



The mathematics learning log and its effects on mathematics achievement, anxiety, and communication
by Scott Alan Brown

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Education
Montana State University

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Abstract:

This research studied the effects of implementing a specific writing paradigm, mathematics learning logs, into high school algebra classes. The study was designed to determine if there were differences in achievement (as measured by standardized testing), ability to communicate in writing about mathematics, and mathematics anxiety levels between students who regularly maintained a prescribed mathematics learning log and those who did not. Of additional importance in this study was teacher feedback concerning the value of learning logs as an alternate assessment method.

The study was conducted August, 1994 through May, 1995.

Participants were four volunteer teachers and 174 ninth through eleventh grade students from two Wyoming secondary schools. The student participants were enrolled in two levels of algebra, Algebra I and Basic Algebra. Each instructor taught one class designated "experimental" and one designated "control." The teachers were trained to implement the prescribed writing structure before the school year began. The students underwent pre-treatment evaluations in writing and mathematics anxiety, and were introduced to the practice of keeping a mathematics learning log. The researcher maintained close contact with the teachers throughout the study and monitored student writing regularly.

Students were assessed on written mathematical communication skills after one semester, took standardized tests in April, and were again assessed in written mathematical communication and mathematics anxiety at the end of the school year. The teachers were formally surveyed twice during the study.

The pre-treatment data verified equivalence of groups before treatment. Analysis of covariance (ANCOVA) was implemented to test for differences relative to treatment, gender, and class placement. Teacher feedback gained in the two surveys was also included in the findings of the study.

It was concluded that the writing group was superior in written mathematical communication and that the writers showed greater reductions in math anxiety than did the non-writers. No differences between experimental and control group performance on the standardized math tests were revealed. Teacher accounts confirmed the value of math learning logs as a means of enhancing appropriate use of mathematical terms, facilitating communication between teacher and student, and integrating instruction with assessment.

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Scott Alan Brown

**A thesis submitted in partial fulfillment
of the requirements for the degree**

of

Doctor of Education

**MONTANA STATE UNIVERSITY
Bozeman, Montana**

November 1995

D378
B815

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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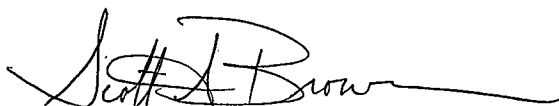
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ACKNOWLEDGMENTS

The author wishes to express his deepest gratitude to the members of his examining committee, who offered their expertise and encouragement throughout the course work and research over the past four and one-half years. Doctors Hall, Allinger, Casagranda, Strohmeier, and Carson were continuous sources of motivation and inspiration--men who spurred the author's desire not only to excel as an educator, but as a writer and researcher.

The author is grateful to his wife Kelly and his entire family for the patience, support, and sacrifice they have so willingly offered in helping to make this goal become a reality.

Most sincere thanks to Gayle Jellum, Tom Hanson, Thor Gunderson, and Terry Quinn, the math teachers who willingly took on this project and worked diligently through the entire nine months to properly implement the writing structure and assessments. Thanks also to Terry Chamberlain and Ed Weber, the Math and Curriculum Facilitators for Campbell County School District, who encouraged the teachers to volunteer and supported the project in innumerable ways.

The administration and staff of Park County School District Six are also recognized for their encouragement to aspire to the highest possible goals in education. The District was most supportive in providing the professional leave necessary to make completion of a graduate program possible.

Most important, the author recognizes the Lord's provision and direction through this challenging, but wonderful and beneficial, period of time.

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ABSTRACT

This research studied the effects of implementing a specific writing paradigm, mathematics learning logs, into high school algebra classes. The study was designed to determine if there were differences in achievement (as measured by standardized testing), ability to communicate in writing about mathematics, and mathematics anxiety levels between students who regularly maintained a prescribed mathematics learning log and those who did not. Of additional importance in this study was teacher feedback concerning the value of learning logs as an alternate assessment method.

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The pre-treatment data verified equivalence of groups before treatment. Analysis of covariance (ANCOVA) was implemented to test for differences relative to treatment, gender, and class placement. Teacher feedback gained in the two surveys was also included in the findings of the study.

It was concluded that the writing group was superior in written mathematical communication and that the writers showed greater reductions in math anxiety than did the non-writers. No differences between experimental and control group performance on the standardized math tests were revealed. Teacher accounts confirmed the value of math learning logs as a means of enhancing appropriate use of mathematical terms, facilitating communication between teacher and student, and integrating instruction with assessment.

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CHAPTER 1

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PROBLEM STATEMENT AND REVIEW OF LITERATURE**Introduction**

For decades, education and assessment experts have embraced the objective paper-and-pencil test as the most appropriate method of assessing highly valued objectives (Stiggins 1991). However, assessment has entered a new era, and educational practitioners are now faced with the challenge of enhancing and updating assessment strategies to ensure that we measure what is of value, not just what is easy to test (National Research Council 1989, p.70). Webb (1992) states, "More than ever before, state and district assessments are exerting pressure on teachers and students to achieve high levels of performance." In a discussion of the history of school assessment, Richard Stiggins (1991) expresses how virtually all elements of business, government, and education are pushing schools to reexamine their traditional outcomes in light of the need to prepare students for the demands of the twenty-first century. The need for teaching higher-order thinking skills and problem-solving processes results in new outcomes for schools which are incompatible with traditional objective testing strategies. Stiggins goes on to discuss the availability and potential of a broader array of assessments as impetus for needed change. Herman, Aschbacher, and Winters (1992, p.1) write that the new heightened emphasis on assessment has grown out of dissatisfaction with traditional forms of testing and has brought about an

"explosion" of interest in, and attempts to create, alternate forms of assessment.

Specific to mathematics, the Introduction of the National Council of Teachers of Mathematics' *Curriculum and Evaluation Standards for School Mathematics* relates the importance of gathering valid information about student growth and achievement for the purpose of aligning methods of instruction and evaluation with a number of standards. In part, these standards underline the importance of problem solving, communication, reasoning, mathematical concepts, mathematical procedures, and mathematical disposition (NCTM 1989, pp. 2,11). Among the recommendations proposed by NCTM's *Curriculum and Evaluation Standards* (1989), *Professional Standards for Teaching Mathematics* (1991), as well as their *Assessment Standards for School Mathematics* (1995), are the following:

- Assessment should enhance mathematics learning;
- It must be ensured that assessment results will be incorporated in subsequent instruction and assessment (NCTM 1995);

- Teachers will use a variety of assessment methods to determine students' understanding of mathematics;
- Teachers will align assessment methods with what is taught and how it is taught;
- Teachers will analyze individual students' understanding of, and disposition to do, mathematics so that information about their mathematical development can be provided to the students, their parents, and pertinent school personnel (NCTM 1991);

- Student assessment will be integral to instruction;
- Multiple means of assessment methods will be used; and
- All aspects of mathematical knowledge and its connections will be assessed (NCTM 1989).

With this newly defined curriculum, math educators recognize that neither curriculum nor instruction will "truly" change without concurrent change in assessment practices. The *Standards* emphasize, "Without changes in how mathematics is assessed, the vision of the mathematics curriculum described in the standards will not be implemented in classrooms, regardless of how texts or local curricula change" (p. 252). The *Assessment Standards* articulate clearly that "assessments that match the current vision of school mathematics involve activities that are based on significant and correct mathematics;" also that "these activities provide all students with opportunities to formulate problems, reason mathematically, make connections among mathematical ideas, and communicate about mathematics" (p. 11). In addition, specific goals for mathematics assessment have now been established by national leaders in both government and education (including President Bush and Education Secretary Lamar Alexander) at the 1991 National Summit on Mathematics Assessment (Mathematical Sciences Education Board (MSEB) 1991, p. 18). The report from that summit stresses the importance of developing contemporary assessments which go beyond routine skills.

Assessments that do not measure what is valued are of no use to teachers and students or to school officials and public policy makers responsible for education. Consequently, assessments must be aligned with the mathematics our students need to know and be able to do, and assessment alternatives to traditional short-answer and multiple-choice tests must be available to measure progress in pursuit of the new and demanding standards for school mathematics (p. 7).

We now find American mathematics teachers, who according to Stiggins and Bridgeford (1985) are among the heaviest users of traditional paper-and-pencil tests, thrust into a major restructuring of the goals and

practices of mathematics education--a curricular framework that will require assessments much different from those traditionally used (MSEB 1990). As a result of contemporary curriculum standards and assessment recommendations at both the federal and state levels, it is reasonable to assume that alternate forms of assessment will inevitably become an integral part of K-12 mathematics assessment. Teachers of mathematics will be called upon to implement alternatives to traditional assessment as means of supporting and giving clearer meaning to these new standards--alternatives that "give recognition to the sorts of understandings that transcend individual mathematics topics and that will provide our students with tools of lasting value" (Clarke, Clarke, and Lovitt 1990).

The origins of this study grew out of personal classroom experiences of the researcher and primarily four sources of external information: (1) the *Curriculum and Evaluation Standards for School Mathematics* (NCTM 1989), (2) a 1990 Marilyn Burns *Math Solution* Workshop held in Casper, Wyoming, (3) assessment alternatives recommended by the California Mathematics Council and presented in the EQUALS publication *Assessment Alternatives in Mathematics: An Overview of Assessment Techniques that Promote Learning* (Stenmark 1989), and (4) a summary of the Vacluse College Study in *Mathematics Assessment and Evaluation: Imperatives for Mathematics Educators* (Clarke, Stephens, and Waywood 1992).

Several of the assessment techniques suggested by these sources have been implemented by this researcher in 8th-grade math and Algebra I classes during the 1990-1991 and 1993-1994 school years and in the Mathematics 130-131 sequence (Mathematics for Elementary Teachers) at Montana State University from 1991-1993. From among those alternate forms of assessment

conducted at both the middle school and college levels, *mathematics learning logs* provided some of the most significant and abundant formative assessment information for this educator and served as impetus for the selection of this research problem.

Statement of the Problem

The vision for mathematics education related in the *Curriculum and Evaluation Standards for School Mathematics* places not only new demands on the instructional practices of classroom teachers, but it "...forces us to reassess the manner and methods by which we chart our students' progress." Mathematics educators are being called upon to implement assessment alternatives that reflect the "scope and intent" of an instructional program devoted to problem solving, reasoning, and communication. Assessment instruments must provide reliable and valid information to help teachers identify and understand student abilities, monitor student thinking processes, and consider student perceptions of mathematical ideas (NCTM 1989, p.192). One such instrument for assessment is a mathematics learning log.

In a mathematics learning log the student is asked, after each math lesson, to write (1) a brief summary of the activity and/or key topic(s) covered, and (2) discussion of what specific mathematics was personally learned. Relevant examples, unanswered questions, and personal reflection concerning the lesson may also be noted. These daily entries are kept in a notebook that is periodically inspected and "checked off" by the teacher for monitoring purposes. Weekly, students are required to summarize their daily log entries in a brief (2-3 paragraph) synthesis of the week's mathematics

experience-- "What we did this week (including specific key topics)" and "What I learned (with relevant examples, questions, and/or reflection)." These "log summaries" are read and responded to by the instructor before being returned to the student and placed in the notebook.

Specific details relative to the development of this particular math log paradigm are included in the Review of Literature presented later in this chapter, but the mathematics learning log described above is a potentially useful tool for (1) improving student learning, conceptual understanding, and retention of mathematics content; (2) fostering student ability to communicate mathematical ideas; (3) enhancing student disposition toward math and the learning of math; and (4) integrating assessment and instruction by facilitating classroom discourse and the tailoring of instruction to better fit student needs. Current literature offers numerous claims concerning the aforementioned benefits, so in the interest of authenticating some of these assertions, this study investigated the use of mathematics learning logs.

The problem of this investigation was to determine if there were differences in (1) mathematics achievement (as measured by standardized tests), (2) ability to communicate about mathematics, and (3) mathematics anxiety when comparing high school Basic Algebra and Algebra I students who regularly maintained a prescribed mathematics learning log to those in comparable algebra classrooms where no learning logs were utilized.

The dependent variables were mean scores on a standardized achievement test, mean scores on a summative writing assessment, and mean pairwise differences (individual change) in mathematics anxiety levels (pre- and post-treatment), as determined by a standardized math anxiety

rating scale. Independent variables were treatment (*i.e.* placement in experimental, "writing" group or control, "non-writing" group), gender of student, and for the analysis of writing and anxiety, class placement (*i.e.* Algebra I or Basic Algebra). The pre-treatment mathematics achievement test scores served as independent covariates for the analysis of norm-referenced achievement data. Scores from a pre-treatment writing sample and the math anxiety pre-test served as independent covariates for the respective summative writing assessment and anxiety analyses.

The study was conducted during the entire 1994-1995 academic year in two Gillette, Wyoming secondary schools; namely, Twin Spruce Junior High School and Campbell County High School. Four teachers were involved in the study, and the student participants were enrolled in two different levels of high school algebra: Algebra I, a traditional course for ninth graders and Basic Algebra, a more informal presentation of algebra meant for tenth through twelfth graders at Campbell County High School who have taken a pre-algebra course, or have perhaps previously failed Algebra I.

Need for the Study

There is little question concerning the potential held by alternative assessment, such as writing in journals or learning logs, to inform classroom instruction, monitor and enhance student learning, foster mathematics communication, and facilitate more positive classroom discourse (Clarke, Clarke, and Lovitt 1990; Countryman 1992; Herman, Aschbacher, and Winters 1992; NCTM 1989, 1991, 1995; MSEB 1991, 1993; Stenmark 1989, 1991). However, with increasing numbers of reports, books and journal articles bearing testimonies of math log/journal users and recommending a

variety of writing paradigms, formal research related to implementation of math learning logs, or any other assessment alternatives for that matter, is wanting. Webb (1992) points out that paper-and-pencil assessment is the dominant practice in upper-level mathematics classes, and *little* research has been done to investigate the actual practice and impact of a variety of other assessment techniques in the classroom. There is great need for research and development of new, more authentic, assessment procedures (Romberg 1992). Clarke, Clarke, and Lovitt (1990) stress the need for continued study to support their work in determining the benefits of math journaling (math learning logs). In a much broader domain, Laborde (1990) urges that investigations linking the language of mathematics with cognition should be the concern of further studies.

Judith Sowder (1989) states that researchable assessment questions induced by the publishing of the NCTM *Standards* will be "numerous and provocative," and that the recommended changes will be more likely to succeed if based on research (p. 38). Extrapolating from the suggestions of Sowder, it is the view of this researcher that the mathematics learning log, as an alternative to traditional assessment, has a place in the mathematics "research agenda," and this research problem has a substantive basis for consideration.

Preliminary Study

For the purposes of further exploring alternative assessment in mathematics, improving as a mathematics instructor, and determining an interesting dissertation topic, this researcher implemented a variety of contemporary assessment techniques while teaching mathematics for

preservice elementary teachers during two-year period, from 1991-1993, at Montana State University - Bozeman. This experience was not only informative, but proved to be highly beneficial to the students and instructor alike. For two years the instructor gained rich and detailed formative and summative assessment information using portfolios, math learning logs, open-ended questions, objective observation checklists, and student self-evaluations. Meanwhile, many of the students expressed, both verbally and in writing, the value of these assessments as facilitators of student learning and classroom discourse.

The students and instructor truly valued the mathematics learning log, in particular, because of its formative nature--allowing the students to synthesize the ideas presented in class, pose questions, exercise self-reflection, develop a personal dialog with the instructor, as well as motivating the teacher to tailor instruction to fit specific student needs. It is this researcher's opinion that the math learning log served as a valuable tool for monitoring student understanding of the concepts presented in class. Additionally, the continuous writing seemed to foster improvement of written mathematical communication for most students.

Upon return to his regular middle school teaching duties in the Fall of 1993, the researcher was quite interested in refining, and supporting appropriate research questions and methods for this study. Therefore, a pilot study was conducted by the researcher in 8th grade pre-algebra classes at Cody (Wyoming) Middle School--a study that would focus on the potential value of implementing mathematics learning logs.

A sample of sixty students, half of which were male and half female, was compared to see if there were differences in standardized achievement

test performance or ability to write about mathematics between those who completed mathematics learning logs and those who didn't. Although there were just two teachers involved, one for the experimental group and the other for the control group, curriculum, text material, final tests, and general teaching strategies were the same. Based on previous achievement test scores, homogeneity of variance and equality of means were tested and groups judged to be approximately equivalent.

End of year testing yielded interesting results. The log-writing students scored significantly higher ($p \leq 0.01$) on the objective-referenced (application- and concept-oriented) final exam; they also scored significantly higher on the concepts subtest of the ITBS (Iowa Tests of Basic Skills); and significantly higher on a summative writing assessment that required them to summarize the mathematical topics covered during the year. There were no significant differences found between treatments on the problem solving and computation subtests of the ITBS. Additionally, the analysis of covariance determined no statistically significant differences between male and female students on the writing or objective-referenced assessment, but did reveal gender differences on the concepts and total norm-referenced assessment. There was also evidence that differences between male and female performance on written math communication tasks were notably diminished in the experimental (writing) group. When the "math log" group was divided into high/low achievement groups (based on previous achievement scores), no significant differences between those group were found on the summative writing assessment--even though there were significant differences on the norm- and objective-referenced test. It was also found that some students failed to regularly record daily log entries.

Students were encouraged to keep a daily log, but participation was not strictly "enforced" by the researcher. Interestingly however, those who regularly wrote their daily log entries produced more substantive and accurate weekly summaries, and the mean scores on their weekly summaries were significantly higher than those who failed to maintain daily entries.

Definition of Terms

For the purpose of this study, the following definitions were used:

daily log- a collection of daily entries in a notebook, which include (1) a brief summary of the activity and/or key topic(s) covered, and (2) discussion of what specific mathematics was personally learned. Relevant examples, unanswered questions, and personal reflection concerning the lesson may also be noted.

Algebra I students- the students who are enrolled in the Algebra I course typically taken by ninth-graders. Placement is based on past performance in math class as well as norm- and criterion-referenced test performance. It should be noted that this group does not necessarily include the "highest" achieving math students in the student population, because approximately five percent of the students take Algebra I at the eighth grade level.

Basic Algebra students- the students who are enrolled in the Basic Algebra course--a course that focuses on presentation of less rigorous algebraic topics. Placement for students (grades 10-12) is based on past performance in math class as well as norm- and criterion-referenced test performance. Placement may also be based on previous failure in Algebra I.

mathematics achievement- broken into two categories, the math total raw score and raw score attained from one mathematics subtest (concepts/problem solving) of the Tests of Achievement and Proficiency (TAP). TAP Form K (Level 15) "Complete Battery" is used for Algebra I students and Form K (Level 16) "Survey Battery" for Basic Algebra students.

mathematics anxiety- a rating determined by the Mathematics Anxiety Rating Scale-Adolescent (MARS-A).

mathematics written communication- clear, purposeful, meaningful, and informative written discussion about mathematics and of mathematical processes (Clarke, Stephens, and Waywood 1992).

mathematics learning log- a notebook that contains all daily log entries and completed weekly summaries (upon return from teacher).

previous achievement level- the raw scores (pct.) attained the previous school year on the Iowa Tests of Basic Skills or Tests of Achievement and Proficiency (math total and math subtest included).

weekly summary- students are required to summarize their daily log entries in a brief (2-3 paragraph) synthesis of the week's mathematics experience-- "What we did this week (including specific key topics)" and "What I learned (with relevant examples, questions, and/or reflection)."

Questions to be Answered

As related in the Statement of the Problem, this research compared standardized achievement test results, mathematical written communication, and change in math anxiety levels among two groups of students, experimental and control. The specific research design for the questions of

interest is clearly delineated in Chapter Two, but certain details must be discussed at this point to clarify the questions posed in this section.

The first two questions stated below require tests for significant differences in norm-referenced achievement test scores. However, the achievement means, determined by a standardized norm-referenced test, are adjusted using analysis of covariance. They are hence related as "adjusted" measurements. The purpose of this adjustment is to account for any initial differences among the achievement scores of the groups along with the correlation of the initial achievement scores on the dependent variable (post-achievement scores). Likewise, questions regarding mathematics communication, as determined by a summative writing assessment, and mathematics anxiety difference scores, determined by the MARS-A, also relate adjusted means. .

Questions to be answered in this study are as follows:

1. Is there a significant difference in adjusted student achievement, as determined by norm-referenced assessment, between the experimental and control groups in the Algebra I classes?
2. Is there a significant difference in adjusted student achievement, as determined by norm-referenced assessment, between the experimental and control groups in the Basic Algebra classes?
3. Is there a significant difference in adjusted mean pairwise difference scores for mathematics anxiety levels between students in the experimental and control groups?
4. Is there a significant difference in adjusted math written communication scores between students in the experimental and control groups?

5. Does *any* combination of treatment, gender, and class (Algebra I or Basic Algebra) interact on the dependent variables of mathematics achievement, anxiety, or written communication?

Review of Literature

Preliminary Comments

The purpose of this study is to determine if there are differences in student achievement, mathematics anxiety, or ability to communicate in writing about mathematics, when students in classes implementing a prescribed mathematics learning log are compared to those in classes using only traditional paper-and-pencil formative assessments. Assessment, in the context of utilizing learning logs, is just one of many alternatives that mathematics teachers are beginning to use in their efforts to better integrate assessment with instruction, promote student learning, and evaluate student performance. The current literature presents numerous writing, journaling, and learning log instructional and assessment strategies in mathematics. This review will rely on many of those sources to substantiate the theory behind the researcher's learning log model. The review includes pertinent research and documentation relative to recent developments and trends in mathematics assessment; it presents a discussion of the relevance of writing to the study of mathematics; and it provides support, from the literature, for this specific learning log model and its relationship to the dependent variables under consideration in this study.

Traditional Testing Practices

Assessment, as it relates to teaching and learning, is attracting the attention of many educators who would challenge the long-standing traditions of a 60 year period which began in the 1920s--the era of "scientifically precise," or "psychometric," objective paper-and-pencil tests (Romberg 1992; Stiggins 1991). Intelligence, aptitude, and achievement tests have actually played an important role in educational decision making since the turn of the century. However, since the early seventies, public policy makers and school officials have increasingly used the results of standardized norm-referenced tests as the major criterion for judging the performance of students and programs. The unfortunate results are that these "high stakes" tests often "drive" the curriculum. "Tests become an end in themselves, not a means to assess educational objectives. Knowing this, teachers often teach to the tests, not to the curriculum or to the children" (National Research Council 1989, p. 68).

Standardized tests are criticized because they are rarely aligned with the objectives of local curricula. Neither are they aligned, at this point, with the ideals of contemporary national standards in mathematics (Mathematical Sciences Education Board (MSEB) 1990, p.50). Standardized tests often emphasize low level procedural skills at the expense of understanding and problem solving (NCTM 1991, p. 8), and overemphasis of these low-level skills, often due to teacher accountability pressures, diminishes local program quality (Herman 1992). In a general sense, standardized tests are fairly accurate indicators of which students are doing best in school and which are doing relatively poorly, but "do not provide a valid indication of subject-matter mastery." A single standardized test "will not provide valid

measurement of the mathematics achievement of individual students or of a group of students" (Stake 1995, p.173). Due to biases caused by nonalignment with local "taught" curricula, and constraints "in the sense that the test items are designed to have only one possible unambiguous answer and that the time one has in which to produce an answer is limited," NCTM (1995, p.75) states that, "Such tests fail to meet several of the Assessment Standards."

