INTEGRATION OF WRITING EXPERIENCES
INTO AN INTRODUCTION TO CALCULUS CURRICULUM

MASTER'S PROJECT

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by

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I take this opportunity to express deep gratitude to all who have encouraged and supported me in my education:

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CHAPTER I

INTRODUCTION

Justification of the Problem

Many Americans openly express anxiety about the way education shapes its future leaders and citizens. Institutions of learning find it increasingly difficult to keep pace with the rapid multiplication of knowledge in a fast-paced world reduced in size by sophisticated communication and available technology. However, rather than giving in to despair, leaders in education have challenged the professionals in their fields to continue to create and promote excellence in education.

The National Council of Teachers of Mathematics (NCTM) is such a leader. One way in which this group responds to the challenge for excellence is through its publications. Recently An Agenda for Action: Recommendations for School Mathematics of the 1980s (NCTM, 1980) has been updated in the document Curriculum and Evaluation Standards for School Mathematics (NCTM, 1989) and the publication of Professional Standards for Teaching Mathematics (NCTM, 1991). Through these writings, the Council attempts to involve, to inform, and to prepare professionals in the field of mathematics education to more effectively empower all students. Goals formulated in these documents call for a change in the teaching and learning of mathematics in American classrooms. Though particular curriculum standards vary, each level contains
standards that focus on increasing student self-confidence through problem solving, reasoning, communication, and making mathematical connections.

In a parallel fashion, undertakings to improve students' abilities to express ideas through writing are being implemented by leaders in the field of English. For the past two decades, for example, many institutes of higher learning in the United States have been supporting and promoting the Writing-Across-the-Curriculum (WAC) movement (Russell, 1991). Though the titles and deliberate aims of this program are varied and controversial, in its broadest application, writing skills of the English curriculum are developed while the content of other subject areas is assimilated.

Incorporating writing experiences into the mathematics curriculum is a current innovation to promote mathematical reasoning and problem solving through means of a type of communication that demands the formation of connected ideas. Because most teachers and students of mathematics are trained to work with numbers rather than with words, the experience of writing may be an unexpected, and perhaps unwelcome, activity in a mathematics classroom. But the real questions are: Unfamiliar or not, will writing in the mathematics classroom improve the understanding and application of mathematical concepts? Will writing in the mathematics classroom enhance students' writing skills and their abilities to express their ideas with confidence?

The author believes that the integration of writing experiences into the mathematics curriculum meets the challenge of the NCTM Standards and does enhance the learning, retention, and use of
mathematical skills and concepts. Additional positive outcomes, such as an improved ability to communicate through the written word and increased self-confidence, may also be gained from such a practice. The author also believes that the students themselves will experience writing in mathematics as an aid to greater learning, conceptualization, communication, and application, and that this increased facility will be reflected in their attitudes.

Problem Statement

The purpose of this study was to analyze the attitudes of beginning calculus students toward the integration of writing experiences into the curriculum of the Introduction to Calculus course at a girls’ Catholic high school.

Hypotheses

There will be no significant difference between the pretest and posttest mean attitude scores toward Introduction to Calculus after the students have been exposed to a project which integrates writing with mathematics.

There will be no significant difference between the pretest and posttest mean attitude scores toward writing in the Introduction to Calculus curriculum after the students have been exposed to a project which integrates writing with mathematics.
Assumptions

In order to carry out this study, the author needed to make several assumptions. First, the author assumed that the responses of the Introduction to Calculus students would be honest. Such responses were assumed on the semantic differential pretests and posttests. Similarly, honesty was assumed on the Likert instrument which was distributed at the end of the testing period in order to assist with the discussion of the results of the project. The author also assumed that the testing instruments were reliable in that they measured the attitudes that were intended to be measured.

Limitations

The design of these experiments, $T_1 \times T_2$ and $T_1 \times T_2$, lent itself to limitations. Several extraneous variables threatened the internal validity of this project (Fuchs, 1980). First, there was the effect of history. The students were exposed to writing in other subject areas, and many of them were also working with difficult mathematical problems in physics class. Secondly, since the project extended over an eight-month period, the natural process of maturation may have accounted for improvement in writing and/or mathematical skills. Also, completion of the pretests may have alerted the students to the project and may have influenced their posttest attitudes. Finally, statistical regression may have influenced the results of this project because Introduction to Calculus was an honors level course open only to the best students.
Two sources of external validity were not able to be controlled: the confounding effects of pretesting and the interaction effects of selection and treatment. The pretest may have sensitized the students to the testing, and the results of the experiment could only be generalized to include a limited population. This population included only the Introduction to Calculus students at the particular girls' Catholic high school at which the experiment was conducted.

Definition of Terms

**Freewriting.** This term is used to indicate a brief period of writing time during the class session. Students reflect in writing on a given topic to introduce an idea, to summarize a lesson, or to individually respond to a question raised during the class.

**Introduction to Calculus.** This is the honors section of the Pre-Calculus course. Juniors and seniors with high averages and the signature of the teacher are eligible.

**Journal Writing.** This term is defined according to the way the author used journal writing. These student-written responses to mathematics were recorded in a special notebook. Sometimes prompts were used to focus writing, at other times the students spontaneously chose the topic and the form in which they wished to express themselves. Creativity was encouraged. Grading was based on completion of entries rather than on the quality of what was
written. Daily entries were assigned to be completed outside of class time.

