. ________
   g. If you made 100 squares in a line, how many toothpicks would you need? 18f. ________
   h. Can you state a rule for finding the number of toothpicks?

   g. Make and label a graph of the data in your table:
20. Choose the three problems you liked working on the best.
   List the numbers of these problems: _______ _______ _______

21. Choose the three problems you liked working on the least.
   List the numbers of these problems: _______ _______ _______

22. Are there some problems on which you wish you could have spent more time? ______
    If so, list the numbers of these problems: _______

23. Did you use a calculator on this test? ______
    If so, list the numbers of the problems on which you used it.

24. What is your opinion of this test?
Appendix C

TOMTOMS Project (Posttest)
TOMTOMS Project

1. Name________________________________________ (Please print first and last name)

2. Teacher_______________________________________ 3. Period____

4. Grade________________________________________

5. School________________________________________

6. School’s City___________________________________

7. Circle: Girl or Boy

8. How old are you? ____________________________

Try your best on this test, we want to find out what middle school students know about math in the spring. Some problems you may not be able to answer, but make a reasonable estimate if you can. Show your work or explain your thinking. This test will also ask you the kinds of math problems you like to work on and how interested you are in the problems you try.
Try your best on these problems. Some problems you may not be able to answer, but make a reasonable estimate if you can. If you want you may skip over a problem and come back to it after you have done the other problems. Feel free to make comments about ideas you have on solving problems even if you can't get an exact answer.

1. What number times 35 is 140?  

2. $10^1 =$

3. Find $-14 + 9$

4. Find 30% of 50

5. Find $0.2 \div 0.014$

6. If $x = 3$ and $y = 1$ find $2x - y$

7. Find $3 + 2(12 - 7)$

8. About how many centimeters long is this line?

9. Grandma left Corvallis at 10:45 am. Her trip to Ashland took 4 hours and 20 minutes. What time did she get to Ashland?
10. a. Shade in 65% of the square: 

b. Shade in $\frac{3}{5}$ of the square: 

c. Which shaded part is bigger? 

11. Jane makes 2 out of every 3 baskets she shoots at the free throw line. If Jane shoots 42 times, how many baskets would she expect to make? 
Show your work. 

12. Suppose you have a strip of wood 10 inches long. You need to cut the strip into $\frac{3}{4}$ inch pieces. 

a. How many $\frac{3}{4}$ inch pieces will you get? 

b. Is there any wood leftover? 
If there is, how much? 
Explain how you got your answer. 

13. Find the difference between 7 1/2 and 3 2/3. 

14. Draw as many isosceles triangles as you can with AB as one side and a point of the grid as the third vertex.

[Diagram showing isosceles triangles]

How many isosceles triangles did you draw?

14. __________

15. Jay knows that half the students from his school play the piano. Also, half of the students play soccer. Jay thinks this adds up to 100% of the students. Is Jay right or wrong? Explain why you think Jay is right or wrong. If possible, draw a picture to explain your thinking.

16. a) Using each of the numbers 1, 2, 3, 4, 5, 6 once, fill in the boxes at the right to get the largest possible answer.

Answer =

b) Show below as many different ways as you can find to get your answer.
17. The following picture shows you my garden. Each square is one square yard

a. How much fence will I have to buy to protect it? 17a. ___________

b. How many scoops of flower seed will I have to buy (1 scoop covers one square yard)? 17b. ___________

18. Cascade Breakfast Cereal Company wants to find out the favorite breakfast cereal of Middle School aged students in Oregon and are willing to pay someone $5 per hour to find an approximate answer. Cascade will hire the person who will most likely find a reasonable answer, but for the least amount of money. Make a plan for finding a good estimate of the answer.
19. Toothpicks:
   a. Make a pentagon with 5 toothpicks.
      \[ \text{pentagon} \]
   b. Next make another pentagon using one side of the first pentagon.
      How many toothpicks do you have now?
      \[ \text{pentagon} \]
   c. Make a third pentagon in the same line.
      How many toothpicks do you have now?
   d. Complete the chart at the right, adding pentagons in the same manner.