A recent study of the six most commonly used achievement tests (Romberg et al. 1992) found that at grade 8, on average, only 1% of the items were problem solving while 77% were computation or estimation. Moreover, administration, the public, and many teachers often fail to recognize these results as a mere snapshot of the students' performance, generated under timed and stressful conditions. However, it can also be contended, "Standardized tests provide some kinds of information that even the most comprehensive internal evaluation cannot, but they constitute only one piece of the kind of informed mathematics evaluation plan we must develop as we revise our curricular programs" (NCTM 1991, p. 9). In our country, unfortunately, "their use appears to be more strongly related to political, rather than educational uses" (Romberg 1992). Consequently, these tests are appropriately criticized for failing to promote student learning (Worthen and Spandel 1991), and in their misuse become one of the greatest obstacles to mathematics education reform (MSEB 1991, p.5).

In the late 1960s, school districts began investing considerable time and effort into the development of competencies or "outcomes" to which they would hold students and programs accountable (Stiggins 1991). Accompanying the district outcomes were objective- or criterion-referenced

tests--those generated by individual teachers, local committees, or professional textbook/test publishing companies for use in determining student mastery of the local objectives. As a supplement to norm-referenced tests, these instruments are quite useful in the monitoring of local instruction relative to student acquisition of certain concepts and skills. Although objective-referenced tests are more closely aligned to local objectives, they lack validity needed to "reflect the inter-relatedness of concepts and procedures in any domain," they are expensive to create, and they rarely assess higher-level thinking or problem-solving skills (Romberg 1992).

Alternate Forms of Assessment

Mathematics assessment is undergoing a metamorphosis from the conventional testing of routine skills, procedures, and rote memorization to assessment and evaluation of student performance from a much broader perspective. Our expectations now are for students to be able to reason logically and to integrate, synthesize, and apply mathematical knowledge and skill to solve complex problems (MSEB 1991, p. 12). As objectives broaden in scope, conventional testing, as previously stated, becomes increasingly deficient. Many current pedagogical strategies involving group explorations, use of manipulatives, or applications of technology, "provide learning experiences that would be grossly misrepresented by a subsequent pencil-and-paper test" (Clarke, Clarke, and Lovitt 1990). Additionally, contemporary assessment is now expected to reflect new emphasis on advancing mathematics that all students need to know in our evolving society; activities that enhance the learning of mathematics; practices that advocate equity--focusing attention on each student's learning experience;

greater openness, relative to content being assessed; greater attention to ensuring that assessment information leads to valid inferences about student learning; and stronger coherence between assessment systems, assessment purposes, curriculum, and instruction (NCTM 1995). Appropriate formative and summative assessment practices may now be expanded to include student products and performance such as:

- extended investigations;
- models, simulations, experiments, and projects;
- written responses to open-ended questions, problems and tasks;
- portfolios of student products;
- self-evaluation and reflection (both oral and written);
- demonstrations, presentations, and discussions;
- student learning logs, journals, and written reports; and
- interviews (Clarke, Clarke, and Lovitt 1990; Stenmark 1989; NCTM 1995, p.29; NCTM 1989, p.192; NCTM 1989, p.192; Herman, Aschbacher, and Winters 1992, p.7).

Students may be assessed as individuals or in the small group setting; they may use a variety of mathematical tools and models, such as manipulatives, calculators, and computers; they may be assessed in more non-traditional cognitive areas of mathematics, such as communication, connections, problem solving, and reasoning; and they may even be assessed in areas other than cognitive growth, such as confidence in using math to solve problems, willingness to persevere and try alternatives, inclination to monitor and reflect on their own thinking and performance, interest and curiosity, and appreciation of the value of mathematics (NCTM 1989, p. 233).

Writing and Learning

Writing is more than just a means of expressing what we think; it is a means of knowing what we think--a means of shaping, clarifying, and discovering our ideas (Bagley and Gallenberger 1992). Because writing is a way of clarifying and refining one's own thinking (Azzolino 1990), and writing has been shown to lead to deeper understanding and improved mastery of a content area (Haley-James 1982), many educators believe that writing should be a regularly used instructional and assessment technique in many areas of the curriculum. Moreover, students and teachers of mathematics rarely link writing with mathematics, and consequently, very little writing is done in the context of K-College mathematics classes. Contrary to this way of thinking, psychologists, cognitive scientists, and mathematics educators now suggest that there are powerful connections between writing and the learning of mathematics.

There are a number of contemporary writing paradigms in the schools and in the literature, such as; *writing to learn* (Knoblauch and Brannon 1983; Mayher, Lester, and Pradl 1983; Zinsser 1988), *writing in the content areas* (Dittmer 1986; Howie 1983), and *writing across the curriculum* (Fulwiler and Young 1983). Some of the models stress writing throughout the curriculum as an instrument for better learning, and some emphasize the "whole" curriculum as the ideal domain for teaching writing skills. This segment of the literature review will not consider the merits of any single writing framework, but instead, focus on the importance of writing as a facilitator of learning.

"We learn to write by writing, and we learn a given subject matter by writing, speaking, and thinking" (Kenney 1990). "The assertion that writing,

as well as other communication systems, can contribute to learning depends essentially on a Vygotskian view of the relationship between language and thought as a dialectic one, where language and thought are both transformed in the act of representation" (Borasi and Rose 1986a; 1986b). Britton used the phrase, "shaping at the point of utterance," to express that it is often at the very moment of speaking or writing that an idea is given form (LeGere 1991a). Psychological theory suggests that verbalizing at the appropriate time improves the ability to organize and recall information; also that writing encourages greater precision than speaking (Geeslin 1977). Emig (1977) has contended that writing can contribute to the process of learning because (1) writing actively engages students in the construction of meaning, (2) it allows learners to work at their own pace, and (3) it provides unique feedback since writers continuously read the product of their own thinking on paper. She also states that writing in a content area can cause students to analyze, compare facts, and synthesize relevant material. "Writing about a topic requires students to think about the topic, focus on and internalize important concepts, and, to some degree, make those concepts their own" (Miller and England 1989a). It is this researcher's opinion that just a brief time spent in reading the literature will serve to convince most that appropriate writing exercises will enhance student cognitive growth.

Writing is not only tied to the cognitive, but also the affective domain. As students write in either a "focused (directed) writing" or "free (non-directed) writing context," they are often provided a non-threatening environment in which to express their feelings and attitudes concerning course content or other related topics. Writing is an important medium for communication between student and teacher--one in which the student-

teacher rapport is enhanced; students' attitudes toward learning often improve; and/or teachers are better able to personally respond, and tailor instruction to, the needs and concerns of the students (Danielson 1988; Stenmark 1991; NCTM 1989; Miller and England 1989b; Burns 1988).

Writing in Mathematics

Student writing can provide essential, highly detailed, information about the strengths and weaknesses of the students as well as the program--information that is not made manifest through the regular, more traditional, modes of instruction and assessment. Writing exercises may establish a context in which students can communicate their understanding, explain their thinking, assess their own performance, and share information concerning their attitudes about the mathematics they are doing.

The National Council of Teachers of Mathematics' *Curriculum and Evaluation Standards for School Mathematics* (1989), *Professional Standards for Teaching Mathematics* (1991), and *Assessment Standards for School Mathematics* (1995) suggest writing as a means through which students should be able to communicate their understanding of mathematics and its applications. These NCTM documents relate that student writing in mathematics can provide more complete and valid evidence of students' understanding of and disposition to do mathematics than will many other activities (e.g. worksheets, textbook assignments, paper-and-pencil tests). According to NCTM (1995, p.13), assessment that enhances mathematics learning often incorporates activities that are the same as those used in daily instruction. Hence, "if students are learning by communicating their

mathematical ideas in writing, their knowledge of mathematics is assessed, in part, by having them write about their mathematical ideas."

Writing can also lend added strength to our pedagogical strategies as we advance these goals. Waywood(1992) states that writing in mathematics is linked to junior and senior high students' learning. Believing that "language and thought are intimately connected" he states, "Mastering forms of communication goes hand in hand with mastering thinking." Writing in mathematics should, says Waywood, help students "formulate, clarify, and relate concepts; appreciate how mathematics speaks about the world; and think mathematically."

When mathematics classes with writing components are compared to those without, research and anecdotal accounts confirm that students who write in the context of learning actually *do* learn and retain concepts better than students who do not write as a part of their course work (NCTM 1989; Evans 1984; Miller and England 1989b; Rose 1990; LeGere 1991b). Johnson (1983) suggests that if high school and college students can write clearly about mathematics concepts, then they probably understand them. Relating experiences with his community college math students, McMillen (1986) contends that writing about how they approach problems makes students' thinking clearer and sharper. Research at the junior and senior high level has shown writing to be an effective and practical tool for teaching mathematics problem solving (Bell and Bell 1985; Wilson and Chavarria 1993), and writing can facilitate student synthesis of content (connections), both within and outside mathematics (Bagley and Gallenberger 1992; Davidson and Pearce 1988). Davidson and Pearce (1988) state that writing not only assisted their junior high students in comprehending math concepts,

but improved their ability to communicate mathematically. Abruscato (1993) emphasizes the urgency of this objective in an article relating the results of the Vermont Portfolio Project when he cites (relative to that project) "two-thirds of eighth-graders showed no use or inappropriate use of mathematical language." This math communication and writing connection is also confirmed by NCTM (1991, p.96; 1989, p.6), Azzolino (1990), Curcio (1990) and Kenney (1990). Many, such as NCTM (1989, p. 142), Miller and England (1989b), Bagley and Gallenberger (1992), LeGere (1991b), and Miller (1991) contend that writing in mathematics classrooms, elementary- through college-level, may improve student attitudes, ease mathematics anxiety and frustration, and enhance students' general disposition to do mathematics.

Kennedy (1985) states, relative to middle school math classes, that writing in mathematics class "helps relieve math anxiety." Because student math journals clarify a frame of reference for teachers to better understand student anxiety and frustration (Skiba 1990) and create a way for students to communicate anxieties, confusion, and misconceptions to the teacher (Dodd 1992), writing in math may curb certain student fears about the math class or mathematics in general. A recent study by Stewart and Chance (1995) associated writing in Algebra I classes with reduced levels of mathematics anxiety. Skiba (1990) also suggests if students reiterate mathematical concepts and vocabulary on a regular basis, as they do with the writing model prescribed herein, the repetition may breed greater familiarity with those terms and ideas, hence reducing anxiety.

With national assessment standards focusing on "equitable practices," (NCTM 1995, p. 15) classroom teachers are urged to implement assessment techniques that take differences among students into account. Gender

differences in achievement and math communication may, as noted in the results of the pilot study, become narrower when the assessment involves written communication as opposed to other modes of assessment. It has been this researcher's experience that although middle school males are more resistant to writing in detail at first, they generally "catch up" and write at levels comparable to the females. An earlier study by Wells (1986) indicated that "lower performing" males in primary grades benefit more than females by writing in math journals. The Australian project IMPACT reported, relative to written reflections of 7th grade math students, that girls offered "more informative and insightful responses" (Clarke, Stephens, and Waywood 1992, p. 188). The Vaucluse College Study, mentioned earlier as an impetus for this study, considered only female students (at a private school for girls), leading this researcher to question how male students would respond to the math learning log paradigm.

Mathematics Learning Logs

The term "learning log" is used to describe a number of classroom writing activities having many interpretations and adaptations. In some cases the word "journal" is synonymous with learning log, such as in Clarke, Stephens, and Waywood (1992), Bagley and Gallenberger (1992), Talman (1990), Mett (1987), and Clarke (1989), but in many cases journals may be assumed quite different from learning logs. Often, student math journals are understood to be a daily diary for free-writing about students' feelings that day, impressions of the mathematics being worked on, informal or spontaneous dialogue with the teacher, or perhaps more focused discussion relative to both cognitive- and affective-oriented writing prompts (Borasi and

Rose 1989c; Rose 1990; Countryman 1992, Nahrgang and Petersen 1986; McIntosh 1991; Sipka 1990). Although journals and learning logs share similarities, the learning log paradigm implemented in this study is patterned after that of Clarke, Stephens, and Waywood (1992), Talman (1990), and Mett (1987), is characterized by its focus on a single writing prompt, and its emphasis lies in the cognitive domain.

As described in the Introduction at the beginning of this chapter, the mathematics learning log has two components; namely, the daily log, and the weekly summaries. As an ongoing assignment, students are asked to record an entry in their daily log after every lesson. Keeping a daily log is important because it engages students in communication of mathematics each day--especially students who are uneasy about participating in oral discussions in the classroom (Bagley and Gallenberger 1992; NCTM 1989, p. 28). Daily writing stimulates questions (Rose 1990), and these questions can be addressed in a more timely manner than would be true with weekly writing only (Mett 1987). The daily entry is meant to reflect and encourage the student's intellectual involvement in the lesson (Clarke, Stephens, and Waywood 1992). In the pilot study, this researcher found that students who kept a daily log wrote more substantive and accurate weekly summaries than those who failed to maintain a daily log.

The weekly summary requires that the students organize, clarify, and synthesize the math content of the week. Articulation of the week's objectives and learning helps to clarify and "crystallize" those ideas in the student's minds. It also helps the students communicate how well they understand the content. The summary may evidence misunderstandings that fail to show up in daily activities or assignments (Mett 1987; Davidson

and Pearce 1988; Azzolino 1990; Talman 1990). Although summarizing the objectives is not deeply analytical, discussion of what was learned and reflection on that experience moves students to a level of thinking that goes beyond a mere re-statement of information given (Durst and Newell 1989). Because the summaries are scored the way they are (see Table 1 in Chapter 2), they provide a new technique for "authentically assessing mathematical communication skills by providing the mechanism for examining transitions in developmental maturity in these skills" (Lajoie 1995, p. 31). The opportunity to reflect on the math learned and ask questions opens a channel for important student-teacher dialogue and informs the teacher of students' understandings so instruction can be more effectively aligned with student needs--in effect, integrating assessment and instruction (NCTM 1989).

The questions in this study imply connections between the implementation of the described writing paradigm and three outcomes; namely, higher achievement (as measured by standardized math tests), ability to better communicate about mathematics, and less anxiety about math. Nearly all the studies in this review portend improved student learning when writing is incorporated regularly in the mathematics classroom. The literature upholds the kind of writing students engage in when keeping this type of learning log as helpful in raising mathematics concept knowledge and retention, enhancing the learning of mathematics, and improving written communication of mathematics (including better use of terms) (Nahrgang and Petersen 1986; Mett 1987; Davidson and Pearce 1988; Borasi and Rose 1989c; Miller and England 1989b; Talman 1990; Rose 1990; Clarke, Stephens, and Waywood 1992; Countryman 1992; Carter, Ogle, and Royer 1993). This type of writing is also said to foster more positive

attitudes, including less anxiety, toward mathematics (Kenney 1990; Skiba 1990; Dodd 1992; Countryman 1992; Bagley and Gallenberger 1992; Borasi and Rose 1989c).

It should once again be noted that the literature contains a limited number of formal research monographs, yet numerous anecdotal claims, relative to the benefits of writing in mathematics. It is therefore this researcher's opinion that quantitative studies, such as this, may contribute significantly to the literature.

CHAPTER 2

4

DESIGN OF THE STUDY**Conceptual Framework**

As detailed in the Review of Literature in Chapter 1, mathematics learning logs are one of many alternatives useful in supplementing traditional formative assessment practices. The NCTM *Standards* suggest that alternatives, such as student learning logs, will provide more complete and valid evidence of student understanding and disposition to do mathematics than will paper-and-pencil testing. Using a variety of assessments will enable the teacher to more effectively tailor instruction to meet the needs of the students, which should, in turn, enhance student performance. Waywood (1992) states that this type of writing exercise is linked to student learning. Believing that "language and thought are intimately connected," he states that "mastering forms of communication goes hand in hand with mastering thinking." Keeping a mathematics journal should, says Waywood, help students "formulate, clarify, and relate concepts; appreciate how mathematics speaks about the world; and think mathematically."

It is the experience of this researcher, after using student mathematics learning logs as an alternate assessment method in middle school classes and university undergraduate classes, both informally and in a pilot study, that this assessment tool provides rich and highly detailed information about the

strengths and weaknesses of the students as well as the program-- information that is not always made manifest through the regular modes of objective testing. A mathematics learning log, as a supplementary assessment, provides a context in which students can communicate, and possibly improve their understanding. The dialogue established between the student and teacher through log keeping may also facilitate improvement of student attitudes toward the mathematics they are doing.

The questions proposed in Chapter 1, relating namely to standardized achievement, mathematical written communication, and mathematics anxiety are each relevant in the study of the effects of student log writing. It is stressed by NCTM (1989, 1995) that assessment be integral to instruction and should enhance learning. To be of value, student achievement should be supported by this type of assessment. Since affect and cognition are inextricably linked (Sowder 1989, p.35), it is important that student attitudes can be monitored and appropriately responded to with the reflections that often accompany log entries. The accounts of Clarke, Stephens, and Waywood (1992) as well as the pilot study by this researcher suggest that for students to articulate their own thinking, mathematical processes, and experiences is an exercise that is both challenging and empowering.

Description of Population

The one hundred seventy-four students who participated in this study were drawn from two Gillette, Wyoming (population 32,000) secondary schools; namely, Twin Spruce Junior High School and Campbell County High School. Twin Spruce has a total student population of approximately 900 and Campbell County High School's enrollment is approximately 1500 students.

The student participants were enrolled in two different levels of algebra: Algebra I, a traditional course for mostly ninth graders at Twin Spruce and Basic Algebra, a more informal presentation of algebra meant for tenth through twelfth graders at Campbell County High School who have taken a pre-algebra course, or have perhaps previously failed Algebra I. Placement in these algebra classes is based upon past mathematics performance, teacher recommendation, counseling, as well as performance on criterion- and norm-referenced measures.

Sampling Procedures

Gillette schools were chosen because Gillette is the only school district in reasonable proximity to the researcher where there were found teachers willing to participate in a *year-long* study--a study requiring some time, work, and commitment; where there was administrative interest and support for a study of this nature; and where the district is truly interested in implementation of alternative assessment in secondary mathematics classes.

The subjects of this study were four teachers along with one hundred seventy-four students in groups referred to as the "Algebra I experimental group," "Basic Algebra experimental group," "Algebra I control group," and "Basic Algebra control group." The experimental groups and control groups were each composed of four classrooms of students, along with their four respective teachers. Two of those classrooms were Algebra I and two were Basic Algebra, making a total of eight classrooms altogether. The combined experimental groups consisted of eighty-two students at the beginning of the study and the combined control groups, ninety-two students. There were

ninety-four Algebra I students and eighty Basic Algebra students at the beginning of the study.

Inclusion of groups in two different levels of algebra is supported by discussion in Evans (1984), Miller and England (1989b), and Talman (1990) relative to possible differences in the effect of writing on students performing at different levels of achievement. Wills (1993, p.132) indicates that "students with below average writing skills become better learners when they write about what they are learning." The pilot study conducted by this researcher indicates that students characterized by their underachievement on traditional assessment instruments may perform quite differently than expected when writing in mathematics.

Conducting this study on algebra classes was primarily the choice of the researcher. This choice is based on an interest in helping students who wrestle daily, and often become quite frustrated with the abstract language of algebra. Burton (1990) relates that many students' problems with calculus are rooted in lack of fluency with the language of algebra. That is, the words fail to connect with the symbols they represent. If one applies Zolton Dienes' framework for learning (Reys, Suydam, and Lindquist 1984), describing mathematical representations in writing (symbolization) is an important step on the way to dealing with formal abstractions. It is therefore reasonable to believe Miller and England (1989b) when they report that summarizing, interpreting, paraphrasing, and making personal notations about material can be useful tools for students to learn algebra.

Since the teachers were volunteers, the research design did not include a formal sampling procedure, nor did it include researcher-directed randomization of subjects and/or treatments. However, due to the large

number of Algebra I sections available (at least twelve) a certain degree of randomization was inherent in the school's scheduling process. Since there were only six Basic Algebra sections, this type of randomization occurring was unlikely. The limitations associated with the sample are more thoroughly addressed in the Research Design section of this paper.

Description of Treatments

This study consists of two treatments that are referred to as the "experimental group" and "control group." As detailed in the Sampling Procedures the experimental groups and control groups each included four classrooms of students (one hundred seventy-four students altogether), along with their four respective teachers. There were two different courses involved, Algebra I and Basic Algebra. Both the experimental and the control groups in the Algebra I courses received regular daily instruction using D. C. Heath's Algebra I (Larson, Kanold, and Stiff 1993) as the main instructional resource. The experimental and control groups in the Basic Algebra courses received regular instruction every other day (ninety-minute periods) using a more traditional and simplified textbook from Houghton Mifflin, Basic Algebra (Brown, Smith, and Dolciani 1993). In addition to regular instruction and textbook use, the treatment groups were assigned a daily writing exercise. For this task each student engaged in writing a prescribed submission to his/her *mathematics* learning log. The word *mathematics* is emphasized because of the objective nature of the writing that was assigned. The *mathematics* learning log consisted of two main components; namely, daily log entries, and weekly summaries. Daily log entries were usually completed by students before leaving class, but weekly summaries were

handled differently in the two levels of algebra. Because of the more remedial nature of the Basic Algebra class, and the students' "track record" relative to completing homework, class time was set aside for writing weekly summaries. The Algebra I instructors chose to assign the weekly summaries as a regular Thursday homework assignment. Summaries were assigned as homework in the pilot study, and this out-of-class responsibility for the students was not found to be a problem.

The Mathematics Learning Log

In a mathematics learning log the students were asked, after each math lesson, to write (1) a brief summary of the math activity and/or key mathematics topic(s) covered, and (2) discussion of what specific mathematics, if any, was personally learned. Relevant examples, unanswered questions, and personal reflection concerning the lesson may also be noted. These daily entries were kept in a notebook, or "daily log" that was only periodically (every three to four weeks) inspected and "checked off" by the teacher for monitoring purposes. After every five to six lessons, students were required to summarize their daily log entries in a brief (2-3 paragraph) synthesis of the past several days' mathematics experience-- "What we did (including specific key topics)" and "What I learned (with relevant examples, questions, and/or reflection)." These "log summaries" were read and responded to by the instructor before being returned to the student. Upon return, the summaries were placed back in the students' notebooks.

Teacher Training and Implementation

The precise structure of the treatment required that the four teachers be trained in the necessary implementation procedures before the study. A three-hour training session was presented by the researcher to familiarize the teachers with the math learning log paradigm. Samples of student log entries were viewed, rated, and discussed; suggestions, questions, and concerns relative to logistics (especially getting kids started, teacher feedback, and grading consistency) of learning log implementation was attended to; the need for student and teacher permission forms was addressed; an outline concerning how data was to be gathered, the need for accuracy in record keeping, and control of contaminating effects were presented; and the role and responsibilities of the researcher were discussed. An outline and written materials used for the training workshop are included in the Appendix.

Teacher response to weekly summaries required special treatment for the classroom implementation of learning logs to be successful. For the writing exercises to be most beneficial, weekly log summaries had to be read and responded to (in writing) by the teacher (McIntosh 1991, Nahrgang and Petersen 1986). Countryman (1992, p. 39) states that "comments can be brief, light and encouraging in tone, or a detailed answer to a specific question." Countryman goes on to emphasize that "most students just want an indication that I (Countryman) have read their comments."

Although grades were not assigned to the daily log entries, students were graded on completion of the weekly summaries. The exact weight of the summaries, relative to the overall course grading structure, was determined in collaboration with each participating teacher. This variable played an

important role in determining levels of student participation and will be discussed in the third chapter of this paper. However, weekly grading of the summaries, in all cases, was quantified using a three-point scoring rubric (see Table 1). The scoring rubric was the result of synthesizing information from Clarke, Stephens, and Waywood (1992), Talman (1990), and Beyer (1993) and was implemented and refined over a two-year period prior to the study in the researcher's math classes.