Writing Across the Curriculum (WAC). WAC is an educational movement that encourages instructors in all fields to integrate writing experiences into their particular curriculum in order to enhance learning.

Writing Experiences. Writing experiences integrated into the mathematics curriculum by the author for this particular project included journal writing, and individual and group essay questions.
CHAPTER II

REVIEW OF THE RELATED LITERATURE

Writing and the Writing Process as a Mode of Learning

Writing enables the writer to deal with actuality in enactive, iconic, and symbolic ways by engaging the hand, the eye, and the brain simultaneously (Bruner, 1971). Of the four traditional language processes of listening, talking, reading, and writing, Emig (1977) defends writing as a unique mode of learning. Writing is also integrative. The right hemisphere of the brain contributes creativity, emotion, and intuition to the composition while the left hemisphere generates the linear product. The slower pace of the hand encourages employment of the higher level thinking skills of analysis and synthesis as well as the welding of past, present, and future experiences. Finally, the written product provides an immediate medium for review, comments, and reinforcement. Writing as a process, then, has the writer actively and personally engaged in strategies characteristic of successful learning: making connections, experimenting with hypotheses, drawing conclusions, and using perceptions of existing relationships to predict future events.

Haley-James (1982) concurs with Emig when saying that writing directed toward learning is an interactive process of thinking, writing, and reading where thoughts are continuously being shaped for a specific purpose. She cites six specific ways in which writing
promotes learning: Writing focuses thought, makes thought available for inspection, allows more complex thought, translates mental images, is multisensory, and motivates communication.

Writing as product and writing as process-and-product are two approaches to the use of writing in the curricula. Britton (1983) contrasted these two functions of writing when he defined knowledge as "a process of knowing rather than a storehouse of the known" (p. 221). Writing as pure product stresses a linear sequence of learning. Void of reflection, it is used to focus on what is known at the moment and is thus a tool used for assessment and diagnosis. In this sense writing touches only the surface structure and writers are viewed merely as memory banks of information. When used in isolation, this approach implies that writing is something one does after one has learned (Freisinger, 1980).

In contrast, a process-and-product method of writing is a dynamic model of learning calling for the interconnection of experience, reflection, and critical reflection (Powell & Lopez, 1989). Writing here is used as a way of understanding both the subject area and oneself as learner. The focuses of writing, then, become the learning inherent in the process of writing rather than the final written product, and the use of writing rather than the evaluation of it (Gribbin, 1991).

Both language functions have a role and a value in education. Process-and-product oriented language, sometimes referred to as expressive language, gets the writer in touch with ideas and learning going on inside the self. Product focused writing, or communicative language, allows the writer to convey ideas and
learning to others. Freisinger (1980) states that: "Language for learning is different from language for informing," (p. 155) and true educators must respect the interdependence of the two functions.

Characteristics of Writing-Across-The-Curriculum (WAC)

British educator James Britton, through a British WAC project, provided a theoretical framework to link the development of writing in the disciplines with personal writing. Later, in the mid 1970s, WAC was introduced in American colleges and universities as a response to a perceived need for greater equity and access to language instruction for previously excluded students. The program was introduced to promote general literacy, critical thinking, improved writing, and active learning (Russell, 1991). WAC is based on the theories of psychologists, linguists, and educators (Bloom, 1956; Britton, Burgess, Martin, McLeod, & Rosen, 1975; Bruner, 1971; Emig, 1977; Vygotsky, 1962).

In an effort to clarify the meaning of WAC, educators have coined a variety of names to describe their programs. "Writing within a discipline," "writing to learn," "writing in the content areas," "writing across disciplines," and other similar terms indicate inconsistent interpretations of the program.

At Georgetown University there is a differentiation in terminology for the sake of meaning. "Writing-across-the-curriculum" is used to denote an emphasis on general writing and writing styles that will apply to all sorts of courses. The phrase "writing within a discipline" is used to refer to writing done by a
student in a particular discipline or writing done by a master of
such a discipline writing within that discipline. In the latter
instance, each teacher needs to address a specific writing style
apropos to that discipline (Slevin, Fort, & O’Connor, 1990). In both
of the above cases, the primary objective is the improvement of
writing itself.

For some educators an improved written product is viewed as a
positive but secondary advantage of writing. “Writing to learn” are
the words preferred by Miller and England (1989) because their
primary objective is to focus student thinking toward an increased
understanding of a specific subject area. Connolly (1989) concurs
with the use of “writing to learn” because he focuses on informal
writing as a means to help students acquire personal ownership of
ideas. Miller (1991) uses “writing in the content area” and
deliberately avoids using “writing-across-the-curriculum.”

Knoblauch and Brannon (1983) utilize the terms “writing-across-
the-curriculum” and “writing across disciplines” interchangeably.
They, however, strongly encourage a broad understanding of the
concepts stressing the priority of the subject material over the
system of technical constraints used to represent the students’
grasp of that material. They note that “the value of writing in any
course should lie in its power to enable the discovery of knowledge”
(p. 466). This pair also view improvement in writing as a desirable
by-product that will result from efforts to learn by composing. Abel
& Abel (1988) agree with this wider perspective claiming that
writing requires the learner to be actively engaged in concepts and
connections, or "writing across the curriculum" might well become 'grammar across the curriculum'" (p. 157).