<table>
<thead>
<tr>
<th>PENTAGONS</th>
<th>TOOTHPICKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td></td>
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<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

   e. If you made 10 pentagons in a line, how many toothpicks would you need?
      19e. ______
   f. If you made 100 pentagons in a line, how many toothpicks would you need?
      19f. ______

   g. Can you state a rule for finding the number of toothpicks?

   h. Make and label a graph of the data in your table:
20. Choose the three problems you liked working on the best.
   List the numbers of these problems:   ______   ______   ______

21. Choose the three problems you liked working on the least.
   List the numbers of these problems:   ______   ______   ______

22. Are there some problems on which you wish you could have spent more time?______
    If so, list the numbers of these problems:

23. If you had a calculator to use, would you have used it on this test?___________
    If so, list the numbers of the problems on which you would have used it.

24. a) How difficult was the test?

   b) Did you enjoy taking it?

25. When will you use the math that you are learning now when you are an adult?
Appendix D

Descriptions of the Major Categories in the Cognitive Domain of the Taxonomy of Educational Objectives

I. Knowledge. Knowledge is defined as the remembering of previously learned material. This may involve the recall of a wide range of material, from specific facts to complete theories, but all that is required is the bringing to mind of the appropriate information. Knowledge represents the lowest level of learning outcomes in the cognitive domain.

II. Comprehension. Comprehension is defined as the ability to grasp the meaning of material. This may be shown by translating material from one form to another (words to numbers), by interpreting material (explaining or summarizing), and by estimating future trends (predicting consequences or effects).

III. Application. Application refers to the ability to use learned material in new and concrete situations. This may include the application of such things as rules, methods, concepts, principles, laws, and theories.

IV. Analysis. Analysis refers to the ability to break down material into its component parts so that its organizational structure may be understood. This may include the identification of the parts, analysis of the relationships between parts, and recognition of the organizational principles involved.

V. Synthesis. Synthesis refers to the ability to put parts together to form a new whole. This may involve the production of a unique communication (theme or speech), a plan of operations (research proposal), or a set of abstract relations (scheme for classifying information).

VI. Evaluation. Evaluation is concerned with the ability to judge the value of material (statement, novel, poem, research report) for a given purpose. The judgment are to be based on definite criteria. These may be internal criteria (organization) or external criteria (relevance to the purpose) and the student may determine the criteria or be given them.
Appendix E

General Scoring Rubric for Open-Ended Questions
**GENERAL SCORING RUBRIC for OPEN-ENDED QUESTIONS**  
Used for Grade 12 CAP questions

Please Note: For each individual open-ended question, a rubric should be created to reflect the specific important elements of that problem. This general rubric is included only to give examples of the kinds of factors to be considered.

Recommendations: Sort papers first into three stacks: Good responses (5 or 6 points), Adequate responses (3 or 4 points), and Inadequate responses (1 or 0 points). Each of those three stacks then can be re-sorted into two stacks and marked with point values.

<table>
<thead>
<tr>
<th>Demonstrated Competence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exemplary Response</strong> ... Rating = 6</td>
</tr>
<tr>
<td>Gives a complete response with a clear, coherent, unambiguous, and elegant explanation; includes a clear and simplified diagram; communicates effectively to the identified audience; shows understanding of the open-ended problem's mathematical ideas and processes; identifies all the important elements of the problem; may include examples and counterexamples; presents strong supporting arguments.</td>
</tr>
</tbody>
</table>

| Competent Response ... Rating = 5 |
| Gives a fairly complete response with reasonably clear explanations; may include an appropriate diagram; communicates effectively to the identified audience; shows understanding of the problem's mathematical ideas and processes; identifies the most important elements of the problems; presents solid supporting arguments. |

<table>
<thead>
<tr>
<th>Satisfactory Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Minor Flaws But Satisfactory</strong> ... Rating = 4</td>
</tr>
<tr>
<td>Completes the problem satisfactorily, but the explanation may be muddled; argumentation may be incomplete; diagram may be inappropriate or unclear; understands the underlying mathematical ideas; uses mathematical ideas effectively.</td>
</tr>
</tbody>
</table>

| **Serious Flaws But Nearly Satisfactory** ... Rating = 3 |
| Begins the problem appropriately but may fail to complete or may omit significant parts of the problem; may fail to show full understanding of mathematical ideas and processes; may make major computational errors; may misuse or fail to use mathematical terms; response may reflect an inappropriate strategy for solving the problem. |

<table>
<thead>
<tr>
<th>Inadequate Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Begins, But Fails to Complete Problem</strong> ... Rating = 2</td>
</tr>
<tr>
<td>Explanation is not understandable; diagram may be unclear; shows no understanding of the problem situation; may make major computational errors.</td>
</tr>
</tbody>
</table>

| **Unable to Begin Effectively** ... Rating = 1 |
| Words do not reflect the problem; drawings misrepresent the problem situation; copies parts of the problem but without attempting a solution; fails to indicate which information is appropriate to problem. |

| **No Attempt** ... Rating = 0 |

This is a page from *Assessment Alternatives in Mathematics*, a booklet from the California Mathematics Council and EQUALS.
Appendix F
Teacher Calendar
Please enter information into the teacher calendar in the following format using the code lists provided.