Table 1. Three-point Scoring Rubric for Weekly Summaries

1 point	Little attempt made to summarize in detail. Lists only chronological events of week with little reflection on what was learned. Does not use, or misuses mathematical terms.
2 points	Identifies most key objectives of week in at least rudimentary form. May relate objectives to examples or applications. Relates learning experiences using generally appropriate mathematical terms.
3 points	Clearly and precisely relates most key objectives of week. Effectively explains learning experiences, and may integrate with objectives and examples. Reflects more on one's own thinking, and may relate connections among concepts learned.

According to Strohmeier (1993a), an " α coefficient" (Cronbach 1970) is appropriate for establishing consistency among different raters or judges of behavior. Herman, Aschbacher, and Winters (1992), recommend a reliability coefficient of at least 0.7 for alternative assessments that are not classified as "high stakes" (e.g. large-scale district- or state-level assessment). Since the summaries were formative, not summative assessment, and since the

numerical grades on the weekly summaries were not emphasized as much as the comments recorded by the teachers, this assessment was not considered to be "high stakes." To establish the needed inter-rater reliability coefficient, three algebra teachers from Cody (Wyoming) public schools rated a sample of twenty-five weekly summaries from the researcher's eighth grade classes. Instructions, scoring criteria, and prototypes of each scoring level in the rubric were provided for the raters, however, since the raters had recently completed training in "holistic" scoring, "practice" scoring was not conducted. Copies of the rating sheets are provided in the Appendix. An inter-rater reliability coefficient of $\alpha=0.73$ was established, and thus, the scoring rubric was judged to be reliable.

This researcher agrees with Countryman (1992) and Miller (1991), that correct grammar, spelling, and punctuation should be *promoted* in the weekly summaries, but not strictly *enforced*. Positive suggestions noted for the writers (e.g. correct spellings, added punctuation) are helpful in producing better student products, but this was not to be made the main objective of the writing exercise. Evaluation of the writing, says Miller (1991), should "focus students' thinking on better understanding of the subject matter."

The researcher contacted each teacher by phone after the first weekly summaries were collected and evaluated to respond to any initial concerns about the evaluation process. Student log summaries from the first week were then mailed to the researcher (after students had a chance to read their teachers' comments) for the primary purpose of developing a set of *prototype* summaries. These prototypes, illustrating summaries graded at point-levels 2 and 3, were created on transparencies for use by the teachers in an activity aimed at developing the students' skill in writing weekly log summaries.

Actual excerpts from student writing were used in the prototypes to exemplify these levels of writing. The transparencies were then mailed back to the teachers to use in the classroom activity. A copy of the activity and a sample set of prototypes used in one of the Algebra I classes are included in the Appendix. Use of prototypes to reinforce writing criteria is encouraged by Talman (1990) as well as Herman, Aschbacher, and Winters (1992). The collaborative group setting in which the activity will take place is recommended by Countryman (1992), Kenney (1990), and Artzt (1994) as a facilitator of student writing in mathematics.

Arrangements were also made for the students' weekly summaries, with grades and comments, to be mailed to the researcher every three to four weeks thereafter, photocopied by the researcher, and returned to the teacher either by mail or during site visits. This process allowed the researcher to more closely monitor the grading consistency and comments on the summaries and is recommended by Herman, Aschbacher, and Winters (1992). These frequent reviews of the summaries, along with the written responses returned to the teachers by the researcher, may have ensured stronger reliability in use of the scoring rubric. In addition, this review process may have encouraged greater accountability relative to teachers giving appropriate written responses to their students. With rating scales, such as the scoring rubric, and even with the subjectivity inherent to written comments, it is important to be fair, avoiding the *halo effect* (Kerlinger 1986, p. 495). Discussion with the teachers about student performance was conducted during scheduled site visits (see Calendar of Special Dates in the Appendix), in writing with summaries that were returned to the teachers, and occasionally over the phone.

The teachers were asked to keep a journal of their own experiences throughout the two semesters of the study. Recording their personal observations on at least a weekly basis would hopefully facilitate the researcher's attempts to gain accurate feedback during site visits and have personally-written teacher reflections for later reference. A personal notebook and checklist for the teacher journal was given to each teacher, and a copy is included in the Appendix. For qualitative purposes, the teachers were formally surveyed two times during the study--a tape-recorded interview at the end of the first semester, and a written questionnaire at the conclusion of the school year. Observations shared by the teachers are summarized in Chapter 3 of this paper. Permission to quote participating teachers was obtained upon initiation of the study. In addition, one of the researcher's site visits, midway through the first semester of the study, included a two-hour work session with all four teachers meeting together. The purpose was to discuss the progress and problems related to the implementation of the study to date. Teachers shared information about their experiences, suggestions relative to improving student performance and participation were discussed and the researcher presented information about writing in the mathematics classroom. The district math facilitator arranged afternoon release time for the teachers to participate in this meeting.

Methods of Data Collection

Achievement Test Data

The Tests of Achievement and Proficiency (TAP) Form K (Riverside Publishing 1994) is currently used as the standardized test for all classes grades nine through twelve in the Gillette school district. The test battery is

administered in early April each year. Form K (Level 15; Complete Battery) is used at the ninth grade level, and Form K (Level 16; Survey Battery) is used at the tenth grade level. According to the literature provided by the publisher of the tests, both the TAP complete and survey batteries include two tests, one on math concepts and problem solving (includes problem solving, reasoning, mathematical connections, algebra, geometry, statistics, probability, and mathematics structure) and the other on computation (includes integers, fractions, decimals, percents, and ratio & proportion).

The content validation process for each test battery is discussed at length in Riverside Publishing's technical manuals and is concerned with the identification of content that "is representative of national instructional emphases and at an appropriate level" (Riverside Publishing 1994, p. 10). Items are constructed by university-based professional educators and psychometricians and are developed using a four-step process. Content specifications are developed; extensive quantitative and qualitative review is carried out by various specialists and independent reviewers; items are field tested; and final judgment and selection, based on all previous data gathered, is executed by professional judges. It is noted in the company literature, however, that "the validity of any assessment is dependent on the purpose of the assessment."

In the Review of Literature, reference was made to NCTM (1995), Stake (1995), and Romberg, Wilson, Khaketla, and Chavarria (1992) concerning non-alignment of most standardized tests with the NCTM *Standards*. Form K was not analyzed in the Romberg, Wilson, Khaketla, and Chavarria study, so there would be uncertainty in projecting those results on to this particular form of the TAP. Riverside Publishing (1994) claims that

the test authors recognize recent changes in mathematics curriculum and instruction, including those prompted by the *Standards*, and have responded by incorporating several changes in the questions and general format of the tests.

This researcher looked carefully at the items in both forms of the test and found them to be quite similar to other standardized achievement tests, that is, quite general in the mathematics they assess and not especially closely aligned with the algebra curricula for the two Gillette classes. In fact, it was judged that at the Algebra I level, approximately 27% of the math items in the Level 15 Complete Battery matched objectives in the actual "taught" curriculum. Likewise, about 50% of the items in Level 16 Survey Battery matched objectives specifically taught in the Basic Algebra curriculum. Therefore, it is difficult for the researcher to place a great deal of emphasis on these test results.

It should be reiterated that standardized achievement tests are but one portion of the total assessment picture. When appropriately interpreted, they can provide valuable information of *general* student achievement relative to the greater population (NCTM 1989, p. 201).

For tests administered in the spring, reliability (internal consistency) coefficients (Kuder-Richardson 20), based on scores from samples of approximately 13,000 students per grade, are presented in the previously cited technical manual. For both the survey and complete batteries, at grade levels ten through twelve, the KR 20 coefficients range from 0.799 to 0.914, with most between 0.85 and 0.90.

Mathematics Anxiety Rating Scale-A

The Mathematics Anxiety Rating Scale-Adolescent (MARS-A) is a diagnostic scale for use in measuring the degree of mathematics anxiety in 7th through 12th graders. The MARS-A was taken by all of the students (treatment and control) in early September of 1994 and late May of 1995. Each administration of the MARS-A required approximately twenty to thirty minutes.

This 98-item instrument was obtained from the Rocky Mountain Behavioral Science Institute in Fort Collins, Colorado. Reliability has been established as follows: Cronbach's alpha was found to be 0.96; Spearman-Brown reliability coefficient was 0.90; and Guttman Split-half was 0.89 on a sample of 1,313 students. Construct validity has been determined by the significant relationships ($\alpha \leq 0.05$) between MARS-A scores and variables such as GPA in math classes, number of math/science courses in which students plan to enroll, and in career choices (Suinn 1979).

Quite relevant to this study, it is suggested by Suinn and Edwards (1982) that utilization of this anxiety rating scale might facilitate decisions concerning "institutional changes in classroom instructional styles or curriculum revisions."

Pre-treatment Writing Sample

In order to further examine initial equivalence among groups (relative to abilities in writing about mathematics) and to generate pre-treatment data for the analysis of covariance, a writing task was administered to all subjects at the start of the first semester. In keeping with the assumptions for analysis of covariance, and attempting to avoid any contaminating effects on

the control group, it was decided by the researcher and his advisor that student mathematics autobiographies could be evaluated as a pre-treatment writing assessment.

A Mathematics autobiography is recommended by Stenmark (1989; 1991), Kenney (1990), Rose (1990), Sipka (1990), and Countryman (1992) as a valuable source of information relative to students' conceptions about math; attitudes about learning; and perceptions of own abilities, needs, and concerns. A math autobiography can also give the teacher a glimpse of the student's ability to communicate specifically about the mathematics topics he or she has experienced. There are other important values associated with this writing activity such as helping students see themselves as central to the learning process, facilitating a positive rapport between student and teacher, and engaging students in an activity that is both motivating and interesting.

Based on suggestions from Sipka (1990) and Countryman (1992), this researcher developed a format for the math autobiography that instructs the students to write about their feelings (positive or negative) toward math, and why they have those feelings; to recount at least one successful experience and one not-so-successful experience in their mathematical career; and detail the topics they are good at and not so good at in math (specific strengths and weaknesses). Over several years of implementation, it has been the experience of this researcher that the information found in math autobiographies is useful in establishing a positive rapport with students and familiarizing the instructor with student's mathematical needs and perceptions. Although never before this study had this writer used the autobiography to "quantify" students' abilities relative to mathematical written communication, it is reasonable to believe, and was the opinion of

this researcher and his examining committee, that this could be accomplished by applying the scoring rubric designed for the summative writing assessment. The last component of the autobiography gives fairly clear evidence of a student's predisposition to write about mathematical topics. A copy of the student instructions for the mathematics autobiography is included in the Appendix.

Summative Writing Assessment

Upon completion of the second semester, the subjects completed a brief in-class writing assignment (limited to twenty minutes). A copy of the Summative Writing Assessment is included in the Appendix.

Mathematical communication is a multifaceted concept, and evaluation of students' ability to communicate mathematically is well beyond the scope of this study. This particular writing prompt was an effort to engage students in a somewhat generic summative assessment task that would yield useful information concerning a *single* dimension of mathematical communication--that of constructing a coherent, fluent *written* summary using appropriate mathematical language and terms.

A task of this nature may serve as one indicator of students' ability to communicate mathematically. NCTM (1989 p. 217; 1995 p. 13) specifies that students' ability to communicate mathematically should be assessed by having students write about mathematics. This writing was judged for accuracy, clarity, precision, and the *proper use of mathematical vocabulary*, and symbols (emphasis added). Assessment should consider fluency of the writing (NCTM 1989, p. 214; Countryman 1992, p. 75) and should be attentive to organization, coherence, and detail (Clarke, Stephens, and

Waywood 1992; Kentucky Department of Education, 1992, p. 8). The scoring rubric presented in Table 2 was used by the researcher to rate students' written summaries based on the above criteria.

Table 2. Point Assignment for Summative Writing Assessment

1 point	Student receives one point for each isolated, but appropriate, mathematical topic stated. These are often in lists with other unrelated topics, and no clear context is established for the topic listed. (Example: "We studied things like exponents, variables, and percents." -- This yields 3 points; one for each topic named.)
3 points	Student receives three points for a minor topic accompanied by a brief description of the topic, or detailing a brief (or incomplete) list of related subtopics. (Example 1: "We studied fractions and then went on to rational expressions." Example 2: "We used proportions to find missing sides on similar figures." --These yield 3 points each.)
6 points	Student receives six points for a major topic followed by a list of 2-3 appropriate subtopics. Or, six points are awarded for logically connecting subtopics within the explanation of a major topic. (Example 1: "We learned about graphs of linear equations, and we determined slopes and y-intercepts of lines." Example 2: "We applied exponents and used percent formulas to solve problems about interest and compound interest." --These yield 6 points each.)

The writing prompt was phrased to imply a different "audience" for the students to respond to. In a task such as this Countryman (1993) believes that being asked to write to an audience different from the teacher elicits a stronger response from most students. Miller and English (1989b) found that

students write *more* when addressing comments to a specific audience.

Some discussion concerning reliability and validity is also necessary at this point. With the possible exception of a simple correlation coefficient using a test-retest strategy, traditional reliability coefficients are not applicable to a single-question assessment. An estimate for the reliability of subject responses to the question has not been established, but since the researcher limited the writing assessment to this one-time-only study and rated the papers himself, the question of reliability in scoring becomes perhaps more critical. Kerlinger (1989, p. 495) warns of the proneness of such rating scales to error. In response the rater took a sample of twenty completed writing assessments, scored them once, and then re-scored them a month later using the same rubric. According to Cronbach (1970) a simple correlation provides an adequate reliability coefficient in this situation. Herman, Aschbacher, and Winters (1992) recommend an intra-rater reliability coefficient of 0.9 for "high stakes" alternative assessments. For this rating scale, a Pearson product moment correlation coefficient of $r=0.96$ was determined, thus verifying the reliability of the scoring process.

Content validity, says Kerlinger (1989, p. 418), "consists essentially in judgment." The researcher, possibly with the help of others, judges whether the item is representative of, or relevant to, the property being measured--in this case, written communication about mathematics. Since the assessment is a single essay question, judgment of content validity may be more an appraisal of "face" validity (Gronlund and Linn 1990, p. 52)--a determination, judging on appearance, of the question's adequacy to inform us concerning student ability to compose a written summary of mathematical ideas. At any rate, to establish validity of this question, relative to the desired outcome,

three mathematics education and/or curriculum authorities were asked to judge the question and scoring rubric. The list of judges includes Doctors William D. Hall and Sharon Walen, both Professors of Mathematics Education at Montana State University; and the third judge, Dr. Judy Skupa, Director of Curriculum for Cody (Wyoming) Public Schools. Affirmative responses were received from all three judges, and it was thus concluded that the writing prompt and scoring rubric were valid for assessing the type of mathematical communication described in this study. A sample copy of the judge's response packet is included in the Appendix.

Mid-year Writing Assessment

Upon completion of the first semester, the subjects also completed a brief in-class writing assignment (approximately twenty minutes). This assessment was recommended by the researcher's examining committee as a safeguard against possible effects of extensive mortality (students dropping out of the study before the end of the year) or perhaps some unforeseen catastrophic event that would have prevented collection of data at the end of the second semester. This assessment was virtually the same as the Summative Writing Assessment discussed in the previous section. A copy of the Mid-year Writing Assessment is included in the Appendix.

Teacher Feedback

As mentioned in a previous section of this paper, the participating teachers were asked to keep a journal of their experiences throughout the two semesters of the study. It was important to the researcher that teacher comments concerning a number of questions relative to the student writing experience be obtained. Therefore, in addition to the request for teacher

journal entries, it was important that a dialogue be maintained throughout the study between the participating teachers and the researcher. Each teacher was contacted by phone a minimum of five times; the teachers were formally surveyed two times during the study--a tape-recorded interview at the end of the first semester, and a written questionnaire at the conclusion of the school year; and conversations took place during site visits. Informal reflection concerning the teachers' experiences was encouraged, but specific questions were also posed by the researcher. Teachers were asked to relate their previous experiences with writing in math; perceived strengths and weaknesses of the prescribed math log model, and about writing in general; to indicate the amount of time spent reading and responding to the students' weekly summaries; to share any instances in which the contents of student summaries affected or altered instruction; to discuss instances in which information about student understanding was gained that might not have been revealed by other class assessments; to discuss results of any unique dialogue they thought developed between teacher and student; and to comment on their perceptions of students' ability to communicate mathematically. Again, responses to these questions are summarized in Chapter 3 of this paper.

Research Design

A commonly used design is "the experimental group-control group pattern in which one has no clear assurance that the experimental and control groups are equivalent" (Kerlinger 1986, p.315). This "compromise experimental group-control group" design has neither the strength of random assignment of subjects to treatments nor that of matching of subjects. The

design, therefore, is subject to "weaknesses due to the possible lack of equivalence between groups in variables other than X" (the independent variable assigned to the treatment). Certain steps had to be taken to diminish the possible influence of intrinsic differences between groups.

The four teachers involved in the study were selected on a volunteer basis, so to control the possible differences between treatment and control groups due to "self-selection" (Kerlinger 1986, p. 316), each of the four teachers also taught an "equivalent" control group class. "Equivalent," in this context, merely implies that the students in each particular class were assigned that level of algebra based on past performance in mathematics.

Randomization is the most desirable method of assigning subjects to potentially equivalent treatment and control groups (Kerlinger 1986, p. 288; Ferguson and Takane 1989; p. 245, 391). When randomization is not controlled by the researcher or the design of the experiment, such as in this study involving intact groups, Kerlinger (1986, pp. 288, 289) suggests possible strategies to control extraneous variance, some of which were used to add strength to the design. It should again be noted here that due to the large number of Algebra I sections available a certain degree of randomization was inherent in the school's scheduling procedure. When the final master schedule became available, the researcher looked for "singleton" classes that ran simultaneously with the treatment groups' to determine if any one type of student might have been "scheduled out" of the Algebra I sections. The only scheduling problems observed were that Symphonic Band, a "singleton" in the schedule, met at the same time as one of the experimental groups and Advanced Spanish conflicted likewise with the other experimental group. Although, in the opinion of the algebra instructors, a few "more

motivated" students were excluded from being scheduled into the algebra classes at those times, the conflicts were not enough to cause this researcher concern. The reader is also reminded that approximately five percent of the top ninth grade math students were enrolled in Geometry, after taking Algebra I as eighth-graders.

Since there was such a small number of Basic Algebra sections, and many of these students were scheduled into other limited section classes, no claim of randomization could be inferred for this group.

As reported earlier in this chapter, previous achievement may exercise influence on any of the dependent variables measured, therefore, the homogeneous grouping of the algebra students allowed for separate analyses of those who were characterized as higher- or perhaps lower-achieving students. By assigning each teacher one treatment and one control group of students, and due to the homogeneous grouping of the students, the influences of teacher style and ability, along with the influences of past student achievement, were better "matched" (Kerlinger 1986) between treatment and control groups. Since complete homogeneity among groups could not be guaranteed, an additional step needed to be taken in the data analysis as a means of considering initial differences among subjects assigned to the treatment and control groups (Kerlinger 1986, p 339; Ferguson and Takane 1989; p. 391, 392). This was achieved by implementing an analysis of covariance.

To further ensure internal validity of the study, the possible effects of measurement, history, maturation, and regression had to be addressed. Two formal pre-assessments were administered; namely, the pre-treatment writing sample (completed as a homework assignment) and the MARS-A. A

twenty minute mid-year writing assignment was administered, and only two post-assessments, requiring a maximum of fifty minutes (thirty minutes for MARS-A and twenty minutes for the Summative Writing Assessment), were administered. All other assessments were administered as a regular part of the curriculum in both schools and were spread throughout the academic year, so there should have been minimum interference caused by testing (Campbell and Stanley 1963). Kerlinger (1986, p. 296) indicates that sensitization to measurement is a potential source of extraneous variance, but over the four and one-half month interval between applications of writing prompts, students were unlikely to establish significant connections between the mathematics autobiography, the mid-year writing prompt, and the summative writing assessment. Similarly, re-administration of the MARS-A as a post-test, should have been free of "memory effects" (Ferguson and Takane 1989, p. 470) due to the long time period that passed between tests.

Regression effect was controlled by having both an experimental and control group in the study, with each taking the pre- and post-assessments. Effects of history, and maturation should have been somewhat diminished by the experimental/control design as well as having a relatively large sample of students in the study. Although, history and maturation are potentially greater threats to the validity of the math anxiety variable (since this is related to attitude) than to the writing or achievement-related variables (Kerlinger 1986), the pre- and post-test structure for administration of MARS-A is recommended by the author of the instrument (Suinn 1979).

When treatment and control groups are both housed in the same building and even taught by the same teachers, there are risks of at least three types of contamination: compensatory rivalry, resentful demoralization,

and compensatory equalization of treatments (Strohmeyer 1993b). Rivalry and demoralization may affect what would be a normal response of students in the control groups, based on their possible perception of receiving the *less desirable* treatment. The relatively large student populations in the two schools may have diminished the potential for close communication between students in the treatment groups and those in the control groups. However, no formal control was implemented to remove these two effects, so this is listed as a limitation of the study.

Compensatory equalization of treatments may occur when a teacher makes a conscious instructional decision in a control group based on what has been learned from the experimental group. It is this researchers experience that most of the instructional decisions stemming from information read in student math logs are directed toward meeting individual rather than group needs. Occasionally however, math logs will bring evidence of a conceptual difficulty or weakness common to several students in the class. It is at this point that instruction for the entire class (experimental group) may be altered, and it is in this case that the teacher must be aware of the potential contamination if the same instructional adjustment is made for the control group. Teachers were warned concerning this potential threat to the internal validity of the study and were urged to record any *group* instructional decisions in their personal journals so possible contaminating effects could be considered and reported by the researcher. This threat is also listed as a limitation of the study.

Extraneous variability would be less of a concern if a large number of classes were available for random assignment of treatments (Kerlinger 1986, p 316), but this was not an option for the researcher. Several controls and

design steps, listed above, were utilized to enhance internal validity, but external validity, or "representativeness," was threatened by the small number of groups involved in the study. Although the researcher sees no reason to believe that the Gillette students and teachers involved in this project were atypical of teachers and students in Wyoming or the surrounding region, this is listed as a limitation of the study.

Analysis of Data

The independent variables used in the study were (1) treatment--experimental or control group, (2) gender, and (3) class placement (Algebra I or Basic Algebra).

For analysis of the TAP, the previous year's raw scores were utilized. The students used in the analysis were tested in the Spring of 1994, and their ITBS (Iowa Tests of Basic Skills) scores for 9th graders, and TAP scores for 10th - 12th graders, functioned as independent covariates in a two-way analysis of covariance (ANCOVA) on the 1995 scores (dependent variable). Because the analysis design involved analysis of covariance, the dependent variable of achievement (measured by the TAP for both courses in the Spring of 1995) was properly referred to as "adjusted" score. Two separate analyses were conducted, one for the Algebra I group and one for the Basic Algebra group. The reason for this is that two distinct forms of the norm-referenced assessment, TAP Complete Battery and TAP Survey, were used for those classes. Treatment and gender served as independent variables in both analyses.

In a similar manner, the scores from the pre-treatment writing sample (administered in the first week of the study) functioned as independent

covariates in a three-way ANCOVA on the summative writing assessment scores. A single analysis was administered for both Algebra I and Basic Algebra since both groups completed the same post-assessment. These scores are likewise referred to as "adjusted." Treatment, gender, and class placement served as independent variables.