No matter the interpretation of WAC, authors agree that writing experiences are most effective when integrated into courses rather than appended to them. For those struggling with introducing written work into their studies, Knoblauch and Brannon (1983) concede to placing a composition or two on the periphery of the existing syllabi. Reluctant instructors might look for objectives within their existing syllabi that call for more than simple recollection of facts and begin there for written assignments (Gribbin, 1991). Lesnak (1989) agrees that an instructor could use isolated writing activities within the framework of a present course design, but he believes that a more creative approach is achieved through designing a new course and deliberately integrating writing. Berlinghoff (1989) and Johnson (1983) strongly believe that writing experiences should not merely be appended assignments to a course but rather an integral part of the students' learning experience.

Positive characteristics of WAC make an impressive argument for the program. Freisinger (1980) believes that writing as a process of learning motivates the transition from concrete to formal operations for a greater percentage of students. WAC fosters cognitive development and higher-order thinking skills. With WAC, the level of intellectual commitment and penetration is likely to be improved in all content areas of the curriculum (Knoblauch & Brannon, 1983). WAC also encourages significant changes in
learners' attitudes toward the subject matter and toward themselves (Dickerson, Fulwiler, & Steffens, 1990).

Students are active learners when engaged in WAC. Knoblauch and Brannon (1983) undermine old assumptions that knowledge is a stable collection of information to be delivered to students through lectures. Rather, "learning is the process of an individual mind making meaning from the materials of its experience" (p. 467).

Writing requires an active effort to make connections and is thus an excellent facilitator of learning. Writing makes it difficult for students to remain passive (Fulwiler, 1980; Fulwiler, 1986).

Further learning can be achieved through the evaluation of written assignments. Although the major concern in designing written assignments should be the benefit of writing rather than the evaluation of writing, forms of assessment need to be considered when WAC is introduced. Since assignments in critical thinking should give students opportunities to puzzle over issues and formulate independent judgments, it is important that the assessment method measure how a student arrives at a conclusion rather than focus merely on the conclusion itself (Meyers, 1986). Fulwiler (1986) suggests 10 ways that evaluators might respond to content rather than to mechanics. Tuttle (1986) also summarizes three methods for evaluating written responses that could be used by educators of all disciplines. These methods include analytical, primary trait, and holistic scoring. These techniques are flexible enough to allow the teachers of various subjects to view the thought engendered as more important than the precision and correctness of the act of writing.
In spite of the positive effects of writing in the various content areas, two studies indicate that writing is not frequently used. Pearce (1984) wanted to determine the extent to which high school content teachers had their students write in the classroom. Among his conclusions were the following: (a) The majority of student writing in content classes appeared to be for purposes of evaluation or copying; (b) excluding English classes, writing assignments that were neither for purposes of review nor testing were sporadic; and (c) high school content teachers were not frequently utilizing original student writing about course content as a vehicle for instruction in or deeper understanding of course concepts. In a more particular study, Pearce and Davison (1988) researched the amounts, kinds, and uses of writing in junior high mathematics classrooms. Their collection of data through teacher interviews and the examination of lesson plans and student work revealed that writing was an approach infrequently used in junior high mathematics classrooms.

**Purposes of Writing in Mathematics**

One purpose of writing in mathematics is to promote a broader student base of achievement. In the United States “more than two-thirds of the bachelor’s degrees and more then 80% of the doctorates in mathematics are held by one-third of the population—Asians and white males” (Steen, 1987, p. 302). Botstein (1986) specifically mentions the emphasis on writing in the teaching of science and
mathematics as empowering minorities and women to emerge higher in the selection process for mathematics and science careers.

Adding English to a mathematics class, because it is the common language for communication, allows more students to enter the mathematical dialogue and be successful (Birken, 1989). Berlinghoff (1989) confirms that writing in mathematics has enabled non-science majors to do "locally original" mathematics, that is, to independently explore mathematical ideas with which they are not familiar. Evans (1984) conducted research to find if writing would help her fifth graders to learn more about math. Three types of writing were used in the study: (a) written explanations to a third party of "how to do" something, (b) written definitions using familiar terms, and (c) written explanations of errors made on homework or quizzes. Her statistics confirmed that writing is an effective tool to help the less-capable student learn.

Other purposes of writing in mathematics include decrease in student anxiety (Tobias, 1989), increase in self-confidence, and improvement in student attitudes toward mathematics. On an agenda to boost mathematical performance to meet the nation's need for trained scientific personnel, Steen (1987) lists that "the chief objective of school mathematics should be to build student confidence" (p. 302). Writing in mathematics is a modern pedagogy aimed toward "retaining natural curiosity, promoting confidence in clear reasoning, and building favorable attitudes" (Steen, 1987, p. 302) which are far more important than practicing specific techniques for solving textbook problems. Writing also helps
students to develop their own criteria for being "right" and encourages them to become responsible learners (Lax, 1989).

Cited below are four works found in recent literature focusing on writing and the improvement of student attitudes toward the learning of mathematics. Originally a skeptical participant in the program sponsored by Robert Morris College, Lesnak (1989) designed an experiment to quantitatively measure the benefits of using writing-to-learn in the teaching of basic algebra. Lesnak's research showed that writing not only helped student academic achievement but also eliminated negative attitudes with respect to mathematics in general, and beginning or remedial algebra in particular" (p. 147).

Powell and Lopez (1989) conducted their study at Rutger University's Newark College of Arts and Science with a group of students in Developmental Mathematics. The team analyzed journal and freewriting activities in this study where, in general, students had negative feelings and beliefs about math. Among the conclusions reached was that writing gave the students control over learning which positively affected their sense of accomplishment.

