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

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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by

Scott Alan Brown

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Scott Alan Brown

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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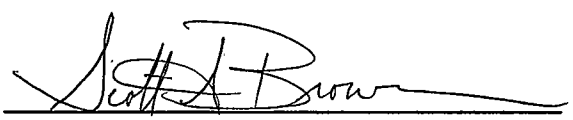
Signature 

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Triple space

CHAPTER 1

Triple-space

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 Vaucluse 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 Vygotskyan 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 asssessing 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

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