The dependent variable of mean pairwise "adjusted" difference scores for mathematics anxiety level (as determined by a standardized rating scale) were analyzed using a three-way ANCOVA since the pre- and post-assessments are the same for the two levels of algebra. Treatment, gender, and class placement served as independent variables in the analysis, and pretest scores functioned as independent covariates.

MSUSTAT Statistical Analysis Package, version 5.2, developed by Dr. Richard E. Lund of Montana State University, and Microsoft[®] Excel, version 4.0, developed by Microsoft Corporation, were used to analyze the data.

Analysis of Covariance

Although the best way to guard against nonequivalence of groups is to use randomization to assign subjects to treatment groups, and when this cannot be accomplished, matching of subjects is often a suitable alternative. There are many situations, as in this study, where the researcher must use intact groups for the treatments. Even with established controls in the sampling procedures and application of treatments, the assumption of equivalent groups is questionable. The analysis of covariance can be used to adjust for initial differences among the groups on the variables of interest (Ferguson and Takane 1989, p. 392).

Analysis of covariance is a form of analysis of variance that tests the significance of the differences among means of experimental groups

after taking into account initial differences among the groups *and* the correlation of the initial measures and the dependent variable measures. That is, analysis of covariance analyzes the differences between experimental groups on Y, the dependent variable, after taking into account either initial differences between the groups on Y (pretest), or differences between the groups in some pertinent independent variable or variables, X, substantially correlated with Y, the dependent variable. The measure used as a control variable--the pretest or pertinent variable--is called a *covariate* (Kerlinger 1986, p. 339).

Since the researcher had access to the previous year's norm-referenced achievement scores, had planned a MARS-A pretest, and could readily administer a pre-treatment writing sample detailed earlier, it was a logical approach to attempt to "equalize" the groups on those three variables by using analysis of covariance (Kerlinger and Pendhazur 1973, p. 266). Taking these possible sources of variance into account provides better control and therefore may yield more power than the analogous analysis of variance design. This is essentially because the within-group variance of the *adjusted* dependent variable will be smaller than the within-group variance of an *unadjusted* dependent variable (Cohen 1969, p. 373).

The analysis of covariance assumes homogeneity of regression for the treatment and control groups. It is recommended by Ferguson and Takane (1989, p.401) that this assumption be statistically tested whenever the analysis is performed, and this was carried out by the researcher. If this assumption is not satisfied, "the covariance adjustment may still improve the precision, but the meanings of the adjusted treatment means become cloudy, and the investigator may fail to discover the differential treatment effects" (Glass and Hopkins 1984, p. 503). One other assumption, unique to the analysis of covariance, is that of no treatment influence on the covariates.

This is not a problem, however, when the covariates are generated prior to the application of the treatment, as was the case in this experiment.

Analysis of Variance

The analysis of variance (ANOVA) model "is useful for studying the statistical relation between a dependent variable and one or more independent variables (Neter, Wasserman, and Whitmore 1988, p. 715). Although ANCOVA was used for the analyses, the aforementioned assumptions of homogeneity of regression and treatment influence on the covariate must be considered *in addition to* the customary ANOVA assumptions. Relative to the data gathered on the dependent variables, analysis of variance assumes the observations to be of approximate normal distribution within groups, of equal variance across groups, and statistically independent of one another. The F test is robust against moderate departures from the normal distribution and equal variance assumptions (Ferguson and Takane 1989, p. 263) but, according to Box, Hunter, and Hunter (1978, p. 182) it would be unwise to carry out the analysis without further diagnostic checks to not only verify agreement with the general assumptions but to possibly gain valuable information not revealed by the analysis. Therefore, normal probability plots and residual plots were analyzed, and a test for significance of the heterogeneity of variance; namely, Hartley's F_{MAX} test (Ferguson and Takane 1989) was carried out prior to each analysis of covariance.

Ferguson and Takane (1989 p. 264) suggest that the independence of observations assumption is the most difficult to diagnose. With intact groups, scheduled together in a school setting, this becomes even more complex. Care was taken by the researcher to determine how the classes are formed--

determining if there were scheduling "bottlenecks" that force certain types of students (*e.g.* gender or ability) into these particular sections. This issue was previously discussed in the Sampling Procedures and Research Design sections. As an additional precaution, however, pretest data for the MARS-A, ITBS (both math *and* language), and TAP (both math *and* language) were checked for differences in means and variances as a safeguard against gross deviations from equivalence between experimental and control groups.

Given that there were no indications of serious violations on the ANOVA or ANCOVA assumptions (delineated in Chapter 3), the analyses were applied and corresponding F ratios obtained and tested for significance. Since the attribute variable of gender may have influenced the dependent TAP variables to varying degrees, interaction effects were included in two-way analysis of covariance models along with consideration of the main effect (treatment variables). Attribute variables of gender and class placement, in concert with the treatment, may have interacted on the dependent writing and anxiety scores, so consideration of this interaction was also part of the three-way analysis of covariance models.

Choice of Alpha Level

Commonly accepted levels of significance are either 0.05 or 0.01 (Ferguson and Takane 1989, p. 182). The potential consequences of committing a Type I or Type II error should dictate the choice of an alpha level. A Type I error occurs when a true null hypothesis is incorrectly rejected; a Type II error occurs when we fail to reject a false null hypothesis. A Type I error could result in a mathematics learning log paradigm being advocated which, in fact, has little or no effect on student achievement,

communication, or anxiety. A Type II error could result in failure to advocate this formative assessment model when, in fact, significant attitude, communication, or achievement gains could result. The consequences of committing a Type II error were quite important to this researcher, but a Type I error could have a more far-reaching effect. That is, the possibility of influencing teachers toward an ineffective assessment paradigm, especially one that requires a great deal of time and effort to implement properly, should be unconditionally avoided. Based on this, a more conservative $\alpha=0.01$ was chosen as the level of significance for all analyses in this study.

Statistical Hypotheses

Questions addressed in this study are now stated in the form of null hypotheses. The reader is once again reminded that two separate analyses were conducted for the Algebra I and Basic Algebra students on standardized achievement test scores, and a single analysis was conducted on communication and anxiety scores. "Adjusted" scores are those which took into account the effect of independent concomitant variables, or "covariates." In the case of TAP scores, the covariates were the 1994 TAP or ITBS scores for each student, and for the summative writing assessment and MARS-A scores, the covariates were pre-treatment scores.

1. There is no statistically significant difference between the means of the adjusted TAP scores (including composite score and concepts/problem solving subtest) for the experimental and control groups in Algebra I classes.
2. There is no statistically significant difference between the means of the adjusted TAP scores (including composite score and concepts/problem

solving subtest) for the experimental and control groups in Basic Algebra classes.

3. There is no statistically significant difference between the means of the adjusted TAP scores (including composite score and concepts/problem solving subtest) for the males and females in Algebra I classes.
4. There is no statistically significant difference between the means of the adjusted TAP scores (including composite score and concepts/problem solving subtest) for the males and females in Basic Algebra classes.
5. There is no statistically significant interaction between treatment and gender on the adjusted TAP scores (including composite score and concepts/problem solving subtest) in Algebra I classes.
6. There is no statistically significant interaction between treatment and gender on the adjusted TAP scores (including composite score and concepts/problem solving subtest) in Basic Algebra classes.
7. There is no statistically significant difference between adjusted mean difference scores for mathematics anxiety levels of the experimental and control groups.
8. There is no statistically significant difference between adjusted mean difference scores for mathematics anxiety levels of the males and females.
9. There is no statistically significant difference between adjusted mean difference scores for mathematics anxiety levels of the Algebra I and Basic Algebra groups.
10. There is no statistically significant interaction between *any* combination of treatment, gender, and class placement (Algebra I or Basic Algebra) on the adjusted mean difference scores for mathematics anxiety level.

11. There is no statistically significant difference between the adjusted means of mid-year writing assessment scores for the experimental and control groups.
12. There is no statistically significant difference between the adjusted means of the mid-year writing assessment scores for the males and females.
13. There is no statistically significant difference between the adjusted means of the mid-year writing assessment scores for the Algebra I and Basic Algebra groups.
14. There is no statistically significant interaction between *any* combination of treatment, gender, and class placement (Algebra I or Basic Algebra) on the adjusted mean mid-year writing assessment score.
15. There is no statistically significant difference between the adjusted means of summative writing assessment scores for the experimental and control groups.
16. There is no statistically significant difference between the adjusted means of the summative writing assessment scores for the males and females.
17. There is no statistically significant difference between the adjusted means of the summative writing assessment scores for the Algebra I and Basic Algebra groups.
18. There is no statistically significant interaction between *any* combination of treatment, gender, and class placement (Algebra I or Basic Algebra) on the adjusted mean summative writing assessment score.

Limitations and Delimitations

The limitations of this study are as follows:

1. The treatment groups were limited to students taught by four teachers from two different schools in one east-central Wyoming school district, who volunteered to participate in the study.
2. The treatment groups were limited to one hundred seventy-four students from two schools (eighty students from the high school and ninety-four students from the junior high school).
3. The highest achieving students (approximately 5% of the student population) will not be a part of this study. They took Algebra I in the eighth grade and were, at the time of this study, enrolled in Geometry.
4. There were teacher differences and effects of history and maturation on students that could not be controlled. These factors may have been more pronounced in a year-long study, such as this, as opposed to a shorter-term study.
5. Control over teacher differences was limited to the effects of inservice training, researcher monitoring and intervention, and matching of one experimental with one control group for each teacher.
6. Control over possible effects of compensatory rivalry and/or resentful demoralization among students in the control groups was limited to the assumption that relatively large student populations in each school would minimize the effects of close communication between students in the experimental and control groups.
7. Control over possible contaminating effects of compensatory equalization of treatments within a single teacher's experimental and

control group structure was limited to the teachers' awareness of this threat to internal validity. Effects of contaminating instructional adjustments in the control groups had to be controlled by individual teachers and could be monitored by the researcher only if accurate instructional records are kept in the teachers' journals.

8. The treatment groups were all limited to intact classroom groups of students who were scheduled randomly within their respective levels of algebra.

The delimitations of the study are as follows:

1. The population of the study consisted of students enrolled in high school algebra classes.
2. The population was drawn from public schools in Gillette, Wyoming.
3. The period of the study was one full academic year.

CHAPTER 3

DATA ANALYSIS AND FINDINGS

Introduction

The research findings related in this chapter are organized as follows: (1) preliminary analyses, (2) TAP (Tests of Achievement and Proficiency) results, (3) MARS-A (Mathematics Anxiety Rating Scale-Adolescent) results, (4) Mid-year Writing Assessment results, (5) Summative Writing Assessment results, (6) additional analyses, and (7) teacher feedback. When stating results on each of the dependent variables, summary tables and statements of corresponding hypotheses are included.

It should be noted before any discussion of the analyses that the sample sizes for both the experimental and control groups varied throughout the study. The relative sizes of the groups are therefore noted with each summary table. Although the study was initiated with one hundred seventy-four students, the final assessments involved numbers that were somewhat smaller. It is expected, in a year-long study such as this, for some students to drop out of school, be suspended or expelled, move away, or undergo class schedule changes.

The Basic Algebra classes were especially vulnerable to this type of mortality, and the diminished sample size for that group therefore became a factor of interest. In addition, there were some students for which certain pretest data was not available. As a result of these factors, the Basic Algebra

group had a net loss of twenty-two students on the April 5 TAP testing date (5 experimental and 17 control group). By the last week in May, when the final writing assessment was administered, the classes had diminished by an additional six students in the experimental group, and three more students in the control group.

There were some notable concerns relative to the implementation of the treatment and administration of some assessments at the Algebra I level. The first concern relates to writing frequency; that is, some of the students in the experimental group failed to write regularly, and some chose not to write at all. Although writing regularity also varied in the Basic Algebra group, due mostly to schedule changes and frequent absences, the problem was more pronounced, and generally based on students choosing *not* to write, in the Algebra I classes. This factor, or possible limitation, is addressed later in the paper but was partially the result of inconsistent monitoring and grading philosophies on the part of the two Algebra I teachers. They were never able to agree on the "weight" the writing should carry in the administration of quarter and semester grades.

There were, similar to the Basic Algebra group, a number of students who did not complete the year (two experimental and eight control), and there were some (nine experimental and seven control) for whom there was no pretest data due to schedule changes or transferring into the system. However, the second notable concern involves questionable control over the administration of the final writing assessment and the math anxiety inventory by one of the Algebra I teachers. The teacher was not present to administer those assessments (leaving them with a substitute teacher), and a group of students chose to sabotage the evaluation process. Seven

experimental group students turned in summaries that could not be scored and three did likewise in the control group. Also, three experimental students and five control students turned in sabotaged anxiety inventories. Although this is unfortunate and could be neither anticipated nor controlled, those students' data had to be excluded from the data analysis.

Preliminary Analyses

Equivalence of Groups

The subjects of this study were four teachers along with an initial total of one hundred seventy-four students assigned to an Algebra I experimental group, a Basic Algebra experimental group, an Algebra I control group, and a Basic Algebra control group. The experimental and control groups were each composed of four classrooms of students, along with their four respective teachers. Two of those classrooms were Algebra I and two were Basic Algebra, making a total of eight classrooms altogether. The combined experimental groups consisted of eighty-two students at the beginning of the study and the combined control groups, ninety-two students. There were ninety-four Algebra I students and eighty Basic Algebra students at the beginning of the study.

The subjects' MARS-A pretests, pre-treatment writing samples (Mathematics Autobiography), and TAP or ITBS scores from the previous year were gathered not only for use as independent covariates but to strengthen the assumption of equivalent groups (experimental/control). Tests for equivalence included one-way ANOVA to test initial equality of means and Hartley's F_{MAX} test (Ferguson and Takane 1989) to test initial heterogeneity of variance. All of the following analyses were administered to

the initial groups, and initial equivalence of groups was verified early in the study. However, the results that follow reflect tests for equivalence of groups smaller than the initial groups. This is because it was the researcher's decision to include only the pretest scores of subjects who also completed the post-treatment assessments.

Equivalence Tests

Table 3. ANOVA of ITBS Math Pretest Scores for Algebra I (N=96)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Between Groups	1	29.4497	29.4497	1.1418	0.2880
Within Groups	94	2424.46	25.7921		
Total	95	2453.91			

Means for the experimental and control groups were 24.0 (N=46) and 23.0 (N=50) respectively. The Hartley's F_{MAX} test yielded a ratio of 1.05 between groups, and this was not significant. The groups were considered equivalent.

As an additional precaution, and since writing was expected of the students, the ITBS language pretest scores were also analyzed in like manner.

Table 4. ANOVA of ITBS Language Pretest Scores for Algebra I (N=96)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Between Groups	1	51.9248	51.9248	0.77416	0.3812
Within Groups	94	6304.81	67.0725		
Total	95	6356.74			

Means for the experimental and control groups were 35.8 (N=46) and 37.3 (N=50) respectively. The Hartley's F_{MAX} test yielded a ratio of 1.007 between groups, and this was not significant. The groups were considered equivalent.

Table 5. ANOVA of TAP Math Pretest Scores for Basic Algebra (N=58)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Between Groups	1	290.049	290.049	0.81570	0.3703
Within Groups	56	19912.6	355.582		
Total	57	20202.6			

Means for the experimental and control groups were 53.4 (N=35) and 58.0 (N=23) respectively. The Hartley's F_{MAX} test yielded a ratio of 1.43 between groups, and this was not significant. The groups were considered equivalent.

Table 6. ANOVA of TAP Written Expression Pretest Scores for Basic Algebra (N=58)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Between Groups	1	40.0233	40.0233	0.51340	0.4766
Within Groups	56	4365.58	77.9568		
Total	57	4405.60			

Means for the experimental and control groups were 35.2 (N=35) and 36.9 (N=23) respectively. The Hartley's F_{MAX} test yielded a ratio of 1.09 between groups, and this was not significant. The groups were considered equivalent.

Table 7. ANOVA of MARS-A Pretest Scores (N=112)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Between Groups	1	1451.67	1451.67	0.52893	0.4686
Within Groups	110	301901	2744.56		
Total	111	303353			

Means for the experimental and control groups were 190.5 (N=58) and 197.7 (N=54) respectively. The Hartley's F_{MAX} test yielded a ratio of 1.04 between groups, and this was not significant. The groups were considered equivalent.

Table 8. ANOVA of Pre-Treatment Writing Sample (Math Autobiography)
(N=146)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Between Groups	1	16.9598	16.9598	1.353	0.2467
Within Groups	144	1805.1	12.5354		
Total	145	1822.05			

Means for the experimental and control groups were 4.53 (N=68) and 3.78 (N=78) respectively. The Hartley's F_{MAX} test yielded a ratio of 1.30 between groups, and this was not significant. The groups were considered equivalent.

Diagnostic Checks

Relative to the data gathered on the dependent variables, analysis of variance assumes the observations to be of approximate normal distribution within groups, of equal variance across groups, and statistically independent of one another. The F test is robust against moderate departures from the normal distribution and equal variance assumptions (Ferguson and Takane 1989, p. 263) but, according to Box, Hunter, and Hunter (1978, p. 182) it would be unwise to carry out the analysis without further diagnostic checks to not only verify agreement with the general assumptions but to possibly gain valuable information not revealed by the analysis. Therefore, residual and normal probability plots were analyzed and tests for significance of the heterogeneity of variance; namely, Hartley's F_{MAX} (Ferguson and Takane 1989) were carried out prior to all the analyses. Relative to the data summary tables that follow, neither experimental nor control data deviated radically from a normal distribution; data outliers were re-checked and accounted for; and F_{MAX} ratios, in all cases verified that there were no significant differences between variances of the two groups.

In addition to the ANOVA assumptions, the analysis of covariance assumes independence of the covariate and homogeneity of regression for the treatment and control groups. It is recommended by Ferguson and Takane (1989, p.401) that the homogeneity of regression assumption be statistically tested whenever the analysis is performed, and this was carried out by the researcher. The homogeneity of regression F ratios were determined for all analyses using the method prescribed by Ferguson and Takane (p.403), and none were found to be significant.

TAP (Tests of Achievement and Proficiency) Results

Algebra I TAP

The results of the ANCOVA for null hypotheses 1, 3, and 5 in Chapter 2 are detailed in Tables 9 and 10. The summary tables are followed by statements of the hypotheses, and subsequent decisions. Criteria for rejection of null hypotheses was set at $p \leq 0.01$ in Chapter 2.

Table 9. ANCOVA of TAP Subtest Concepts/Problem Solving for Algebra I (N=96)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Treatment	1	52.162	52.162	1.88	0.1737
Gender	1	0.0	0.0	-	-
Trt*Gen	1	7.1463	7.1463	0.26	0.6130
Residual	91	2524.5	27.741		

Table 10. ANCOVA of TAP Mathematics Total for Algebra I (N=96)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Treatment	1	238.23	238.23	1.16	0.2842
Gender	1	66.941	66.941	0.33	0.5694
Trt*Gen	1	71.390	71.390	0.35	0.5568
Residual	91	18680	205.27		

Hypothesis 1: There is no statistically significant difference between the means of the adjusted TAP scores (including composite score and concepts/problem solving subtest) for the experimental and control groups in Algebra I classes.

Decision: Fail to reject the null hypothesis. No significant difference in means between the two treatment groups was detected. Means for the experimental and control groups on the TAP concepts/problems solving subtest were 22.4 (N=50) and 23.89 (N=46) respectively. Means for the experimental and control groups on the TAP math total were 64.4 (N=50) and 67.59 (N=46) respectively.

Hypothesis 3: There is no statistically significant difference between the means of the adjusted TAP scores (including composite score and concepts/problem solving subtest) for the males and females in Algebra I classes.

Decision: Fail to reject the null hypothesis. No significant difference in means between the two gender groups was detected. Means for the female and male groups on the TAP concepts/problems solving subtest were equal at 23.15 (N=48) and 23.15 (N=48) respectively. Means for the female and groups on the TAP math total were 66.84 (N=48) and 65.16 (N=48) respectively.

Hypothesis 5: There is no statistically significant interaction between treatment and gender on the adjusted TAP scores (including composite score and concepts/problem solving subtest) in Algebra I classes.

Decision: Fail to reject the null hypothesis. No significant interaction was detected.

Basic Algebra TAP

The results of the ANCOVA for null hypotheses 2, 4, and 6 in Chapter 2 are detailed in Tables 11 and 12.

Table 11. ANCOVA of TAP Subtest Concepts/Problem Solving for Basic Algebra (N=58)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Treatment	1	14.684	14.684	1.06	0.3087
Gender	1	2.0210	2.0210	0.15	0.7045
Trt*Gen	1	0.88206	0.88206	0.06	0.8021
Residual	53	736.59	13.898		

Table 12. ANCOVA of TAP Mathematics Total for Basic Algebra (N=58)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Treatment	1	20.509	20.509	0.83	0.3658
Gender	1	0.069055	0.069055	0.0	0.9580
Trt*Gen	1	0.0081739	0.0081739	0.0	0.9855
Residual	53	1306.3	24.647		

Hypothesis 2: There is no statistically significant difference between the means of the adjusted TAP scores (including composite score and concepts/problem solving subtest) for the experimental and control groups in Basic Algebra classes.

Decision: Fail to reject the null hypothesis. No significant difference in means between the two treatment groups was detected. Means for the experimental and control groups on the TAP concepts/problems solving subtest were 14.06 (N=35) and 13.02 (N=23) respectively. Means for the experimental and control groups on the TAP math total were 21.48 (N=35) and 20.26 (N=23) respectively.

Hypothesis 4: There is no statistically significant difference between the means of the adjusted TAP scores (including composite score and

concepts/problem solving subtest) for the males and females in Basic Algebra classes.

Decision: Fail to reject the null hypothesis. No significant difference in means between the two gender groups was detected. Means for the female and male groups on the TAP concepts/problems solving subtest were 13.73 (N=27) and 13.35 (N=31) respectively. Means for the female and groups on the TAP math total were 20.84 (N=27) and 20.91 (N=31) respectively.

Hypothesis 6: There is no statistically significant interaction between treatment and gender on the adjusted TAP scores (including composite score and concepts/problem solving subtest) in Basic Algebra classes.

Decision: Fail to reject the null hypothesis. No significant interaction was detected.

MARS-A (Mathematics Anxiety Rating Scale - Adolescent) Results

The results of the ANCOVA for null hypotheses 7, 8, 9, and 10 in Chapter 2 are detailed in Table 13 (see also the graphic presentation in the Appendix). The summary table is followed by statements of the hypotheses, and subsequent decisions. Criteria for rejection of null hypotheses was set at $p \leq 0.01$ in Chapter 2.

Table 13. ANCOVA of MARS-A Difference Scores (N=112)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Treatment	1	12712	12712	4.29	0.0408
Class	1	872.22	872.22	0.29	0.5885
Gender	1	530.73	530.73	0.18	0.6729
Trt*Class	1	422.47	422.47	0.14	0.7064
Trt*Gen	1	13.078	13.078	0.0	0.9471
Class*Gen	1	315.72	315.72	0.11	0.7447
Trt*Gen*Class	1	137.80	137.80	0.05	0.8296
Residual	103	305010	2961.3		

Hypothesis 7: There is no statistically significant difference between adjusted mean difference scores for mathematics anxiety levels of the experimental and control groups.

Decision: Although the p-value approaches a significance level of $\alpha=0.01$, the null hypothesis was not rejected. The mean difference for the experimental group was -20.17 (N=58), meaning the anxiety levels were reduced, on average, 20.17 points per student. The mean difference for the control group was 1.441 (N=54), meaning anxiety levels increased slightly, on average.

Hypothesis 8: There is no statistically significant difference between adjusted mean difference scores for mathematics anxiety levels of the males and females.