Miller and England (1989) described their experiment on writing to learn algebra in great detail in an article bearing the same title. They wanted to ascertain what influence the use of regular writing in algebra classes would have on students' attitudes toward algebra and their skills in algebra. The experimental group showed a statistically significant (at the 0.01 level) improvement in attitude toward mathematics as compared to the control groups.

Project Registrar was conducted with 200 students from Michigan Technological University over a four year period. The
research was aimed at determining whether students' attitudes toward writing had changed in general, and if so, if this attitude change was related to students' encounters with the activities that had been initiated through WAC workshops. Although there was no clear pattern of overall correlation between the writing workshops and a change in attitudes, Selfe, Gorman, and Gorman (1986) observed that students had become generally more confident about composing and had become less anxious about having their compositions evaluated, though they did not seem to enjoy writing any more than they had as first year students.

Another purpose for writing in mathematics is that it fosters communication. The fact that "Mathematics as Communication" is the second standard in the NCTM publication *Curriculum and Evaluation Standards for School Mathematics* (1989) conveys that the use of the language of mathematics is important to government officials, industry, and the whole modern world as well as to modern educators. Writing stimulates dialogue between the student and the teacher and gives each student the chance to communicate with his or her teacher on a daily basis (Miller, 1991). The opportunity to write allows quiet students to express their confusion and questions privately. It also allows the teacher to provide individual feedback (Bell & Bell, 1985). Mett (1989) notes that students themselves are enthusiastic about writing as a means of two-way communication and as a personal learning tool.

The actual use of mathematical language best develops the language of mathematics (Curcio, 1990). Hurwitz (1990) claims that writing about a problem is a benefit because improved
communication about the ideas behind mathematical symbols is an indication of greater understanding. Carton (1990) suggests that allowing students to work in cooperative groups within the classroom or to use telecommunication systems to link classrooms in order to develop and/or solve real-world problems increases the probability that students will acquire the ability to communicate their mathematical understanding.

A key purpose for writing in mathematics is fostering the understanding and the use of mathematical concepts. Writing takes students beyond putting numbers into formulas and makes learning a matter of constructing meaning (Burns, 1988; Rose, 1989). For this reason, Nahrgang and Petersen (1986) encourage their students to answer with words and sentences rather than with equations which do not as readily demonstrate an understanding of a concept. Students who can write about mathematical concepts understand them (Johnson, 1983). Whitney (1989) concludes that writing as a process of re-representing knowledge can have important repercussions for individual understanding. The act of writing in mathematics gives students the opportunity to formulate, organize, internalize, and evaluate concepts.

Writing experiences in the mathematics classroom are an effective tool to teach critical thinking skills and to promote the problem-solving strategies needed in a technological society. Meyers (1986) understands that effective written assignments intending to teach critical thinking skills will have a stepwise development and will focus on real problems and issues. Schillow (1987) states: "The conceptualization needed to fully synthesize and
integrate prior knowledge into coherent, fully-developed, well supported written responses can be a powerful mechanism to foster critical thinking skills" (p. 11).

Participants in the University of California, Irvine, (UCI) Writing Project based their recommendations to teachers regarding fostering critical thinking skills through writing on the foundation that the thinking and the writing processes are integrally connected (Olson, 1984). They discovered that the structure of their writing process matched the taxonomy of educational objectives listed by learning theorist Benjamin Bloom (1956). Both cycles involve a increasingly complex sequence of progression from concrete to abstract levels of operating. The stages of prewriting, precomposing, writing, sharing, revising, editing, and evaluation of writing provide a way to move learners through the hierarchical cognitive levels of thinking involving knowledge, comprehension, application, analysis, synthesis, and evaluation.

The very act of writing is problem solving. The logical order involved in expository writing is parallel to the problem solving involved in mathematical processing. Therefore, it seems that practice in one of these areas can reinforce competency in both by strengthening critical thinking ability (Baker, 1983; Bell & Bell, 1985; Birken, 1989). Bell and Bell (1985) tested this hypothesis using two ninth-grade general math classes. The results of their experiment were significant at the 0.01 level showing that the writing component positively affected progress in math problem solving. It follows that having students describe the thinking processes that verify their solutions develops problem solving
ability as well as a deeper understanding of mathematics (Burns, 1988).

In 1986 the MATHCAPS project (White & Dunn, 1989) was conducted in Tennessee and Virginia to study teachers' views and practices on important components in the teaching and learning of mathematics. The teachers in this four-year project discovered that the regular journal writing required of them in this study was an agent of change in their self-confidence and ability to problem solve.

Methods to Implement Writing in Mathematics

The same stages used in writing in a composition class may be used for writing in mathematics. Pearce and Davison (1988) describe the general stages of prewriting, drafting, and revision as they can be used in a mathematics class. Britton et al. (1975) outline the writing process with the words conception, incubation, and production. These stages include: (a) drawing on primary experience and the interrelations of this experience; (b) gathering, challenging or rejecting the facts, and explaining the matter to oneself; and (c) making corrections and improvements. The above-mentioned literature also discusses the advantages of writing to a specific audience other than the mathematics teacher.

Since writing in the discipline of mathematics has a unique style, specific methods may be helpful in the implementation of the writing process. Gopen and Smith (1989) give numerous and detailed tips for writing in mathematics stressing the need for active verbs and clear sentence order. A strict style of writing geared for
science and mathematics is discussed by Tobias (1989). Their suggestions allow students to spend less time on structure and more time on written substance.