<table>
<thead>
<tr>
<th>Identify Source</th>
<th>Activity Name</th>
<th>Instructional Mode</th>
<th>Manipulatives</th>
</tr>
</thead>
</table>

### Identify Source

- **Name**: From participant packet (Project 1 stuff)
- **Code**: *
- **Name**: TOMTOMS MATERIAL (Maggie, Di, Leaders...)
- **Code**: **
- **Name**: My Original Stuff
- **Code**: ***

### Purpose

- **Name**: Warm Up
- **Code**: WU
- **Name**: Check Pre-Requisite Skill
- **Code**: CPR
- **Name**: Foreshadow a Coming Development
- **Code**: CD
- **Name**: Developing a Postive Attitude
- **Code**: PA
- **Name**: Motivation
- **Code**: M
- **Name**: Develop Understanding
- **Code**: DU
- **Name**: Practice
- **Code**: P
- **Name**: Application
- **Code**: A
- **Name**: Maintainance of Skill
- **Code**: MS
Recreation
Filler
Develop Problem Solving Skill
Closure

Activity Name
When using TOMTOMS material, please include the specific name from the packet.

Instructional Mode
Name | Code
--- | ---
Teacher Instruction | TI
Large Group Discussion | LG
Small Group Work | SG
Individual Seatwork | I
Homework | H
Lab Discover | L
Pairs | PR
Coop Learning | CL
Project | PJ

Manipulatives
If a manipulative is used in the lesson, please make a checkmark in the last section.
If the checkmark is entered and the type of manipulative is not indicated by the handouts or by the journal entry, please enter a code below the checkmark.

Name | Code
--- | ---
Computers | COM
Calculator | CAL
Compasses and/or protractors | CP
Measurement Devices | MD
Algebra Tiles | AT
Base 10 Blocks | BB
Miras | MI
Pentominoes | P
Tangrams | TG
Dices, spinners, or other random number generators | RNG
Pattern Blocks | PB
Geometric Figures | GF
Other | Please Specify
Appendix G

Interview Questions

**Focused Questions:**

In your target class this year, what mode of instruction do you use most often? Why?

How often do your students work in cooperative learning groups?

What size of groups do you use?

How do students move between groups?

How long are they together?

Do you use warmups? What is their purpose?

Do you plan for closure?

How often do you have homework?

What is the purpose?

Do you consciously give students an anticipatory set?

Did your students use calculators in class?

At your discretion or theirs?

How often did you use computers?

Did you have math manipulatives available in your classroom?

Have you had any training in the use of manipulatives?

How were manipulatives used? What types? How often?

Do you consciously plan activities which will develop higher level thinking skills?

What types of assessment tools did you use this year?
What is the highest level of mathematics which you have studied?

How did you choose the lessons for your videotapes?

Are the behaviors in the videotape typical of the behaviors you exhibit in your classroom?

**Non-Directive Questions:**

Could you describe a typical class day?

How would you describe the classroom climate?

Have you always been successful in mathematics?

What makes you different from other teachers?

How would you rate yourself as a planner?

Would you describe your style of teaching?

Is there anything about you that I would need to know in order to better understand you as a teacher?
Appendix H
Non-Triangulated Variables

Characteristics:
1. Teaching certification
2. Ability grouped classes
3. Math content preparation
4. Professional development
5. Training in use of manipulatives
6. Success in mathematics
7. Early interest in mathematics
8. Size of class
9. Years teaching middle school

Behaviors:
10. Use of supplementary materials
11. Student journals
12. Student portfolios
13. Scientific calculators
14. Time in class spent on homework
15. Time in class spent on algebra
16. Activities designed for practice or to maintain skills
17. Activities designed to develop understanding
18. Activities designed for closure
19. Activities designed for motivation or recreation
20. Use of TOMTOMS materials
21. Use of participant packet materials
22. Use of original materials