Decision: Fail to reject the null hypothesis. No significant difference in means between the two gender groups was detected. The mean difference for the females was -11.78 (N=57) and -6.949 (N=55) for the male students.

Hypothesis 9: There is no statistically significant difference between adjusted mean difference scores for mathematics anxiety levels of the Algebra I and Basic Algebra groups.

Decision: Fail to reject the null hypothesis. No significant difference between the two class levels was detected. The mean difference for the Algebra I group was -6.391 (N=60), and the mean difference for those enrolled in Basic Algebra was -12.34 (N=52).

Hypothesis 10: There is no statistically significant interaction between any combination of treatment, gender, and class placement (Algebra I or Basic Algebra) on the adjusted mean difference scores for mathematics anxiety level.

Decision: Fail to reject the null hypothesis. No significant interaction was detected.

Student Writing Assessment Results

Mid-Year Writing Assessment

The results of the ANCOVA for null hypotheses 11, 12, 13, and 14 in Chapter 2 are detailed in Table 14 (see graph in Appendix). The summary table is followed by statements of the hypotheses, and subsequent decisions. Criteria for rejection of null hypotheses was set at $p \leq 0.01$ in Chapter 2.

Table 14. ANCOVA of Mid-Year Writing Assessment Scores (N=146)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Treatment	1	336.97	336.97	14.33	0.0000
Class	1	198.57	198.57	8.45	0.0043
Gender	1	51.308	51.308	2.18	0.1419
Trt*Class	1	6.2587	6.2587	0.27	0.6067
Trt*Gen	1	33.16	33.162	1.41	0.2370
Class*Gen	1	7.9298	7.9298	0.34	0.5623
Trt*Gen*Class	1	0.39858	0.39858	0.02	0.8966
Residual	137	3220.8	23.510		

Hypothesis 11: There is no statistically significant difference between the adjusted means of mid-year writing assessment scores for the experimental and control groups.

Decision: Reject the null hypothesis. There is a significant difference between the mean scores of the experimental and control groups. The mean for the experimental group was 9.769 (N=68), and the mean for the control group was 6.623 (N=78).

Hypothesis 12: There is no statistically significant difference between the adjusted means of the mid-year writing assessment scores for the males and females.

Decision: Fail to reject the null hypothesis. No significant difference in means between the two gender groups was detected. The means for the females and males were 8.282 (N=74) and 7.563 (N=72) respectively.

Hypothesis 13: There is no statistically significant difference between the adjusted means of the mid-year writing assessment scores for the Algebra I and Basic Algebra groups.

Decision: Reject the null hypothesis. There was a significant difference between the mean scores of the students who were enrolled in Algebra I and those enrolled in Basic Algebra. The mean for the Algebra I group was 9.404 (N=83), and the mean for the Basic Algebra group was 6.987 (N=63).

Hypothesis 14: There is no statistically significant interaction between any combination of treatment, gender, and class placement (Algebra I or Basic Algebra) on the adjusted mean mid-year writing assessment score.

Decision: Fail to reject the null hypothesis. No significant interaction was detected.

Summative Writing Assessment

The results of the ANCOVA for null hypotheses 15, 16, 17, and 18 in Chapter 2 are detailed in Table 15 (see graph in Appendix).

Table 15. ANCOVA of Summative Writing Assessment Scores (N=100)

Source	DF	Sum of squares	Mean squares	F-value	p-value
Treatment	1	206.09	206.09	9.04	0.0034
Class	1	446.48	446.48	19.58	0.0000
Gender	1	46.985	46.985	2.06	0.1546
Trt*Class	1	155.63	155.63	6.83	0.0105
Trt*Gen	1	56.446	56.446	2.48	0.1191
Class*Gen	1	1.8054	1.8054	0.08	0.7790
Trt*Gen*Class	1	92.365	92.365	4.05	0.0471
Residual	91	2074.9	22.801		

Hypothesis 15: There is no statistically significant difference between the adjusted means of summative writing assessment scores for the experimental and control groups.

Decision: Reject the null hypothesis. There is a significant difference between the mean scores of the experimental and control groups. The mean for the experimental group was 10.39 (N=50), and the mean for the control group was 7.267 (N=50).

Hypothesis 16: There is no statistically significant difference between the adjusted means of the summative writing assessment scores for the males and females.

Decision: Fail to reject the null hypothesis. No significant difference in means between the two gender groups was detected. The means for the females and males were 9.585 (N=50) and 8.071 (N=50) respectively.

Hypothesis 17: There is no statistically significant difference between the adjusted means of the summative writing assessment scores for the Algebra I and Basic Algebra groups.

Decision: Reject the null hypothesis. There was a significant difference between the mean scores of the students who were enrolled in Algebra I and those enrolled in Basic Algebra. The mean for the Algebra I group was 6.527 (N=51), and the mean for the Basic Algebra group was 11.13 (N=49).

Hypothesis 18: There is no statistically significant interaction between any combination of treatment, gender, and class placement (Algebra I or Basic Algebra) on the adjusted mean summative writing assessment score.

Decision: Fail to reject the null hypothesis. No significant interaction was detected, although one of the combinations, treatment \times class, does very closely approach significance ($p=0.0105$). The reason for this ordinal

interaction is that the difference between the experimental and control group means was notably greater for the Basic Algebra group than for the Algebra I group.

Additional Analyses

In the Introduction of this chapter the researcher expressed a concern that some of the students in the experimental groups failed to write regularly, and some chose not to write at all. Consequently, the researcher, along with the statistics professor on his examining committee, was interested in the respective correlation, if any, between the frequency with which students wrote their weekly summaries and their subsequent performance on the assessments included in this study. For this analysis, each student's writing frequency was stated as the average number of summaries per semester. Regression statistics were computed and one-way analysis of variance performed for each assessment. Two pretests were included to see if students performing at higher levels initially were possibly inclined to write more frequently. Table 16 lists the findings.

Table 16. Regression Statistics and ANOVA for Student Writing Frequency

Assessment	Number Assessed	Correlation Coefficient	F-value	p-value
Mid-Year Writing	81	0.1037	0.8592	0.3568
Summative Writing	63	0.408	12.213	0.0009
MARS-A	56	0.301	5.3701	0.0243
Algebra I TAP Math	41	0.2649	2.9424	0.0942
Total				
Basic Algebra TAP Math Total	38	0.1071	0.4170	0.5225
Algebra I ITBS Math Total Pretest	41	0.0644	0.1628	0.6888
Basic Algebra TAP Math Total Pretest	34	0.1023	0.3386	0.5647

Teacher Feedback

For qualitative purposes, the teachers were asked to keep a journal of their own experiences throughout the two semesters of the study. In addition, the four teachers were formally surveyed two times during the study--a tape-recorded mid-year interview at the end of the first semester, and a written questionnaire at the conclusion of the school year. The final sections of this chapter contain the results of those surveys and discussion concerning the teacher journals.

Mid-Year Interview

During this tape-recorded interview, conducted on January 16, 1995, the teachers were asked a series of six questions. Each question is restated in the text to follow and is accompanied by responses that were common to the teachers as well as selected observations that were unique to individual teachers.

Question 1: Based on your implementation of this writing strategy, what have you learned about your students' written communication of mathematical ideas?

All teachers agreed that the students' correct usage of mathematical terminology was poor at first but had improved, to varying degrees, over the semester. It became more common for students to use very specific and precise terms in their writing, but the same was not necessarily observed in classroom (oral) discussions. One teacher, however, noted that the control group students were often "at a loss" for the correct words to use in class discussions, whereas this was not often the case for the experimental group.

Question 2: Have you gained any specific information regarding a student's understanding that probably would not have been revealed through regular classroom assessments? If so, please give an example.

The summaries served as a medium in which "quieter" students could express their understanding and misunderstanding of material. All the teachers observed that students expressed if they "get it" or "don't get it" in their summaries. Students in all classes often revealed what they procedurally or conceptually understood by the inclusion of correct or, as was often the case, *incorrect* examples in their summaries. One teacher conveyed that it was a good way to "verify if students' homework assignments were really their own." Another found that it was important to see what terms or ideas the students *don't* write about. Avoidance of material was a common indicator that the students had poor understanding of something covered in class. It was also observed that the summaries were a place for "students who shine to *really* shine," meaning that some students could show more of their personal learning on a summary than on teacher-written quizzes or tests.

Question 3: Have you learned anything about student's attitudes toward math? Again, cite an example.

All teachers noted that the students had remained pretty objective and impersonal on the summaries so far, except an occasional comment about whether the material was hard, easy, fun, or boring. Teachers again noted that many of the more "shy" students took an opportunity in their summaries to briefly relate their feelings of success or failure--something more than they would do orally.

Question 4: Have you made any instructional decisions based on information students have included in their log summaries? If so, tell me about one or two.

Three of the four teachers had specific examples of decisions they had made based on what was revealed in the summaries. One had learned that his students were really struggling with identifying greatest monomial factors when factoring trinomials. This happened when the students all elaborated on the other objectives of the week but avoided any discussion relative to this particular factoring technique. The factoring was subsequently retaught. Another teacher completely retaught combined inequalities based on "bad examples" in the student writing. Several students showed one instructor that they were confusing the concepts of area and perimeter. They also showed that they were confused about the relationship of a triangle's altitude to its base. The teacher did some adjusting of instruction based on these revelations. All of the teachers, however, expressed that the summaries were sometimes too far apart for staying right on top of the students' difficulties, especially if there was a quiz scheduled a day or two before the summaries were due.

Question 5: As the writing continues, do you see a unique dialogue developing between you and any of your students? If yes, please discuss this.

No unique dialogue, on a personal level, was noted at this time. Again, most students did use the summary as an opportunity to express whether the material was easy, hard, fun, or boring. It was also common for the students to express whether they were feeling successful with the math content. From the standpoint of a couple of the teachers, reading and responding to the summaries provided a special opportunity to encourage or exhort students in

a discrete and very personal way. One teacher noted that a couple of students "disliked" this teacher and would never talk to or greet the teacher. Yet, the students would write good summaries "for some reason." The teacher expressed that the students seemed as though it was okay to write because they were really writing to somebody else--perhaps to this unknown researcher.

Question 6: Based on your experiences so far, make a statement about the pros and cons of this writing strategy, or writing in general, as an instructional or assessment tool in mathematics.

All instructors mentioned that their students were somewhat resistant to the notion of writing summaries at first, but after only a short time, there was "no complaining." Three of the teachers stated that the students were now *reminding them* about the writing being due. The teachers all basically felt, in the words of one teacher, "if the writing isn't helping, it certainly isn't hurting the students." One Basic Algebra teacher expressed that the summaries were "a place where all students could have success in math class." Two of the teachers said that the change had been good for them. "It takes lazy, fat teachers and makes them come out of their shell. It has made me a better teacher," said one instructor. Teachers expressed concern that, although one class of summaries was easy to deal with, it would be difficult to find enough time to implement this strategy in all classes throughout the day. One stated, "we keep adding things to our day and never taking anything out." But the same teacher also said, "I wish could do this with my control group." "They are really the brighter group, and I'd like to see them writing."

End-of-the-Year Survey

In a written survey, issued on May 26, 1995, the teachers were asked a series of seven questions to which they responded in writing. Upon completion, the surveys were mailed to the researcher. Three of the teachers completed their survey within three weeks of the end of school, but no response was received from the fourth until the beginning of September. This teacher, identified below as Teacher C, was the same mentioned at the beginning of this chapter. Each question is restated in the text to follow and is accompanied by the actual written response from each participating teacher.

Question 1: What do you see as the benefit(s) of *this* particular classroom writing strategy? (*i.e.* writing weekly log summaries in mathematics classes) Please discuss possible benefits to the student *and* possible benefits to the teacher.

Teacher A: Having the students write in their daily logs and complete weekly summaries should help the students use correct mathematical terminology. Putting the terminology down in writing may possibly make communication between the teacher and learner more meaningful. It seemed to me that my experimental group used terms like "trinomials" and "completing the square," etc., more often than the control group.

Teacher B: The most obvious benefit is the students were actually forced to learn the math terms as we go. I saw this a benefit towards the middle of the year, when I no longer had to explain every term we had previously mastered. Even the students who did not do logs on a regular basis knew the terms better than I had noticed in previous years. Also for some students (*i.e. name withheld*), I am relatively certain that the logs helped pull her from a C student to an A.

Teacher C: The students that did a good job of writing the weekly logs would have a better command of the vocabulary in the chapters. A benefit for me would be that some students would write things in the log that they would not say to me personally.

Teacher D: I saw plenty of benefits from the writing exercise! For me: (a) I had a "better picture" of who each student was and what made them tick. The writing allowed me to be closer to my students. (b) The writing proved to be a "microscope" for me to further examine my students and their knowledge of mathematics. For students: (c) This activity allowed/forced the students to spend time looking inward at their mathematical strengths/weaknesses. It gave them the occasion to come to grips with what has been an academic weakness for most of them.

Question 2: What problems do you believe to be associated with implementation of this writing paradigm? Again, include discussion relative to the student *and* the teacher.

Teacher A: Using the 3-point rubric was at times hard to deal with simply because of the large range of writing ability in the students I was dealing with, varying from severely learning disabled students to good writers. I also felt that the daily logs were too vague and time consuming. Maybe giving the students one or two questions to respond to in a two minute period would be more efficient and beneficial.

Teacher B: The major problem is one of time management. This is for the teacher more so than the student. This would not have been such a major problem had all my classes been involved in the study, but with three classes of Algebra, this was a problem.

Teacher C: Some of the students would rather not do it at all. At our school I did it as extra credit and [*name withheld: other algebra teacher*] did it as an assignment. I saw problems in both ways of grading them. The extra credit seemed to me to be the most fair but in most cases the good students would do it all the time and the poorer students (the ones that needed extra credit) would not do it at all or do a poor job.

Teacher D: The problems I encountered with writing are few. For me: (a) I found myself, at times, short of the time necessary to implement that day's writing effectively. (b) I felt uncomfortable grading each student's writing with only a mathematics background. (Not terribly uncomfortable, but uneasy.) For students: (c) The students tired of the writing on occasions and I had to motivate them to write for points. (d) The small minority of students felt that writing belonged in the English class and not in the math class.

Question 3: Did you personally gain assessment information from the students' weekly summaries that you may not have gained from other regular classroom activities (e.g. homework, quizzes, classroom discussion)? If so, please give an example or two.

Teacher A: Yes, students would write things that would surprise me. For instance, after talking about the differences of area and perimeter, and explaining in depth how carpet layers would use area in their occupation, some students wrote, "an example of a career using perimeter is carpet layers." So I'd go back the next class and attempt to clarify this misunderstanding.

Teacher B: I feel on the students who took the writing seriously, I did find out they were having trouble with certain concepts that I thought they understood. An example of this would be many times in *[name withheld]*'s logs--her homework scores and tests were not indicative of the amount of times she asked for help in her log. I also was not that big of a fan of Algebra Tiles until I noticed how many students responded favorably to them in their logs.

Teacher C: No. In most cases the students that were having problems would write a log that was correct, then still make mistakes on the quizzes or tests.

Teacher D: I most certainly gained insight into my students' knowledge via the writing, almost daily. Examples: (1) *[name withheld]* let me know that she was good at math but had to repeat because of a dislike for her previous instructor. (2) *[name withheld]* stated that she was really poor on dividing fractions which I wouldn't have known because she had a LD Aide that helped her with her homework.

Question 4: Describe the extent to which you implemented writing in your algebra classes during years prior to participating in this study.

Teacher A: Hardly at all in Basic Algebra. I can't think of one solid example.

Teacher B: I have asked my students to write a summary of what they felt they learned after each chapter. This did not work as I never really pushed them nor made it mandatory, and thus it was more of a sounding block for "whiners."

Teacher C: The student would be required to take notes in all the classes.

Teacher D: In years prior I have attempted various forms of writing in my Algebra classes. (a) Essay questions on math exams. "Discuss where we use inverses when working with fractions." (b) Students would write chapter summaries. (c) Students would have to write course evaluations and teacher evaluations.

Question 5: Looking to next year, do you anticipate that you will incorporate *any* writing exercises (not necessarily *this* strategy) into your algebra classes? If so, why? If not, why not?

Teacher A: Yes, such as explaining how to do problems in their own words, possibly projects that require writing, and also notebooks where at times writing exercises will be required. Once again, I believe that students better understand concepts if they can express them in writing.

Teacher B: I will seriously try to implement it in all my classes. I felt that it reached some students that I would not have otherwise.

Teacher C: Yes. I will still have them take notes and maybe the last week before the chapter test I might have them do a CHAPTER LOG. A good way to make them review for the test and still count it as extra credit.

Teacher D: I will definitely plan on using writing in my classes next year!! (a) One class will do logs. (b) One class will do creative writing tasks. (c) My upper level classes will keep journals. (d) One class will write books.

Question 6: If you choose to use *this* writing model (*i.e.* weekly log summaries), what modifications would you make, and how would you adapt your lesson plans to accommodate the time needed to read and respond to students' summaries?

Teacher A: See answer 2. Also, I might have students trade journals or get in groups to discuss what they've written. This

would require specific instructions from me, but would be a time saver, also.

Teacher B: The only difference I can see is to implement it in all my classes.

Teacher C: See #5 Above.

Teacher D: The only adaptation I would make is to give them occasional topics or key words to help stimulate thought processes.

Question 7: Are there any other observations you wish to make about the experiences you've had throughout this project? Please comment!

Teacher A: I'm very interested in seeing the data you develop from the study. The results will probably help me decide how much, and what kind of writing I'll have my students do in future years of teaching math.

Teacher B: I felt pushed at times especially towards the end of school, but all change is painful.

Teacher C: No.

Teacher D: Scott, I really thank you for helping me branch out in my teaching experiences!! This has helped me become a more effective teacher.

Teacher Journals

During the teacher training session at the beginning of the study teachers were issued special notebooks and specific instructions detailing the rationale for keeping a journal and suggestions for the contents of that journal. The instructions and suggestions given to the teachers are included in the Appendix. However, even with continued reminders (or exhortations) throughout the study, including requests to view the journals, the teachers unequivocally failed to implement this aspect of the research. Two of the teachers refused to keep the journal at all, and one made an average effort,

recording fourteen entries over the year (weekly entries were requested). The last teacher recorded abundant entries and set a good example for the students by writing in his journal while they wrote in their math logs. However, the nature of the entries continually lost the intended focus of discussing implementation of the prescribed writing paradigm in favor of general discussion about what the kids were doing in class. The journal contents that *did* manifest the appropriate focus spoke of general improvement in and satisfaction with student writing, but the writers also mentioned occasional "dips" in the students' motivation to write well.

CHAPTER 4**CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS****Summary of the Study**

The purpose of this research endeavor was to study the effects of implementing a specific writing paradigm, mathematics learning logs, into high school algebra classes. The study was conducted over one full academic year, from August of 1994 through May of 1995 and was designed to determine if there were differences in achievement (as measured by standardized testing), ability to communicate in writing about mathematics, and mathematics anxiety (pre- versus post-study levels) between students who regularly maintained a prescribed mathematics learning log and those who did not. Of additional importance in this study was teacher feedback relative to the value of the learning log as an alternate assessment method.

In the mathematics learning logs students were asked, after each math lesson, to write (1) a brief summary of the math activity and/or key mathematics topic(s) covered, and (2) discussion of what specific mathematics, if any, was personally learned. Relevant examples, unanswered questions, and personal reflection concerning the lesson could also be noted. These daily entries were kept in a notebook, or "daily log" that was only periodically (every three to four weeks) inspected and "checked off" by the teacher for monitoring purposes. After every five to six lessons, students were required to summarize their daily log entries in a brief (2-3

paragraph) synthesis of the past several days' mathematics experience-- "What we did (including specific key topics)" and "What I learned (with relevant examples, questions, and/or reflection)." These "log summaries" were read and responded to with written comments by the instructor before being returned to the student. Upon return, the summaries were placed back in the students' notebooks.

As participants in the study, four volunteer teachers and one hundred seventy-four ninth through eleventh grade students were drawn from two Gillette, Wyoming secondary schools; namely, Twin Spruce Junior High School and Campbell County High School. The student participants were enrolled in two different levels of algebra: Algebra I, a traditional course for ninth graders at Twin Spruce and Basic Algebra, a more informal presentation of algebra meant for tenth through twelfth graders at Campbell County High School who have taken a pre-algebra course, or have perhaps previously failed Algebra I. Each teacher, as part of their regular teaching assignment, taught two sections of algebra, one designated "experimental," (the group implementing log writing) and one designated "control." The combined experimental groups consisted of eighty-two students at the beginning of the study and the combined control groups, ninety-two students. There were ninety-four Algebra I students and eighty Basic Algebra students at the beginning of the study.

In August, 1994 the teachers attended a training session, presented by the researcher, intended to prepare them for implementation of the project. The teachers were briefed on the expected timeline, prescribed writing structure, intended student assessments, and virtually all other important details relative to their role in the study.

When school began, and upon gaining parental permission, the participating students' ITBS and TAP scores were obtained by the researcher from the school office. The students underwent pre-treatment evaluations in writing and mathematics anxiety, and they were introduced to the practice of keeping a mathematics learning log. The researcher maintained close contact with the teachers throughout the study and monitored student writing on a regular basis. During the first quarter, the teachers planned activities to improve the quality of the students' learning logs, and throughout the year the teachers were to provide written feedback to the students aimed at making their log summaries more substantive.

Students were assessed in their written mathematical communication skills at the end of the first semester, they took the Tests of Achievement and Proficiency (TAP) in April, and were again assessed in written mathematical communication and mathematics anxiety at the end of the school year. The teachers were formally surveyed twice during the study, once in a taped interview and once in a written questionnaire.

The pre-treatment data was acquired from the school district offices at the beginning of the study, and this information was used to verify equivalence of the experimental and control groups. Because randomization of subjects was not possible with the intact class groups, even with strong indications of group equivalence, the analysis of covariance (ANCOVA) was chosen as the most suitable method of testing statistical hypotheses on the post-measures. The pre-treatment data sets were then also used in all analyses as independent covariates. Post-treatment data was gathered in May, agreement with appropriate statistical assumptions confirmed, and all analyses completed. Again, the quantitative data analyzed considered

achievement (as measured by the standardized tests), ability to communicate in writing about mathematics, and mathematics anxiety (pre- versus post-study levels as measured by the Mathematics Anxiety Rating Scale-Adolescent (MARS-A)). Independent variables considered in the analyses were treatment (*i.e.* placement in experimental, "writing" group or control, "non-writing" group), gender of student, and for the analysis of writing and math anxiety, class placement (*i.e.* Algebra I or Basic Algebra). Teacher feedback gained in the two surveys was also considered an important qualitative contribution to the findings of the study.

Conclusions and Implications

TAP (Tests of Achievement and Proficiency) Results

No statistically significant differences ($\alpha=0.01$) were detected between the adjusted means of the experimental and control groups on the TAP (Tests of Achievement and Proficiency). There were neither differences among gender groups nor significant interaction of treatment and gender on the dependent achievement variables. This outcome was the same for both of the class levels, Algebra I and Basic Algebra.

Although these findings do not support the findings of the pilot study, it is difficult to say if the objectives measured by these standardized tests were aligned closely enough with the actual content taught in each class to support their validity as measures of student achievement *this year in algebra class*. The reader is reminded of earlier comments by Stake (1995) concerning the failure of this type of testing to provide a valid indication of specific subject-matter mastery. Also, biases caused by non-alignment with local curricula and special testing "constraints" placed on the student cause

such tests to "fail" in meeting several of the NCTM Assessment Standards (NCTM 1995, p.75).