Many types of writing are popular for use in mathematics courses. Journal writing within or outside of the classroom is one such method. The experience of Nahrgang and Petersen (1986) indicates that "the most effective method of using writing to help students learn mathematics is through the use of journals" (p. 461). Journals are a private place to express opinions and to encourage dialogue between the student and teacher, a place where there is no fear of formal evaluation of writing or mathematical skill (Nahrgang & Petersen, 1986; Zoltek, 1990). Journals are a place to make connections between new and old material and to generate thoughts and feelings and questions about math (Rose, 1989). Yinger and Clark (1981) explain that journals with their "focus on personal thoughts, feelings, and reflection, put writers into a position to learn at least four important things about themselves: (a) what they know, (b) what they feel, (c) what they do (and how they do it), and (d) why they do it" (p. 10). One journal entry allows the student to use a variety of intellectual skills, such as synthesis, analysis, interpretation, translation, and evaluation.

Various authors have suggested methods to introduce students to the use of journals in a math class. McIntosh (1991) distributes an information sheet to explain and clarify what is meant by journal writing to help students get started with this experience. In the beginning students may write their math autobiography or give input regarding class and tests (LeGere, 1991; Zoltek, 1990). Fulwiler
explains to his class that journals exist somewhere between diaries and class notebooks. Three aspects of complete writing are essential to Mett (1989) who requires journal writing in her course: (a) a summary of new material learned in class, (b) a discussion of individual work outside class, and (c) an analysis of connections, difficulties, and open questions. Miller and England (1989) suggest that the teacher give writing prompts to solicit responses to specific questions. Teachers, too, may journal to model the writing they expect (Abel & Abel, 1988; Fulwiler, 1980).

Seife, Petersen, and Nahrgang (1986) designed an experiment to identify the effect of journal writing assignments on students in a college-level mathematics class at Michigan Technological University (MTU). In this study involving two teachers and three sections of an Analytic Geometry and Calculus class, 30 students in section one wrote 20 journal entries, 24 students in section two with the same teacher took 10 quizzes, and 28 students in section three with a different teacher took no quizzes and wrote no journals. Though the study had its shortcomings, the results included that: (a) test scores showed no significant differences; (b) journal writing exercises had prepared students equally as well for the tests as had the quizzes; (c) journals did not change student attitudes toward writing; and (d) journals did not reduce student apprehension toward writing. Although quantitatively the study was not favorable toward journal writing, qualitative analysis revealed that, in general, the students felt the journal was a positive addition to the math class.

Writing can be used in testing within the mathematics classroom. Problem analysis is suggested by LeGere (1991). He requires that
students analyze and describe their approach to the solution of the test problem that they find to be the most difficult. For quiz items he occasionally asks students to identify problem types recently studied and to give a brief analysis of the approach to each problem. According to Tuttle (1986), essay tests are most appropriate when students are asked to describe, contrast, compare, explain, discuss, develop, summarize, or evaluate and present their ideas in their own way. Azzolino (1990), who shows concern for the time needed for writing on a test, suggests allowing students to bring handwritten outlines to the test. A clear statement of both the essay question and the evaluation criteria are very important to the student for successful completion of the test.

Freewriting is another type of writing used within mathematics classes. Elbow (1983), Huse-Inman (1980), and Mett (1989) suggest similar ways to use freewriting in conjunction with a class lecture. Introducing a lecture with a five-minute writing, and perhaps following it with a short discussion, can be used to bridge the gap between the students' former activity and the math classroom. Another option is interrupting a long lecture for a short writing; this can keep the students on task and put them in a participant role. Ending the class with a short written summary of the lesson is another possibility. King (1990) uses what she calls "reciprocal peer-questioning and responding" as a tool to help students manage their thinking and learning during lecture presentations. This method involves both freewriting and oral involvement of groups of students for brief periods of time during a lecture. Abel and Abel (1988) suggest having the students freewrite answers to specific
questions at the top of a homework paper so that the teacher can get quick feedback on such things as confidence, amount of time taken to complete an assignment, and difficulties encountered. It is evident that freewriting can be used as a valuable learning and evaluative tool.

Writing in mathematics can take unique forms. Abel and Abel (1988), Azzolino (1990), Connolly (1989), Kenyon (1989), McIntosh (1991), and Rose (1989) give detailed lists and examples of a variety of forms of writing for use in the mathematics classroom. Unique among the exercises suggested by Connolly (1989) is what he refers to as "metacognitive process writing." In this type of writing students reflect and write on how they read, how they take an exam, how they write a paper, or how they think about a problem. Whitesitt (1990) suggests that students use 3 X 5 cards to explain concepts and to define terms in their own words. The accumulated file can then be used as an efficient tool for reviewing material. A term paper to illustrate the use of mathematics in relation to another discipline or to show a practical job-related application of mathematics is required by Lipman (1981). Birken (1989) describes what she calls a "logical order question." The students work with two sheets of paper on which are posed the same question. The students write the mathematical steps of solution on one sheet while writing English sentences to correspond to the mathematical steps on the other. Geeslin (1977) asks his students to write sentences concerning the relationships between pairs of words (e.g., circle-ellipse or function-relation). As these various examples
illustrate, there are as many ways to incorporate writing into a mathematics classroom as there are teachers of mathematics.