Based on these results, however, it is important to say that implementation of this particular writing structure is not necessarily associated with improving standardized test scores in one year. Stake (1995) also points out that many institutions *are* placing great emphasis on standardized testing, many people are hoping that "clarity about education will come with increased standardized testing" (p. 211), and most secondary teachers associate the increase of standardized testing with "good changes happening in their schools" (p. 205). The unfortunate result is that these "high stakes" tests often "drive" the curriculum (National Research Council 1989, p. 68). Therefore, if raising of standardized test scores is the cardinal goal of the school district, this research would not support, nor would the researcher necessarily recommend, implementation of mathematics learning logs.

As for accounts cited in the Review of Literature relating better understanding, problem solving, and retention of mathematical concepts associated with writing in mathematics classes (NCTM 1989; Evans 1984; Miller and England 1989b; Rose 1990; LeGere 1991b; Johnson 1983; Bell and Bell 1985; Wilson and Chavarria 1993), quantitative verification was not within the scope of this study. There were broad differences between the participating teachers and the researcher concerning beliefs about appropriate assessments of student understanding of algebra--especially assessments that the teachers were willing to jointly administer. Hence, common ground for criterion-referenced assessment was never established for this research project. However, among the important understandings noted

in contemporary literature and associated with writing in mathematics, are mathematical communication and mathematical connections (NCTM 1989, 1991, 1995; Bagley and Gallenberger 1992; Davidson and Pearce 1988; Abruscato 1993; Azzolino 1990; Curcio 1990; Lajoie 1995). These were addressed in the context of this study by the administration of Mid-Year and Summative Writing Assessments.

Student Writing Assessment Results

A statistically significant difference ($\alpha=0.01$) was detected between the adjusted means of experimental and control groups on both the Mid-Year Writing Assessment and Summative Writing Assessment. Significant differences were also noted for both assessments between the class levels, Algebra I and Basic Algebra. There were no other differences of statistical significance found in the analysis of interaction effects, including gender. However, the interaction of treatment \times class placement did very closely approach significance ($p=0.0105$) for the Summative Writing Assessment. This interaction was ordinal and was caused by the difference between experimental and control group means being notably greater for the Basic Algebra group.

The writing prompt used in both these evaluations was aimed at engaging students in a somewhat generic assessment task that would yield useful information concerning a *single* dimension of mathematical communication--that of constructing a coherent, fluent *written* summary using appropriate mathematical language and terms. NCTM (1989 p. 217; 1995 p. 13) specifies that students' ability to communicate mathematically should be assessed by having students write about mathematics.

Additionally, since mathematically correct explanations of topics as well as logical connections between mathematical topics were both regarded highly in the scoring rubric, at least partial measurement of students' ability to communicate mathematically and make connections is accomplished by this assessment. The fact that statistically significant differences existed between the experimental and control groups implies an association between maintaining a mathematics learning log and student improvement in the type of written communication described above.

The Algebra I classes wrote at a significantly higher level than the Basic Algebra classes on the Mid-Year Writing Assessment, but just the opposite was true on the Summative Writing Assessment. That is, the adjusted mean writing scores were significantly higher for the Basic Algebra students on the end-of-the-year writing prompt. In fact, the Algebra I mean writing score went down second semester whereas the Basic Algebra mean score went up, as it should have. This was possibly attributable to control inconsistencies as the end of the school year approached. The frequency of log summaries submitted in one of the Algebra I classes noticeably decreased and, as mentioned in Chapter 3, the instructor failed to appropriately administer the Summative Writing Assessment. As a result, a number of the Algebra I students exhibited a less than desirable effort on the final writing task, and this contributed to a diminished mean score in comparison to the semester writing task. This factor may have contributed to the overall treatment/control mean difference being slightly smaller on the final assessment than on the semester assessment.

The difference in final writing performance between the Algebra I and Basic Algebra groups also underlines the importance of the teacher's role in

motivating the students to write consistently. It is this researcher's view that the Basic Algebra teachers' acute sensitivity to the "high maintenance" nature of this assessment structure, and their choosing to do the majority of the writing during class time contributed considerably to the improvement of their students' writing during the second semester. Additionally, the striking progress from first semester to the end of the year demonstrated by the Basic Algebra group supports Evans (1984) as well as Miller and England (1989b) who related improved performances of lower ability groups when regular writing accompanied instruction.

MARS-A (Mathematics Anxiety Rating Scale-Adolescent) Results

There was no statistically significant difference ($\alpha=0.01$) between adjusted mean difference scores on the Mathematics Anxiety Rating Scale-Adolescent (MARS-A) for the experimental and control groups. However, the difference between those scores did approach statistical significance with $p=0.0408$. There were no significant differences found on the other two independent variables of class or gender, nor were there significant interactions between any of the combinations of the independent variables.

Although significance at the 0.01 level was not attained, declines in anxiety levels among all of the experimental classes was notable. The findings imply the coexistence of reduced student mathematics anxiety levels with implementation of the mathematics learning log framework. If, in fact, the diminished anxiety levels of these students were associated with their writing practice, this would support the views of Stewart and Chance (1995) who claim that their quantitative findings, similar to those of this study, associate journal writing in first-year-algebra classes with reduced math

anxiety. They too measured student anxiety levels using MARS-A and recorded "changes-in-anxiety scores...that approached significance ($p \leq 0.07$)."

They stated, in relating the value of math journals, that their statistical analyses served to extend and corroborate other evidence both in their study and in the literature. Miller and England (1989b), NCTM (1989, p.142), Bagley and Gallenberger (1992), LeGere (1991b), and Miller (1991) all contend that writing in the mathematics classroom may improve student attitudes, ease mathematics anxiety and frustration, and enhance students' general disposition to do mathematics. Kennedy (1985), Dodd (1992), and Skiba (1990) suggest an explicit relationship exists between writing in math class and reduced mathematics anxiety.

Although the emphasis of this particular writing structure lies in the cognitive domain, it is this researcher's belief that the findings of this study quantitatively point to the possible positive effects of learning log writing in the affective domain as well.

Additional Analyses

The Additional Analyses section of Chapter 3 presented some "unplanned" statistics relative to possible correlation between the dependent variables measured in the study and the frequency with which students submitted learning log summaries. Data for two of the pretests, ITBS and TAP, were also included in the regression analyses. For each analysis, individual student writing frequency, expressed as the average number of summaries per semester, functioned as the independent variable, and each assessment score served as a dependent variable. Regression statistics were computed and one way analysis of variance performed for each assessment.

A significant correlation ($r=0.41$; $p=0.00089$) was determined in the analysis of the Summative Writing Assessment scores and a correlation approaching significance ($r=0.30$; $p=0.0243$) was found on the MARS-A difference scores. Although the existence of a significant correlation does not necessarily indicate a direct causal relation (Ferguson and Takane 1989, p. 133), the existence of such a correlation implies that writing frequency *may* in some way contribute to the related assessment performance and suggests the need for further investigation. There is probably no question however that in order to reap the full effect of writing one must write consistently.

No significant correlation was detected for the Mid-Year Writing Assessment, the TAP math total for Algebra I, or the TAP math total for Basic Algebra. The two aforementioned pretests were included to see if students performing at higher levels *initially* were possibly inclined to write on a more consistent basis. If there were a direct causal relation between the pretests and the writing frequency, these two variables would have been correlated (Ferguson and Takane 1989, p. 133). However, there was no such correlation, implying that higher-performing students on the standardized pretests were not necessarily "predisposed" to better writing habits.

Teacher Feedback

The information gained from the teachers who implemented the mathematics learning logs in their classrooms was invaluable. Although the original research design emphasized quantitative analysis and testing of hypotheses, a great deal was gained from the teachers' personal accounts. Very specific observations made by the teachers are included in Chapter 3,

but a summary of general conclusions drawn from the teachers' experiences is presented in the following paragraphs.

The teachers unanimously agreed that marked improvement was evident in the experimental groups' correct use of mathematical terminology. Some noted unquestionable superiority in mathematical communication skills, both oral and written, exhibited by the log writing group. This upholds the findings of Davis and Pearce (1988), Azzolino (1990), Curcio (1990) and Kennedy (1990) as well as supporting recommendations by NCTM (1989, p.6) and Abruscato (1993).

Teachers reported, as do Bagley and Gallenberger (1992) and NCTM (1989, p.28; 1991, p.96), that the writing provided valuable feedback as well as a medium for demonstrating understanding or asking questions for the students who were uneasy about speaking up in class.

Although one teacher specifically expressed preference for formative paper-and-pencil quizzes and homework assignments, the other three cited several specific instances in which they diagnosed student misunderstanding or confirmed student understanding of concepts based on what was written in the log summaries. Those same teachers were able to detail instances in which they made instructional adjustments based on their findings in the math logs. In conjunction with the findings in the literature and the researcher's past experiences, this verifies, in this researcher's mind, the legitimacy of the mathematics learning log as an alternate assessment tool--a tool that integrates assessment with instruction (NCTM 1989, 1995; Clarke, Clarke, and Lovitt 1990), and because of more informed teaching may serve to enhance learning (NCTM 1995, pp. 13, 22).

Two of the teachers attributed the writing shared in the learning logs to development of closer relationships with students and better understanding of the students' thinking and attitudes. This corroborates similar suggestions by Danielson (1998), Stenmark (1991), Miller and England (1989b), and Burns (1988).

All teachers reported a "slow start" relative to getting the students interested in writing and improving the quality of their summaries. The use of prototypes seemed to work well for the teachers, and this was a possible contributor to the improvement of student interest and writing quality. This supports suggestions by Talman (1990) as well as Herman, Aschbacher, and Winters (1992). By the end of the first quarter, teachers advised the researcher that there were relatively few student complaints, and in many cases, the students were reminding the teacher that the learning logs were due.

When asked if the teachers would continue with this writing paradigm in their classes next year, the response was quite positive. Concerns were expressed about a single writing prompt leading to student motivational "dips," the process of quantitatively scoring weekly summaries, and especially the amount of time spent reading and responding to the summaries if several classes were involved in writing. Regardless of those concerns, all four of the teachers were positive that writing, in some form, would be a part of their mathematics assessment repertoire in the future.

Recommendations

Recommendations for Curriculum and Instruction

The implementation of mathematics learning logs is a practice that, based on the literature and the findings of this study, is recommended by the researcher. Though generally improved student learning of algebra was not statistically verifiable in the context of this study, student improvement in written mathematical communication *was* verified. In addition, possible reduction of mathematics anxiety, and more informed instruction were both clearly supported by the findings. If the particular writing strategy implemented in this study, or perhaps some close adaptation thereof, is not utilized, it remains that the literature and teacher accounts in this study firmly establish writing as a general means of enhancing classroom discourse and students' mathematical communication skills.

If the goal of the school district is to immediately raise standardized achievement test scores, this writing paradigm will likely not contribute a great deal to that process. However, the statistical analyses in this study appear to support one of the participating teacher's remarks, "They (the students) can't do worse in math because of using this as an assessment tool," and another's statement, "if it (the log writing) isn't helping their learning, it certainly isn't hurting it." Additionally, the use of mathematics learning logs may work well in mathematics programs as an alternate assessment that promotes openness, is reasonably equitable, and integrates nicely with instruction--demanding a response from the instructor (NCTM 1995).

Use of student writing for assessment of their understanding is a time consuming process. Teachers wishing to implement this or any other writing

strategy into their classroom should weigh the constraints this will place on their time. This instructor, along with others who have implemented writing successfully in their classes, recommend reducing the number of formative quizzes or graded homework assignments to make room in the instructional schedule for this type of assessment.

Recommendations for Further Study

The learning log data collected from all of the students this year provide a rich source of information on students' mathematical communication skills, conceptual understanding, and procedural knowledge. These documents can be further explored to seek patterns relative to the ways students mature in mathematical written communication as well as investigating the evidence of algebraic understanding and misunderstanding found in the writing. An inquiry of this nature is a relatively immediate personal goal of the researcher.

It was noted in the conclusions that participating teachers cited several instances in which they made instructional adjustments based on what they read in their students' math logs. It was also noted that this fact upholds the accounts in the literature as well as the researcher's past experiences relative to the legitimacy of the mathematics learning log as an alternate assessment tool--a tool that integrates assessment with instruction (NCTM 1989, 1995; Clarke, Clarke, and Lovitt 1990). A reasonable and interesting response to this would be to devote a study to the question of exactly *how* math logs "inform" instruction. That is, how does what the teacher learns from student writing change what they teach and the methods they use to teach it?

To further investigate the findings of this study, it is recommended that the study be replicated with a larger, perhaps more representative, sample of students. A larger number of teachers involved would guard against some of the problems encountered by having one or two of the teachers inappropriately administer parts of the experimental treatment. Also, further study should incorporate a dependent variable more closely associated with the valid measure of student learning--one that goes well beyond the "achievement" measured by standardized tests. Ideally, the mathematics learning log could be further substantiated as an alternative assessment that contributes to the advancement of student learning.

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APPENDIX

Mathematics Autobiography

Please write a detailed autobiographical sketch for the purpose of familiarizing me with some of your past math experiences and your present view of mathematics. Please write neatly on notebook paper or, if you prefer, use a word processor. This paper should include at least the following information:

- ✓ your feelings (positive *or* negative) toward math, and why you think you have those feelings;
- ✓ a description of at least one successful experience and one not-so-successful experience in your career as a mathematics student; and
- ✓ a detailed description of the things you believe you are good at (your strengths) and things you are not so good at (your weaknesses) in math. (To best familiarize the teacher with your individual needs, it is important that you be very specific here using the most accurate math terminology you can.)

Please be honest and candid in your remarks, and refrain from using the names of any previous teachers. Use nice penmanship, write your thoughts in complete sentences. You will not be graded on the content of this paper, but you will receive a deduction of credit for failing to complete this assignment.

Summative Writing Assessment

[Time for this exercise is limited to approximately 20 minutes.]

PROBLEM: You are asked by the parents of a younger friend to explain what their child can expect to learn in Algebra I class. Wishing to sound as though you have learned some useful mathematics this year, summarize what you would tell them concerning the main concepts covered in algebra class.

HINTS: Remember to use complete sentences, and since you are speaking to adults, use accurate mathematics terminology. Your discussion will be strengthened by organizing related topics together.

Mid-year Writing Assessment

[Time for this exercise is limited to approximately 20 minutes.]

PROBLEM: You are asked by the parents of a younger friend to explain what their child can expect to learn in Algebra I class. Wishing to sound as though you have learned some useful mathematics this semester, summarize what you would tell them concerning the main concepts covered in algebra class so far.

HINTS: Remember to use complete sentences, and since you are speaking to adults, use accurate mathematics terminology. Your discussion will be strengthened by organizing related topics together.

Judge's Information and Response Sheet

Please refer to the enclosed Introductory Information, Summative Writing Prompt, and Scoring Rubric as you respond to the following questions.

As noted in the Introductory Information, this writing prompt is meant to engage students in a somewhat generic summative assessment task that yields useful information concerning a **single** dimension of mathematical communication--that of constructing a coherent, fluent written summary using appropriate mathematical language and terms.

In your opinion, is this prompt representative of the type of question necessary to elicit the type of mathematical communication described above?
(√ one box)

yes**no**

Do you believe the hints give clear direction concerning the need to use appropriate terminology in a coherent and fluent discussion?

yes**no**

In your view, does the scoring rubric support the intent of the writing prompt?

yes**no**

If you have suggestions for improving either the writing prompt or wording of the scoring rubric, please record them in the space below. Also, please sign and date this form on the line at the bottom of the page. Thank you for your time.

(NAME)**(DATE)**

Introductory Information

Mathematical communication is a multifaceted concept, and evaluation of students' ability to communicate mathematically is well beyond the scope of this study. This particular writing prompt is an effort to engage students in a somewhat generic summative assessment task that yields useful information concerning a **single** dimension of mathematical communication--that of constructing a coherent, fluent written summary using appropriate mathematical language and terms.

A task of this nature can serve as one indicator of students' ability to communicate mathematically. NCTM (1989) states that "students' ability to communicate mathematically can be assessed by having students write about mathematics." This writing is judged for accuracy, clarity, precision, and the *proper use of mathematical vocabulary*, and symbols (emphasis added). Assessment should consider fluency of the writing (NCTM 1989; Countryman 1992) and should be attentive to organization, coherence, and detail (Clarke, Stephens, and Waywood 1992; Kentucky Department of Education, 1992). The scoring rubric presented in Table 1 is used by the researcher to rate students' written summaries based on the above criteria. Notice that more points are given for writing that accurately and fluently details related mathematical topics, as opposed to simple listings of isolated topics. It should also be noted here that scoring reliability (consistency) for this rating scale has been statistically established.

The writing prompt is phrased to imply a different "audience" for the students to respond to. In a task such as this Countryman (1993) believes that being asked to write to an audience different from the teacher elicits a stronger response from most students. Miller and English (1989) found that students write *more* when addressing comments to a specific audience.

The Summative Writing Prompt

Each student will be asked to respond in writing to the following prompt:

PROBLEM: You are asked by the parents of a younger friend to explain what their child can expect to learn in Algebra I class. Wishing to sound as though you have learned some useful mathematics this year, summarize what you would tell them concerning the main concepts covered in algebra class.

HINTS: Remember to use complete sentences, and since you are speaking to adults, use accurate mathematics terminology. Your discussion will be strengthened by organizing related topics together.

The Scoring Rubric

Table 1. Point Assignment for Summative Writing Assessment

1 point	Student receives one point for each isolated, but appropriate, mathematical topic stated. These are often in lists with other unrelated topics, and no clear context is established for the topic listed. (Example: "We studied things like exponents, variables, and percents." -- This yields 3 points; one for each topic named.)
3 points	Student receives three points for a minor topic accompanied by a brief description of the topic, or detailing a brief (or incomplete) list of related subtopics. (Example 1: "We studied fractions and then went on to rational expressions." Example 2: "We used proportions to find missing sides on similar figures." --These yield 3 points each.)
6 points	Student receives six points for a major topic followed by a list of 2-3 appropriate subtopics. Or, six points are awarded for logically connecting subtopics within the explanation of a major topic. (Example 1: "We learned about graphs of linear equations, and we determined slopes and y-intercepts of lines." Example 2: "We applied exponents and used percent formulas to solve problems about interest and compound interest." --These yield 6 points each.)

References Cited in "Introductory Information"

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**Log Summary Scoring Reliability
Prototypes and Samples**

These summaries were written by 8th grade math students in November, 1993. They summarize a week's class work and all classes were beginning a unit on basic ideas of algebra. The students will not necessarily describe the same activities, because some were in different places (relative to the curriculum) than others. All summaries are typed as written by students (*i.e.* spelling and punctuation errors are included). The first three summaries are prototypes representing use of the three-point scoring rubric.

EXAMPLE 1 (This summary received a score of 1 point.)

This week were getting into algebra. We played a card game. Ive always had a fear of algebra but now that we've done that sheet its actually pretty easy.

This week I learned to do some algebraic expression, and what it's useful for.

EXAMPLE 2 (This summary received a score of 2 points.)

This week we got a test back and wrote about it. We also did this activity using calculators. We took a scientific calculator and a regular calculator and saw how different answers could be by doing a problem like $8-9+4\div5$.

We played a game called Krypto. It was about using order of operations. It was fun to see the different ways everyone put together the numbers to equal the number on the card. It was hard to get the answer 1. I thought it was easier to get a high even answer.

EXAMPLE 3 (This summary received a score of 3 points.)

This week we got a test back on basic geometry and wrote a Test Aftermath. We did activities on order of operations. One was a card game and the other one was a thing with two kinds of calculators. We also did worksheets on algebra.

I learned that I did good on my test 90%, and I learned to use "please excuse my dear Aunt Sally" to be sure that the arithmetic is done right. Scientific calculators do order of operations the way its done in algebra. I learned what a variable is and how to "substitute" numbers in expressions to get an answer.

The algebra is easy so far. We've done some before when we used geometry formulas. I was glad about my test. Thats all for now.

#1

This week we talked about patterns and area worked on order of operations in algebra problem like $(3+15)(11-2\cdot 3)$. So you do parentheses, exponents, multiplication, division, addition, & then subtraction. We also worked on changing an English expression to an algebraic ones.

This week I learned the order of operations, which I wish I knew before. I also learned how to read and change English expressions to algebraic ones & learned a lot of new signs like \leq , \geq , \neq .

I thought this week was interesting and kind of fun. The worksheets that we did were not too hard and made the time go by fast.

#2

For the past week we have been working hard on algebra and the various ways to use it.

I like your attitude towards teaching algebra, you don't want us to be scared of it but sometimes the info can kinda overwhelm you but only if you let it.

We learned for the past week, the order of operations, which is the order you do expressions in, we also learned the difference and meaning of specific and general, then we learned what variables are. And more.

#3

We learned algebra this week, and learned stuff like this;

$$9+n\cdot 3\div 1=13 \text{ instead of } 63$$

$$n=12$$

I learned how to do algebra in "Please excuse my dear aunt Sally" order.

I think algebra is kind of fun, and not as hard as I thought it would be.

#4

On Monday we found the difference between a scientific calculator and a regular one. We found out that they can come up with different answers. The scientific calculator was the most accurate.

On Tuesday I wasn't here but we got a worksheet about expressions. On the worksheet we had to translate English into an algebraic expression. That was easy and even kinda fun.

On Wednesday we got another worksheet on evaluating algebraic expressions. We had to find the expression, value of variable, and value expression.

On Thursday we got another worksheet on algebraic & numerical. We had to translate English into algebraic expressions. And we evaluated lots of expressions.

It was easy and even kind of fun.

#5

This week we talked about algebra. We did worksheets out of a book. We did worksheets that taught us the difference between numerical & algebraic expressions or sentences.

I learned a lot because I really didn't know the difference between numerical and algebraic expressions or sentences.

It was hard to grasp at first but it got to be easier and now I understand.

#6

This week we started Algebra. We started using variables, algebraic and english expressions.

I learned what the word ambiguous meant and how to use algebraic and english expressions.

I understand algebra pretty well and think I will do O.K. in it.

#7

Monday we started algebra. We did an assignment out of the book on doing arithmetic expressions and sentences mentally.

Tuesday we got a worksheet with algebraic problems on English expressions and algebraic expressions. Which we learned how to change an English expression into an algebraic expression. And then from algebraic to English, but not as many that way.

Wednesday we finished the worksheets well 4-2, then we got 4-3 worksheet and we did the first seven questions. We had to name the variable, the most common way to write the expression, and what the value of n was.

Thursday we graded Wednesday's work, talked about some of the confusing stuff like, seven less a number, expression stuff like that. Then we had to take a quiz which was easy until the bonus question came up.

I learned how to change an English expression into an algebraic expression. I also learned that just because a teacher says ok now we're going to start algebra, that I don't need to be scared! Because we get worksheets that explain how to do the work and it's pretty fun I guess. Not!

#8

This week we took a test and got the test back. We also started algebra and on Tuesday we played a game with cards that dealt with algebra.

This week I learned that algebra is not scary, but that we use it everyday and don't really know it.

Do I have any missing work?

#9

This week we started a new unit. Algebra.

We learned arithmetic expressions & sentences; English expression, algebraic expression, numerical expression, value of the variable, value of the expression, & variables.

I know there is a bunch of other things that we learned but the ones I listed are the ones that are on the top of my head.

I really like Algebra & I understand it better than most math.

#10

This week in math we worked more on algebra. Monday we handed in our homework which we had to write two letters on our best work and update our learning logs, and do a worksheet. Tuesday we went over the geometry test and had to write down our strengths and weaknesses. Then we had to make a summary about our test. Then wednesday we talked about algebraic expressions, numerical expressions, equations = $8+2=10$, and inequality = $8+2>1$. Then we got our homework, worksheet 4-6, and a page in the book. I thought it was easy.

#11

This week we have mostly been working on algebra. Most of it is really confusing. We have done evaluating algebraic expressions, translating expressions, patterns, term numbers, and parenthesis. I thought that the term number worksheet was the easiest, and the other ones were really confusing. Some of the work on the pages that were hard was not as confusing, and when we took a test on it, I really did good. I am hoping that we don't have another quiz until I am sure that I understand the confusing stuff. But, since we just started on algebra, maybe it will get easier, like geometry.

Other than those few confusing worksheets, I still enjoy math class, and hope to be able to understand algebra better after we work on it for a while.

#12

This week we started a little of algebra. We also got some worksheets on using parentheses and guessing what number goes to fit the pattern.

On Friday we took the class period and voted on tessellations. It was hard to choose because there was alot of interesting ones. We also started our portfolios. You get to pick two of your best pieces of work and write a cover page about each of them. I had fun doing the work sheets on patterns. It's fun to figure out how the pattern goes and to see what numbers will be next.

#13

This week we had a lot of activities I'm going to mention the activity that I enjoyed most. We played Krypto. The object of the game Krypto is to pick or hand out 5 cards to everyone then you pick any card out of the deck and you have to make all the numbers that you got equal to the number that was picked by \times , \div , $-$, $+$. it was fun & we enjoyed it then we worked and looked at some algebra & thats about all.

#14

This week we did some work on our test and we learned some Algebra. Algebra not that easy. I learned that a scientific calculator does the algebra in the order it is supposed to and a regular calculator does not.

I learned on our home work from Tuesday night that Algebra can be written long hand, and not just in numbers. I think that is all we did this week.

#15

This week we spent most of our time discussing algebra. We went over things like algebraic expressions, sentences, and how to arrange them in parentheses. We also went over the geometry test and wrote a paper on it.

This week we learned a few new algebra terms & symbols, like how to use parentheses, $<$, $>$, \leq , \geq , \neq . In algebra you can use parentheses to show which phrase of an algebraic sentence to simplify first. You can also use nested parentheses, they look like this: $5+4(6+(2-3)\circ 1)=-19$ in this sentence, you do the inner most parentheses first, & work outward from there.

This was a pretty good week, I did very well on the geometry test, & I think that the algebra we are doing now is very interesting & fun.

#16

We corrected worksheets we did in past days, went over an exam, talked about order of operations, and handed in work from Monday. Played a game to practice order of operations.

We learned the answers to the worksheets from past days, and learned how to do order of operations, and how to do algebraic expressions.

#17

This past week I did problems concerning parentheses. I also wrote about my two best pieces of work. One of my best pieces of work was a quiz, the other piece was my tessellation. A few other things I did were worksheets on guessing the rule, making sequences, and knowing the constant difference.

This past week I learned that parentheses make problems easier. I also learned that nested parentheses are the parentheses inside parentheses. I

also learned to do in the parentheses first. Two other things I learned were making sequences and finding constant differences.

I have a question on knowing how to determine a rule for the 50th term in a sequence.

#18

This past week we took a math test. I didn't do very well on it. I learned to study alot harder for tests. We just started algebra and arithmetic expressions and sentences. I learned to start with division or multiplication first or start with parentheses.

#19

This week we got our exam scores back, played Krypto, and talked about order of operation. We also corrected 4-3 (translating expressions), got 4-4 (evaluating expressions), and took notes on what algebra is valuable for, signs, kinds of expressions, got another worksheet (values of expressions), and voted on tessellations. We talked about portfolios and handed in 4-3 and 4-4.

This week I learned that order of operation can be really hard, that algebra is valuable for describing patterns and generalizing situations, different ways to write multiplication and division signs, and four kinds of expressions (open, algebraic, sentence, and numerical). I also learned what a variable and ambiguous is, how to recognize and "write" patterns, and that sometimes order of operation doesn't matter. I learned what I have to do for my portfolio, that my tessellation doesn't appeal to all people, and that there may be more than one way to generalize a pattern. I also learned how to find "differences" in patterns.

This week had a pretty good reflection on me. Krypto made me realize I'm not as good at order of operation as I thought. I learned alot and took good notes. Monday we had alot of homework but I'm starting to realize an objective in algebra- recognizing patterns.

#20

This week in math we worked on worksheets that contained algebraic sentences. We played a card game where each person received five cards and had one target for each person. The game is played using all five cards to reach the target number.

The algebraic sentences that we worked on the majority of them were simple. I learned this week that in algebraic sentences that instead of using the regular math "times" symbol you can use letters next to the number an example $5n$ means 5 times n . Another way to show times which I already knew is to put a dot between a letter and a number. An example would be $5 \cdot n$, means 5 times n .

On other worksheets we have found different kinds of patterns, such as 1, 4, 7, 10. They share a constant difference of three or plus three. We also learned how to study the patterns and be able to tell what they will equal when the term number is out of numerical order, such as term numbers going as 1, 2, 3, 4, ...10, ...50, ...100.

I found this week's work was simple but long. On worksheet 3 I found the backside to it easy but different than I remember doing in the past.

#21

This week in math we got into partner groups and did a worksheet on algebra. I wasn't here on Tuesday so I don't know what we did. We also talked about variables and numerical expressions. On Thursday we took a quiz and got a worksheet for homework. On Friday we went over our algebra quiz and talked about portfolio papers.

This week I learned that product stands for multiplication.

22

This week we talked about arathmatic sequences. We also went over the test and did a test aftermath. We discussed what algebra is used for. That includes such things as, describing patterns, generalizing situations, applying formulas, etc. Solved algebraic problems by finding the values of the variables.

I learned about arathmatic sequences. Learned some algebraic vocabulary. On Solve Each some of the problems I didn't understand how to find the answers.

#23

We worked on algebra and order of operations. I lernd how to exted patterns without wrighting them all out. We allso work on parentetses and simtefyng them.

#24

This week in math we worked mostly on algebraic expressions, took a quiz on it, & received our test scores.

I learned how to write algebraic expressions & I learned the difference between numerical expressions & algebraic expressions. Algebra is mainly used on describibng patterns.

#25

This week we did some worksheets on evaluating and translating algebraic expressions. We also did a page thirty-seven in our text book. It was on simplifying arithmetic expressions. We also took a test. We did have some fun though. We nominated the different tessellations that we thought were the best. We also got our tests back. (I only missed two!)

This week I learned that a numerical expression uses only numbers, and an algebraic expression uses letters as well as numbers. I also learned to translate an algebraic expression from words to numbers. I also learned how to work them out.

This week was fun! I did get a little confused on translating like, seven less than the number. I couldn't figure out if I was supposed to write the seven subtract the number ($7-n$) or the number subtract seven ($n-7$). Mr. Brown showed me how to do them by using some examples so now I know how to do them.

All-in-all this week I had a lot of fun.

Dear Rater:

Please rate the twenty-five weekly summaries using the 3-point scoring rubric below. Record all scores in the table at the bottom of this page.

Three-point Scoring Rubric for Weekly Summaries

- 1 point** Little attempt made to summarize in detail. Lists only chronological events of week with little reflection on what was learned. Does not use, or misuses mathematical terms.
-
- 2 points** Identifies most key objectives of week in at least rudimentary form. May relate objectives to examples or applications. Relates learning experiences using generally appropriate mathematical terms.
-
- 3 points** Clearly and precisely relates most key objectives of week. Effectively explains learning experiences, and may integrate with objectives and examples. Reflects more on one's own thinking, and may relate connections among concepts learned.
-

Rating Sheet for 25 Student Summaries					
#	score	#	score	#	score
1	3	10	2	19	3
2	1	11	2	20	3
3	2	12	2	21	1
4	3	13	2	22	1
5	2	14	1	23	1
6	1	15	3	24	1
7	2	16	1	25	3
8	1	17	2		
9	1	18	1		

J.C. Addams


Dear Rater:

Please rate the twenty-five weekly summaries using the 3-point scoring rubric below. Record all scores in the table at the bottom of this page.

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- 3 points** Clearly and precisely relates most key objectives of week. Effectively explains learning experiences, and may integrate with objectives and examples. Reflects more on one's own thinking, and may relate connections among concepts learned.
-

Rating Sheet for 25 Student Summaries					
#	score	#	score	#	score
1	2	10	2	19	3
2	2	11	1	20	3
3	1	12	2	21	1
4	2	13	2	22	2
5	2	14	1	23	1
6	1	15	3	24	1
7	2	16	1	25	3
8	1	17	2		
9	2	18	1		

 Nov '93

Dear Rater:

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Three-point Scoring Rubric for Weekly Summaries

- 1 point** Little attempt made to summarize in detail. Lists only chronological events of week with little reflection on what was learned. Does not use, or misuses mathematical terms.
-
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-
- 3 points** Clearly and precisely relates most key objectives of week. Effectively explains learning experiences, and may integrate with objectives and examples. Reflects more on one's own thinking, and may relate connections among concepts learned.
-

Rating Sheet for 25 Student Summaries					
#	score	#	score	#	score
1	2	10	2	19	3
2	2	11	1	20	3
3	1	12	1	21	1
4	2	13	1	22	2
5	2	14	1	23	1
6	1	15	3	24	1
7	2	16	1	25	3
8	1	17	3		
9	2	18	2		

JAB July 1994

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Three-point Scoring Rubric for Weekly Summaries

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-
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-
- 3 points** Clearly and precisely relates most key objectives of week. Effectively explains learning experiences, and may integrate with objectives and examples. Reflects more on one's own thinking, and may relate connections among concepts learned.
-

Rating Sheet for 25 Student Summaries					
#	score	#	score	#	score
1	3	10	2	19	3
2	2	11	2	20	2
3	1	12	1	21	1
4	3	13	1	22	1
5	2	14	1	23	1
6	2	15	3	24	1
7	3	16	1	25	3
8	1	17	2		
9	2	18	1		

Sondeno, July 1994

Calculation of Cronebach's alpha coefficient for consistency among raters

Student #	Rater			
	Addams (july)	Brown (july)	Brown (nov)	Sondeno (july)
1	3	2	2	3
2	1	2	2	2
3	2	1	1	1
4	3	2	2	3
5	2	2	2	2
6	1	1	1	2
7	2	2	2	3
8	1	1	1	1
9	1	2	2	2
10	2	2	2	2
11	2	1	1	2
12	2	1	2	1
13	2	1	2	1
14	1	1	1	1
15	3	3	3	3
16	1	1	1	1
17	2	3	2	2
18	1	2	1	1
19	3	3	3	3
20	3	3	3	2
21	1	1	1	1
22	1	2	2	1
23	1	1	1	1
24	1	1	1	1
25	3	3	3	3

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	47	24	1.965	11.82943141	6.249E-16	1.66945568
Columns	0	3	0.01333333	0.08026756	0.97052965	2.73180945
Error	12	72	0.16611111			
Total	59	99				

Estimated variance of subject effects: 0.44972222

Estimated Residual variance: 0.17

Rater variance: 0.62

Estimate of alpha: 0.73026613

Teacher Training Material
Teacher Training Session Outline
(August 18, 1:00-4:00 pm)

I. Introductions

II. Overview of the project

A. Need for research in alternative assessment and support of local administration

B. Sketch of the experiment

1. Hand out packet of materials
2. Experimental/control group design
3. Daily log
4. Weekly summaries (briefly...detailed discussion in part C)
5. Teachers' role in data collection
 - a. Student and teacher release forms
 - i)* what if parents won't release scores?
 - b. Math autobiography
 - c. Getting students started on logs and summaries
 - i)* student instructions
 - ii)* class writing activity
 - iii)* addition of new students during year
 - d. Scoring summaries (see part C)
 - e. Mailing of scored summaries (refer to calendar)
 - f. Site visits by researcher (refer to calendar)
 - g. Teacher journal (hand out notebooks)
 - h. Brief discussion of test data I will personally access
 - i. Care in avoiding contamination
 - i)* Experimental/control separation
 - ii)* Maintain student participation
 - iii)* Consistent evaluations of summaries
 - iv)* Discussion of teacher-observable tests
 - v)* Year-long commitment of teacher
 - vi)* Importance & benefits to teacher and district

C. Scoring of summaries

1. Discussion of rubric, criteria, and goal of writing
2. Need for consistency
3. Prototypes for each point value
4. Practice scoring samples
5. Discuss comments goals of comments
 - a. encourage dialog between students and instructor
 - b. encourage involvement of student in thinking about his/her own learning
 - c. encourage positive attitudes
 - d. encourage questioning
 - e. encourage better math communication and writing
6. Determine weight of summaries in total grading scheme

Teacher Resource Packet

for

**THE MATHEMATICS LEARNING LOG AND ITS EFFECTS ON
MATHEMATICS ACHIEVEMENT, ANXIETY,
AND COMMUNICATION**

**A Research Project Conducted in Cooperation
With the Campbell County School District
Gillette, Wyoming**

by
Scott A. Brown

August 1994-June 1995

Information About the Study

Why Mathematics Learning Logs?

Mathematics learning logs are one of many alternatives useful in supplementing traditional formative assessment practices. The NCTM *Standards* suggest that alternatives, such as student learning logs, will provide more complete and valid evidence of student understanding and disposition to do mathematics than will paper-and-pencil testing. Using a variety of assessments will enable the teacher to more effectively tailor instruction to meet the needs of the students, which should, in turn, enhance student performance. Waywood (1992) states that this type of writing exercise is linked to student learning. Believing that "language and thought are intimately connected," he states that "mastering forms of communication goes hand in hand with mastering thinking." Keeping a mathematics journal should, says Waywood, help students "formulate, clarify, and relate concepts; appreciate how mathematics speaks about the world; and think mathematically."

It is the experience of this researcher, after using student mathematics learning logs as an alternate assessment method in middle school classes and university undergraduate classes, that this assessment tool provides rich and highly detailed information about the strengths and weaknesses of the students as well as the program--information that is not always made manifest through the regular modes of objective testing. A mathematics learning log, as a supplementary assessment, provides a context in which students can communicate, and possibly improve their understanding. The dialogue established between the student and teacher through log keeping may also facilitate improvement of student attitudes toward the mathematics they are doing.

The questions proposed in this study, relating namely to achievement, communication, and mathematics anxiety are each relevant in the study of the effects of student log writing. It is stressed by NCTM (1989, 1993) that assessment be integral to instruction and should enhance learning. To be of value, student achievement should be *supported* by this type of assessment. Since affect and cognition are inextricably linked (Sowder 1989, p.35), it is important that student attitudes can be monitored and appropriately responded to with the reflections that often accompany log entries. This researcher's experience and that of Clarke, Stephens, and Waywood (1992) indicates that for students, articulation of their own mathematical thinking, processes, and experiences are both challenging and empowering.

What is the "Set Up?"

This study will consist of two treatments that will be referred to as the "experimental group" and "control group." The experimental groups and control groups will each include four classrooms of students (approximately two hundred students altogether), along with their four respective teachers. There will be two different courses involved, Algebra I and Basic Algebra. Both the experimental and the control groups in the Algebra I courses will receive regular daily instruction using D. C. Heath's Algebra I (Larson, Kanold, and Stiff 1993) as the main instructional resource. The experimental and control groups in the Basic Algebra courses will receive regular daily instruction using a more traditional and simplified textbook from Houghton Mifflin, Basic Algebra (Brown, Smith, and Dolciani 1993).

In addition to regular instruction and textbook use, the experimental groups will be assigned a daily writing exercise. For this task, which is assigned as regular homework, each student engages in writing a prescribed submission to his/her *mathematics* learning log. The word *mathematics* is emphasized because of the objective nature of the writing that will be assigned. The mathematics learning log will consist of two main components; namely, daily log entries, and weekly summaries.

What is a Mathematics Learning Log?

In a mathematics learning log the student is asked, after each math lesson, to write

- (1) a brief summary of the math activity and/or key mathematics topic(s) covered; and
- (2) discussion of what specific mathematics, if any, was personally learned.

Also, relevant examples, unanswered questions, and personal reflection concerning the lesson may be noted in the log. These daily entries are kept in a notebook, or "daily log" that is only periodically inspected and "checked off" (every three to four weeks) by the teacher for monitoring purposes.

Weekly, students are required to summarize their daily log entries in a brief (2-3 paragraph) synthesis of the week's mathematics experience--

- ✓ "What we did" (including specific key topics); and
- ✓ "What I learned" (with relevant examples, questions, and/or reflection).

These "log summaries" are read and responded to by the instructor before being returned to the student for replacement in his/her notebook. **For the purpose of this research however, after the students have a chance to look over the teacher comments, the summaries are to be returned to the teacher and placed in an envelope provided for mailing to the researcher.**

What Do We Do With Them Once We've Got Them?

Weekly summaries must be read, responded to, graded, and returned to the students in a timely manner. Teacher response to weekly summaries will require special care if the classroom implementation of learning logs is to be successful. For the writing exercises to be most beneficial, weekly log summaries must be read and responded to (in writing) by the teacher (McIntosh 1991, Nahrgang and Petersen 1986). Countryman (1992, p. 39) states that "comments can be brief, light and encouraging in tone, or a detailed answer to a specific question. Countryman goes on to emphasize that "most students just want an indication that I (Countryman) have read their comments."

It is recommended that the comments be designed to encourage continued dialogue between the teacher and students, encourage involvement of students in thinking about their own learning, encourage positive attitudes, encourage questioning by the student, and encourage better math communication and writing.

Although grades are not assigned to the daily log entries, students will be graded on completion of the weekly summaries. The exact weight of the summaries, relative to the overall course grading structure, will be determined in collaboration with you, the participating teachers. However, for the sake of consistency, weekly grading of the summaries will be quantified using a three-point scoring rubric (see the table below). The scoring rubric is the result of synthesizing information from Clarke, Stephens, and Waywood (1992), Talman (1990), and Beyer (1993) and has been implemented and refined over a two-year period in this researcher's math classes. It has also been statistically tested for inter-rater consistency and found to be reliable. After some practice, you will find the scoring rubric quite simple to use.

Three-point Scoring Rubric for Weekly Summaries

- | | |
|----------|---|
| 1 point | Little attempt made to summarize in detail. Lists only chronological events of week with little reflection on what was learned. Does not use, or misuses mathematical terms. |
| 2 points | Identifies most key objectives of week in at least rudimentary form. May relate objectives to examples or applications. Relates learning experiences using generally appropriate mathematical terms. |
| 3 points | Clearly and precisely relates most key objectives of week. Effectively explains learning experiences, and may integrate with objectives and examples. Reflects more on one's own thinking, and may relate connections among concepts learned. |
-

This researcher agrees with Countryman (1992) and Miller (1991), that correct grammar, spelling, and punctuation are *promoted* in the weekly summaries, but not strictly *enforced*. Positive suggestions noted for the writers (e.g. correct spellings, added punctuation) are helpful in producing better student products, but this is not to be made the main objective. Evaluation of the writing, says Miller (1991), should "focus students' thinking on better understanding of the subject matter."

Remember that you are not alone in this project. You are encouraged to contact the researcher with any questions or concerns, and you are especially encouraged to collaborate with the other participating teachers concerning implementation of the weekly summaries. The researcher will be contacting you frequently to inquire about your experiences with learning logs, so please be sure to note your own comments and questions in your journal.

Mathematics Autobiography

Please write a detailed autobiographical sketch for the purpose of familiarizing me with some of your past math experiences and your present view of mathematics. Please write neatly on notebook paper or, if you prefer, use a word processor. This paper should include **at least** the following information:

- ✓ your feelings (positive *or* negative) toward math, and why you think you have those feelings;
- ✓ a description of at least one successful experience and one not-so-successful experience in your career as a mathematics student; and
- ✓ a detailed description of the things you believe you are good at (your strengths) and things you are not so good at (your weaknesses) in math. (To best familiarize the teacher with your individual needs, it is important that you be very specific here using the most accurate math terminology you can.)

Please be honest and candid in your remarks, and refrain from using the names of any previous teachers. Use nice penmanship, write your thoughts in complete sentences. You will not be graded on the content of this paper, but you will receive a deduction of credit for failing to complete this assignment.

[duplicate for students]

MATHEMATICS LEARNING LOG

This year in algebra class one of your regular homework assignments will be to maintain a Mathematics Learning Log. The purpose of the log is to help you "re-think" the mathematics you are working on and to express your understanding (or perhaps misunderstanding) to the teacher. Here's what you need to do.

1. Purchase a spiral notebook to be designated "Math Log."
2. As homework, or during appropriate class time, record (and date) a brief entry in the notebook each day. The entry should include (1) a brief summary of the math activity and/or key mathematics topic(s) covered, and (2) discussion of what *specific* mathematics, if any, was personally learned. You may also want to briefly note any helpful examples, questions you have, or comments about the day's activity. Remember, these daily entries stay in your Math Log. The teacher will periodically check the log to see how you are progressing.
3. As a weekly homework assignment you will write a summary of the daily log entries. This paper will be a brief (2-3 paragraph) run-down of the week's activity; in other words, "what we did in algebra class" (including specific key topics) and "What I learned" (with any helpful examples, unanswered questions, and/or general comments about the week).
4. Hand in the summary on time. It will be read and evaluated by the teacher. Remember, you will be graded on this assignment, so please do your very best on each summary.

[duplicate for students]

Student Writing Activity

Objective: After students have written a couple of weekly log summaries and had a chance to see the teacher responses to their writing, it is necessary to reinforce the expectations (or criteria) relative to the writing task. This activity will engage students in reflection and group interaction to improve their understanding of what constitutes a "good" weekly log summary.

Materials: Transparencies of prototype weekly log summaries.

Time needed: 20-30 minutes

Instructions: **Part A (10-15 minutes)**

- (1) Divide the class into groups of three or four students each. Try to assign to each group at least one student who has been successful on the first weeks' log summaries.
- (2) Display the two prototype summaries on the overhead projector and allow students to brainstorm positive and negative characteristics of each prototype. Be sure that one group member serves as a recorder for the group.
- (3) Engage groups in sharing their findings with the whole class, and conduct the discussion in such a way that student findings lead to emphasis of the qualities cited in the three-point scoring rubric. These important qualities can be informally recorded on the chalkboard by a student or the teacher.

Part B (10-15 minutes)

Based on the discussion in Part A, students can now compose a weekly summary for their group. Rather than completing individual weekly log summaries in the usual manner, students are instructed to do this week's summary as a group. Groups are to discuss and outline the information they want in the summary, get as much of their summary written as possible, and finish any remaining work at home.

Each student is still responsible for handing in a written log summary on Friday, but they will have the advantage of determining the contents of the summary with their group on Thursday.

Teacher Journal

As a participating teacher, you are asked to keep a journal of your experiences throughout the two semesters of the study. **It is important in this study that accurate teacher comments concerning a number of questions relative to the student writing experience be obtained.** As you are aware, you will be interviewed throughout the study, and tape-recorded transcripts of some interviews will be analyzed by the researcher. Your written comments will serve to facilitate and support both the interview process and the generalization of conclusions in the research findings. Therefore, please be diligent in completing weekly journal entries in the notebook provided.

Here is a checklist of suggestions for possible journal contents:

- ☞ What is my general impression of the week's summaries?
- ☞ What is my general impression of log summaries, so far?
- ☞ Are there troubles grading the summaries?
- ☞ How much time was spent responding to the log summaries?
- ☞ How many students did, or did not, turn in summaries?
- ☞ What intervention was administered to improve participation?
- ☞ What, of interest, was learned about the individual needs of students?
- ☞ Did I make any individual or group instructional decisions based on the contents of this week's summaries?
- ☞ Did I visit with other participating teachers concerning implementation of math logs? Was anything learned in that discussion?