Some literature is aimed at creatively integrating writing with reading assignments. Martin, Martin, and O'Brien (1984) expound on five categories of activities to encourage learners to react to content material in new ways. Writing and reading are also integrated when students write book reviews of teacher-selected titles pertaining to mathematics or re-write pages of a math textbook to more clearly explain a concept (Johnson, 1983). Responding to a text, not by outlining or taking notes, but by writing observations, reactions, and connections is suggested by Marwine (1989). These ideas give new insight into the relationship existing between the three R's of "reading, 'ritin', and 'rithmetic."

A frequently mentioned impediment to usage of writing in the mathematics classroom is that writing is a time-consuming process. Keith (1989) suggests that the use of calculators in the classroom allows more time for such things as the integration of writing into the curriculum. Time pressure will also be felt by teachers who attempt to read and correct written assignments. Miller (1991) advises that teachers not implement the use of writing in every class at the same time but select the class that would benefit the most from such an experience. Efforts to deal with time pressure are important because teachers confirm that writing in the mathematics classroom is worth the time.

Methods vary for evaluating writing employed in mathematics. Because Nahrgang and Petersen (1986) feel that grading the journals gives an indirect message to the students that there is "a right way"
to do the journal, they decided to contribute extra points, based on the journal contents, to the next exam grade. Tobias (1989) has an interesting way of grading an essay question. She gives one-third credit each for the right answer, for finding a variety of ways to get the answer, and for the essay on that particular problem. Some teachers promote correction of spelling, punctuation, and grammar while others feel that mathematical correctness and open communication should be the primary area of concern (Abel & Abel, 1988; Elbow, 1983; Geeslin, 1977; Mett, 1989; Miller, 1991). The most influential type of assessment, according to the students, were the comments, questions, and responses written in the journal by the teacher (Mett, 1989; Nahrgang & Petersen, 1986).

Writing in Calculus

Some literature focuses specifically on writing in calculus. Perhaps it is at this level of study that the students can best begin to link unrelated building blocks of mathematical skills and concepts that they have been collecting in their classes through the years. Yet, "little opportunity exists in the fast pace of college courses for professors to reflect on past learning, to tie together concepts, or more importantly, to ask students to make these connections on their own" (Birken, 1989, p. 38). It is here that writing can play a vital role.

Much literature is available with suggestions for writing in mathematics at the university level. Birken (1989) reflects on the value of writing in a college mathematics class and gives calculus-
level suggestions of essay questions and detailed examples of technical report and logical order questions that she uses in her classes. Hurwitz (1990) lists 20 possible precalculus topics and 30 possible calculus topics for expository writing projects. Snow (1989) discusses the two advanced writing proficiency requirements of St. Mary's College: proficiency in general writing and proficiency in writing within a student's particular major. Focusing specifically on the second requirement as it would be applied to a mathematics major, three papers are required. During the sophomore year an expository paper from coursework in Calculus III is written. Working as an individual or with a team, a technical paper on the analysis of some applied topology, graph theory, or statistics problem is to be completed the junior year. The senior comprehensive project is to be a summary of independent study work on which the student is to give three lectures. Keith (1989), Mett (1987), and Schillow (1987) also list several specific calculus topics for writing activities. Writing practice that begins in elementary school mathematics classes suggests that these same students should be better able to construct logical and well-ordered explanations of their mathematical thinking with confidence and skill at the college level.

In summary, writing is a unique, interactive, and effective means of actively engaging the learner in the learning process. Writing enables the learner to discover ideas and manipulate concepts in order to logically connect them to the structure of knowledge already possessed. Through the use of writing, both the teacher and the learner observe how a concept is assimilated. The founders of
the WAC movement in America recognized the important contribution that writing could effect in all disciplines and developed methods to help teachers implement its use in courses beyond English. Because it fosters self-confidence and communication, as well as problem-solving and critical thinking skills, modern educators encourage the use of writing in the mathematics classroom. For these very same reasons, leaders in government, industry, and research concur with the NCTM Standards established by leaders in education and view writing in the mathematics classroom as a valuable tool to better prepare students to be responsible leaders and members of America and of our world. Several studies have been reported in the literature to support the use of writing in the mathematics classroom. The literature also gives myriad suggestions for implementing and evaluating writing in all levels of mathematics.
CHAPTER III

PROCEDURE

Subjects

The subjects were 21 young high school women who were members of one section of the Introduction to Calculus course. Of these young women, 8 were juniors and 13 were seniors. Most of the subjects took at least one of the three pre-requisites of Algebra I, Geometry, and Algebra II at the honors level. Therefore, they were high achievers and excellent students. Juniors in this class are eligible for Calculus their senior year.

Setting

School. The high school where this study was conducted is a four-year academy for young women. Approximately 675 young women attend this Catholic school annually.

Community. This study was conducted in a large city in Northwest Ohio. Members of this community are oriented toward business or other professional occupations.
Data Collection

Construction of the Semantic Differential for Introduction to Calculus. The pretest and posttest were parallel forms of a semantic differential on attitudes toward the Introduction to Calculus course. Each form consisted of 19 polar adjective pairs derived from the literature. Osgood's Factor Analyzed List (Osgood, Suci, & Tannenbaum, 1957) was consulted when organizing the instrument which was designed to elicit responses about attitudes toward Introduction to Calculus. The instrument had random placement of favorable responses and was based on a seven-point scale. A copy of the pretest is found in Appendix A, and a copy of the posttest is found in Appendix B.

Construction of the Semantic Differential for Writing. The pretest and posttest were parallel forms of a semantic differential on attitudes toward writing. Each form consisted of 19 polar adjective pairs derived from the literature. Osgood's Factor Analyzed List (Osgood et al., 1957) was consulted when organizing the instrument which was designed to elicit responses about attitudes toward writing. The instrument had random placement of favorable responses and was based on a seven-point scale. A copy of the pretest is found in Appendix E, and a copy of the posttest is found in Appendix F.

Construction of the Likert Instrument for Introduction to Calculus. The piloted form of the Likert-type instrument consisted
of one open-ended question and 10 questions based on particular objectives from the Introduction to Calculus curriculum (Diocese of Toledo Catholic School Services [CSS], 1992). Students were forced to select from three given responses for each question. This instrument was piloted with a group of four students who were members of the author's Introduction to Calculus class last year. The final form of the instrument was made according to the recommendations of this group of students. The final form consisted of 15 questions based on particular objectives from the Introduction to Calculus curriculum (CSS, 1992) and the suggestions of the piloting group. Students were forced to select from three given responses for each question. One open-ended question was also included. A copy of the test that was piloted is found in Appendix H. A copy of the finalized version of this test is found in Appendix I.

Construction of the Likert Instrument for Writing. The piloted form of the Likert-type instrument consisted of one open-ended question and 10 questions based on particular objectives from the language arts curriculum (Diocese of Toledo Catholic School Services [CSS], 1993). Students were forced to select from three given responses for each question. This instrument was piloted with a group of four students who were members of the author's Introduction to Calculus class last year. The final form of the instrument was made according to the recommendations of this group of students. The final form consisted of 14 questions based on particular objectives from the Language Arts Course of Studies
and the suggestions of the piloting group. Students were forced to select from three given responses for each question. One open-ended question was also included. A copy of the test that was piloted is found in Appendix J. A copy of the finalized version of this test is found in Appendix K.

**General Administration Procedures for the Semantic Differential and Likert Instruments.** Some standard procedures were followed by the author, who was the Introduction to Calculus teacher, in the administration of each of the six instruments. The author tried to create a friendly and non-threatening atmosphere and assured the students that their responses to the surveys would not affect their grades in any way. The author conducted this entire study with all three sections of the Introduction to Calculus classes in an identical fashion. In analyzing the study, however, only the responses of one section, the class held in the middle of the day, were used. The author encouraged the students to be honest in their responses. For each of the four semantic differential surveys, the author pointed out the pattern of adjective pairs lining the sides of the papers. She explained that each student was to respond with a check mark on the line that best represented her attitude with regard to the respective subject located at the top of the survey. For the two Likert instruments, the author read aloud the directions written on each form. The students gave themselves a number within a given range and identified each of their surveys with this same number. This identification number allowed for comparison of pretest and posttest scores while assuring anonymity. Only after the final
survey was given at the end of the school year did the author explain to the students the purpose of the surveys.

**Administration of the Semantic Differential for Introduction to Calculus.** The author administered the semantic differential for Introduction to Calculus during Introduction to Calculus class time in late August 1992. After approximately eight months of treatment with journal writing and essay test questions within the mathematics class, this teacher administered the posttest, a parallel form of the semantic differential, during class time in May 1993.

**Administration of the Semantic Differential for Writing.** The author administered the semantic differential for writing during Introduction to Calculus class time in late August 1992. After approximately eight months of treatment with journal writing and essay test questions within the mathematics class, this teacher administered the posttest, a parallel form of the semantic differential, during class time in May 1993.

**Administration of the Likert Instrument for Introduction to Calculus.** The Introduction to Calculus teacher administered the finalized form of the Likert Instrument for Introduction to Calculus during class time in May 1993. The results of this test were used to help the author analyze the attitudes of the students toward the integration of writing experiences into the Introduction to Calculus course.
Administration of the Likert Instrument for Writing. The Introduction to Calculus teacher administered the finalized form of the Likert Instrument for Writing during class time in May 1993. The results of this test were used to help the author analyze the attitudes of the students toward the integration of writing experiences into the Introduction to Calculus course.

Design

Design to Test the First Hypothesis. The design for testing the first hypothesis regarding attitudes toward Introduction to Calculus after the students were exposed to writing integrated into the course was $T_1 \times T_2$.

Design to Test the Second Hypothesis. The design for testing the second hypothesis regarding attitudes toward writing after the students were exposed to writing integrated into the Introduction to Calculus course was $T_1 \times T_2$.

Treatment

Treatment to Test the First Hypothesis. The independent variable in the first hypothesis was the integration of writing experiences into the Introduction to Calculus class. The dependent variable was the attitude toward Introduction to Calculus. The treatment was journal writing and individual and group essay tests integrated into
the mathematics course. The treatment was administered over an eight-month period.

Treatment to Test the Second Hypothesis. The independent variable in the second hypothesis was the integration of writing experiences into the Introduction to Calculus class. The dependent variable was the attitude toward writing. The treatment was journal writing and individual and group essay tests integrated into the mathematics course. The treatment was administered over an eight-month period.
Chapter IV

RESULTS

Presentation of the Results

The author wished to quantitatively measure the students' attitudes on the four distinct semantic differential surveys testing the two hypotheses. In order to accomplish this, the author gave a numerical value to each individual mark made on the seven-point scales separating each of the 19 polar adjective pairs. This was done by giving a value of seven to the marks closest to the positive polar adjective of each pair, the value of six to the marks in the next position, and so on, down to the mark closest to the negative polar adjective which was given a value of one. Then the sum of the 19 marks on each survey was tabulated to give a score for each respective pretest or posttest.