Please take the matter of keeping an accurate and up-to-date journal very seriously as this is a critical element of the study. Thank you for your help.

Tentative Calendar of Special Dates**1994**

- Thursday, August 18: Training session (1:00 PM)
- Thursday, September 1: Administer MARS-A and assign autobiography
Distribute release forms to students
- Friday, September 2: Hand out math log instructions (exper. group)
Collect release forms and autobiographies
- Tuesday, September 6: BEGIN DAILY MATH LOGS. Mail auto-
biographies, MARS-A, and student release
forms to researcher.
- Friday, September 9: Students hand in first log summary
- Tuesday, September 13: Researcher will call regarding 1st week's summary
Mail 1st week's summaries to researcher.
- Thursday, September 22: Student writing activity in experimental group
- Tuesday, September 27: Mail summaries to researcher
- Monday, October 10: Site visit and afternoon work session
- Tuesday, November 1: Mail summaries to researcher
- Tuesday, November 22: Mail summaries to researcher
- Tuesday, December 13: Mail summaries to researcher

1995

- Tuesday, January 10: Mail summaries to researcher
- Thursday, January 12: Administer Mid-year Writing Assessment and
mail to researcher.
- Monday, January 30: Site visit by researcher and taped interviews
- Tuesday, February 21: Mail summaries to researcher
- Tuesday, March 14: Mail summaries to researcher
- Tuesday, April 4: Mail summaries to researcher

- Tuesday, March 14:** Mail summaries to researcher
- Monday, April 24:** Site visit by researcher
- Tuesday, May 16:** Mail summaries to researcher
- Tuesday, May 30 and
Wednesday, May 31:** Summative evaluations and site visit by researcher
- Thursday, August 24:** (Tentative) workshop for Gillette teachers sharing results and conclusions of the study.
- Friday, October 6:** Sharing of results and conclusions at Wyoming Interdisciplinary Conference in Gillette.

STATEMENT OF PERMISSION

I _____ grant permission to Scott A. Brown to use data gathered from the classroom work of my students and my personal written and verbal comments in his doctoral research dissertation and any subsequent publications. It is agreed that my personal identity and that of my students will remain confidential in all publications excepting citation of participating teachers in the dissertation acknowledgments.

Signature _____

Date _____

Information About the Researcher (Through August, 1994)

Scott A. Brown
2114 Gentle Street
Cody, Wyoming 82414
(307) 587-3536

General Information: Age: 38; Born on August 29, 1955 in Greybull, WY; Raised in Cody, WY (moved to Cody in 1957); Married in 1978; Wife: Kelly, Children: Ryan (12 yrs.), Stacie (4 yrs.)

Education

- 1993 Course work and comprehensive exams completed for doctoral program (Doctor of Education in Curriculum and Instruction w/ mathematics minor), Montana State University
- 1985 MST (Master of Science in Teaching Mathematics) University of Wyoming
- 1978 BS (Mathematics Education), University of Wyoming
- 1973 High School Diploma, Cody High School

Teaching Experience

- 1993-1994 8th math and Algebra I, Cody Middle School
- 1991-1993 Mathematics for Elementary Teachers, Montana State University
- 1979-1991 7th/8th Mathematics and Algebra I, Cody Junior High School
- 1987-1989 Mathematics With Manipulatives and Technology in Mathematics, University of Wyoming
- 1989-1990 Computer Literacy 7-8, Cody Junior High School
- 1983-1985 Adult Education Computer Awareness, Cody Public Schools
- 1978-1979 Mathematics 8-12, Lyman Nebraska

Local Professional Experience

- 1984-1990 Mathematics K-12 Department Chair
- 1993-1994 Site-Based Management Administrative Team, Middle School Representative
- 1990-1991 Site-Based Management Administrative Team, Jr. High Representative
- 1983-1985 District Computer Planning Committee
- 1984-1988 District Curriculum Council
- 1986-1989 MATHCOUNTS Coach (District Champions: 1986, 88, & 89, and State Champions: 1989)
- 1980-1985 Student Council Sponsor

Other Professional Experience

- 1990-1992 President, Wyoming Council of Teachers of Mathematics
1990-1992 Board of Directors, Wyoming Mathematics Coalition
1988-1990 President-Elect and Newsletter Editor, Wyoming Council of Teachers of Mathematics
1986-1993 Member, National Council of Teachers of Mathematics

Honors

- 1991 University of Chicago School Mathematics Project Summer Institute
1989 Wyoming State MATHCOUNTS Coach (accompanied the State Team to national competition)
1987,1988 Wyoming Presidential Award for Excellence in Science and Mathematics Teaching
1987 Cody High School Honored Alumnus
1982 Cody Junior High Teacher of the Year

Publications

- An Assessment in Algebra Readiness, Co-author
One-time contributor to NCTM Arithmetic Teacher
Contributed a number of activities and articles to WCTM Random Walk.

List of References for Teacher Resource Packet

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- Brown, John R., Douglas A. Smith, and Mary P. Dolciani. Basic Algebra. Boston: Houghton Mifflin Company, 1993
- Clarke, David J., Max Stephens, and Andrew Waywood. "Communication and the Learning of Mathematics." In Mathematics Assessment and Evaluation: Imperatives for Mathematics Educators, edited by Thomas A. Romberg. 184-212. Albany: State University of New York Press, 1992.
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- Nahrgang, Cynthia L., and Bruce T. Petersen. "Using Writing to Learn Mathematics." Mathematics Teacher 79 (September 1986): 461-465.
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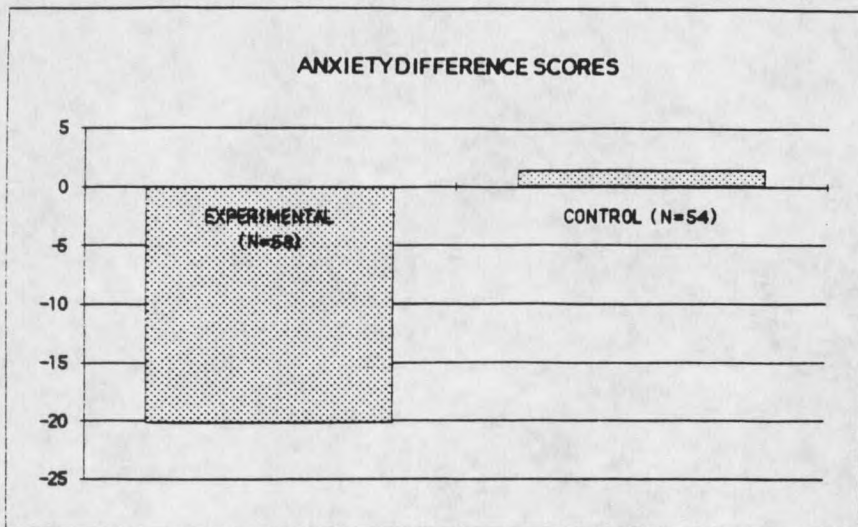
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Talman, Louis A. "Weekly Journal Entries--An Effective Tool for Teaching Mathematics." In Using Writing to Teach Mathematics, , edited by Andrew Sterrett, 107-110. Washington D.C.: Mathematical Association of America, 1990.

Waywood, Andrew. "History and Rationale for Student Mathematics Journals: A school Perspective." In Mathematics Assessment and Evaluation: Imperatives for Mathematics Educators, edited by Thomas A. Romberg. 312-320. Albany: State University of New York Press, 1992.

GRAPHS OF SELECTED ANCOVA RESULTS

MARS-A Findings



p-values

treatment
p=0.0408

class
p=0.5885

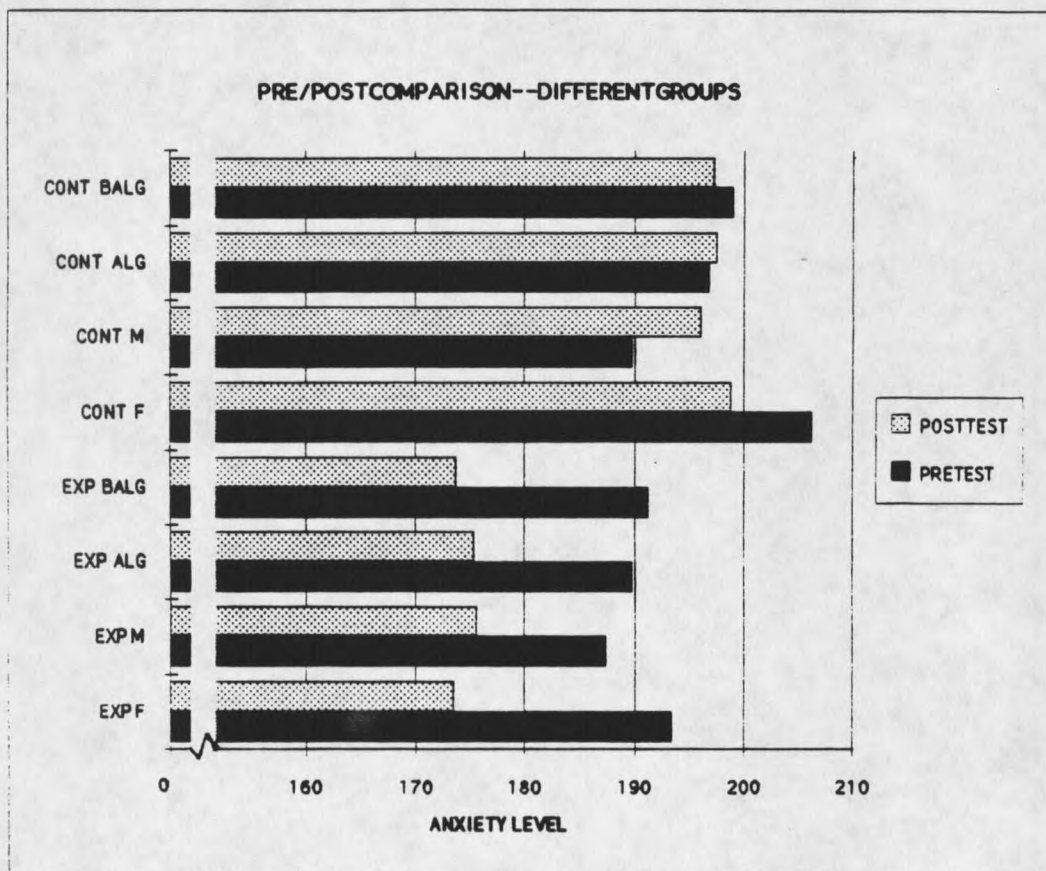
gender
p=0.6729

trt*class
p=0.7064

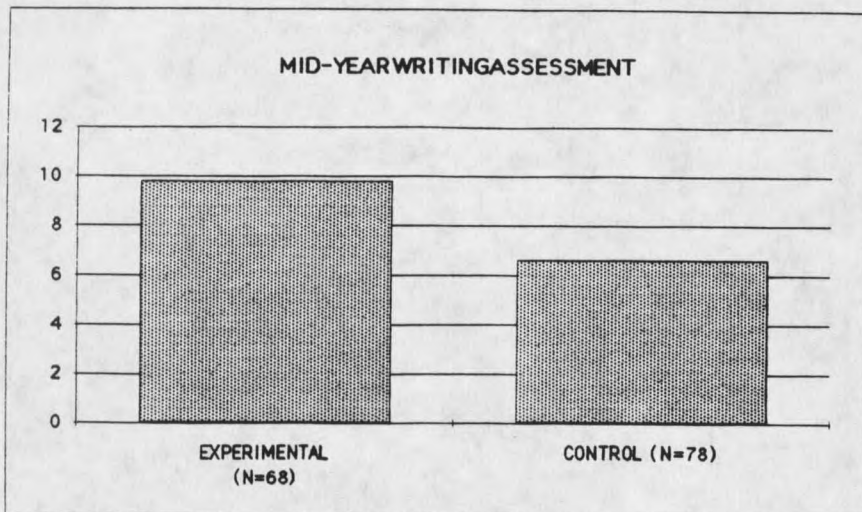
trt*gen
p=0.9471

class*gen
p=0.7447

trt*gen*class
p=0.8296



Mid-Year Writing Assessment Findings



p-values

treatment
p=0.0000

class
p=0.0043

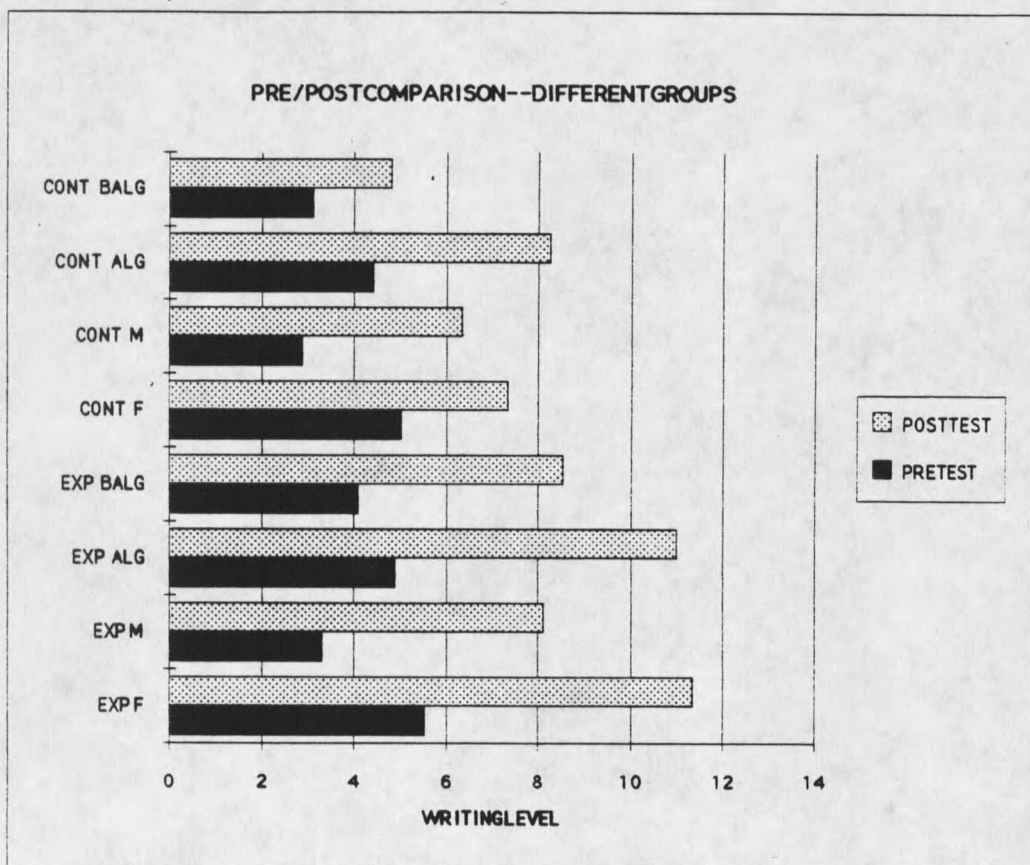
gender
p=0.1419

trt*class
p=0.6067

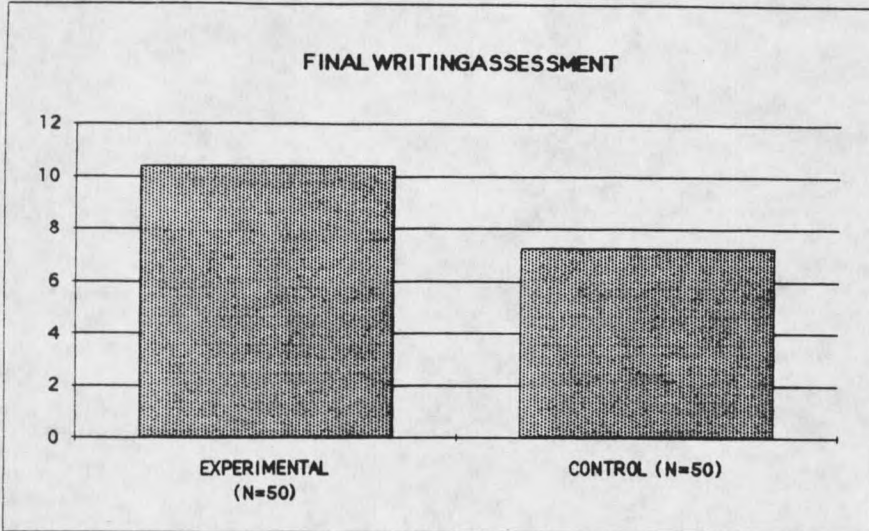
trt*gen
p=0.2370

class*gen
p=0.5623

trt*gen*class
p=0.8966



Summative Writing Assessment Findings



p-values

treatment
p=0.0034

class
p=0.0000

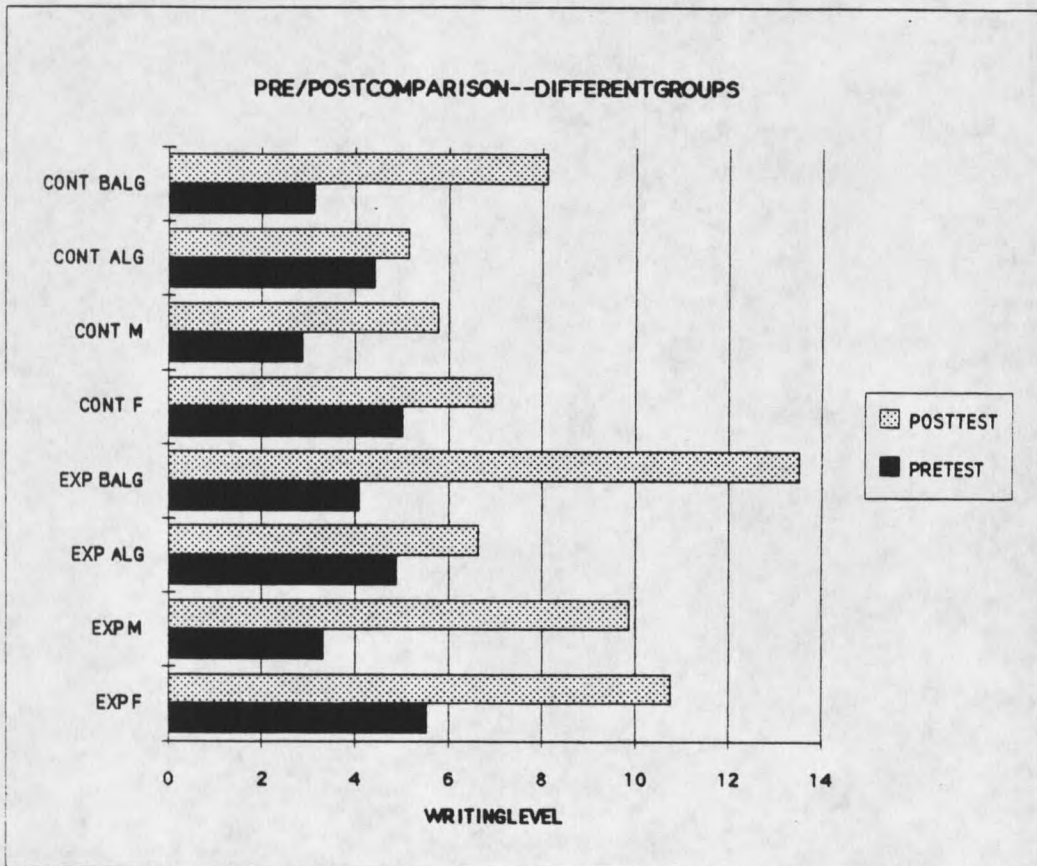
gender
p=0.1546

trt*class
p=0.0105

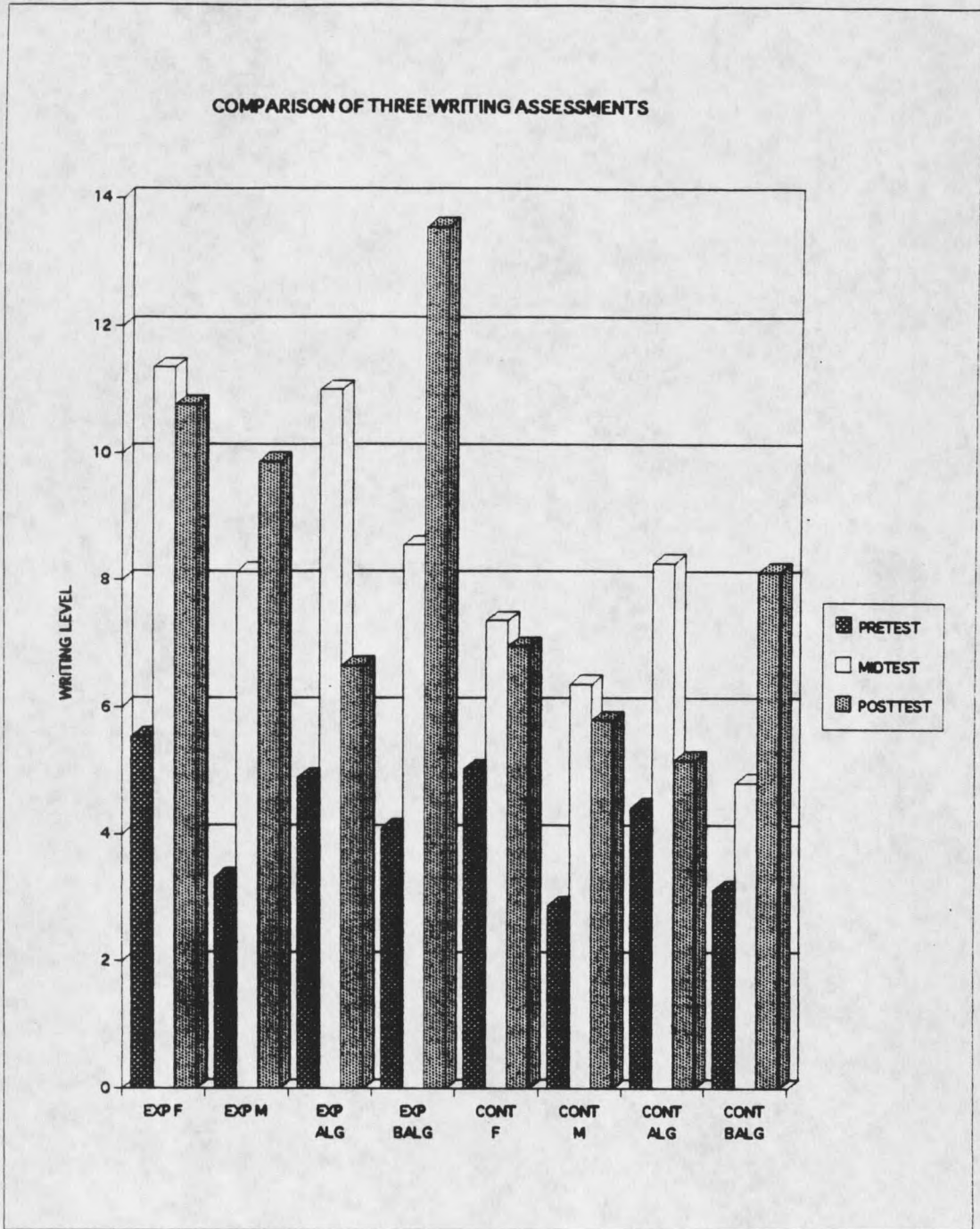
trt*gen
p=0.1191

class*gen
p=0.7790

trt*gen*class
p=0.0471



Combined Findings for Writing Assessments



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