The author referred to Osgood’s Factor Analyzed List (Osgood et al., 1957) whenever possible in selecting which of the polar adjectives was to be considered the positive term. Individual students, however, may have had different perspectives. For example, “complex” may have appeared to be a more positive term than “simple” to a student in an honors course, or “mysterious” may have been a more positive term than “understandable” to a student who appreciates a challenge. Appendix C contains the numerical values used by the author for each of the polar adjective pairs of the semantic differentials.
Toward Introduction to Calculus. To test the hypothesis, the two-tailed t-test for dependent samples was used at a significance level of 0.05 for 20 degrees of freedom. The number of students (N), the sum of the differences of the pretest and posttest scores (ΣD) taken from the Semantic Differential for Introduction to Calculus, the sum of the differences of the pretest and posttest scores squared (ΣD)², the sum of the squared differences of the pretest and posttest scores (ΣD²), and the computed mean gain score (D) were used in calculating the t-value. A detailed account of the calculation of the t-value is found in Appendix D. A summary of the results of the semantic differential surveys for Introduction to Calculus are presented in Table 1.

<table>
<thead>
<tr>
<th>TESTS</th>
<th>N</th>
<th>ΣD</th>
<th>D</th>
<th>ΣD²</th>
</tr>
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<tbody>
<tr>
<td>PRE- POST-TESTS</td>
<td>21</td>
<td>100</td>
<td>4.76</td>
<td>2070</td>
</tr>
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</table>

\[ t = 2.44^* \quad \text{d.f.} = 20 \quad ^*p < .05 \]

Toward Writing. To test the hypothesis, the two-tailed t-test for dependent samples was used at a significance level of 0.05 for 20 degrees of freedom. The number of students (N), the sum of the
differences of the pretest and posttest scores ($\Sigma D$) taken from the Semantic Differential for Writing, the sum of the differences of the pretest and posttest scores squared ($\Sigma D^2$), the sum of the squared differences of the pretest and posttest scores ($\Sigma D^2$), and the computed mean gain score ($D$) were used in calculating the t-value. A detailed account of the calculation of the t-value is found in Appendix G. A summary of the results of the semantic differential surveys for writing are presented in Table 2.

**TABLE 2**  
DIFFERENCES, MEANS, AND t-VALUE FOR WRITING

<table>
<thead>
<tr>
<th>TESTS</th>
<th>N</th>
<th>$\Sigma D$</th>
<th>$D$</th>
<th>$\Sigma D^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE- POST-TESTS</td>
<td>21</td>
<td>158</td>
<td>7.52</td>
<td>7342</td>
</tr>
</tbody>
</table>

$t = 1.96$  
d.f. = 20  
$p < .05$

Discussion of the Results

The initial part of the discussion of the results of this project relates directly to the two hypotheses stated for this project utilizing the Semantic Differential for Introduction to Calculus and the Semantic Differential for Writing instruments. The author then includes additional observations made from analyzing several
selected aspects of the Likert Instrument for Introduction to Calculus and the Likert Instrument for Writing. Although the latter discussion neither supports nor rejects the findings of the two hypotheses, the author believes that inquiry into these attitudes reflects important information regarding the mathematics and language arts classes and curricula.

**Hypothesis I: Introduction to Calculus.** The calculated t-value of 2.44 is well above the critical value of 2.086 for significance level 0.05 with 20 degrees of freedom. The null hypothesis is rejected; the results are due to factors other than chance or sampling error. Therefore, there was a significant difference between the pretest and posttest mean attitude scores toward Introduction to Calculus after the students had been exposed to the integration of writing with mathematics.

**Hypothesis II: Writing.** The calculated t-value of 1.96 is within the critical value of 2.086 for significance level 0.05 with 20 degrees of freedom. The null hypothesis is not rejected and the results can probably be attributed to chance or sampling error. Therefore, there was not a significant difference between the pretest and posttest mean attitude scores toward writing in the Introduction to Calculus curriculum after the students had been exposed to the integration of writing with mathematics.

The author's interest led her to test the correlation between selected attitude measurements from the four semantic differential
The Product-Moment Correlation Coefficient (Pearson r) formula was used in the calculations.

(Pearson r) Correlation of "Important" and "Positive": The author calculated the correlation coefficient between the adjectives "important" and "positive" using the pretest of the Semantic Differential for Introduction to Calculus. A coefficient of 0.56 which is significant at both the 0.05 and 0.01 levels for 20 degrees of freedom indicated that the two terms were indeed related in this test. The correlation coefficient found between the same two terms in the posttest was 0.73. This number is also significant at both the 0.05 and 0.01 levels for 20 degrees of freedom. This indicated to the author that as the students had a positive experience of Introduction to Calculus they found it to be more important, and as the students found Introduction to Calculus to be important they were more open to making it a positive experience. It seems that the students' expectations as well as their actual experience of the Introduction to Calculus class were both important and positive.

The above procedure was repeated with the Semantic Differential for Writing. The author calculated the correlation coefficient between the adjectives "important" and "positive" using the pretest of the writing semantic differential. A coefficient of 0.31 which is not significant at the 0.05 level for 20 degrees of freedom indicated that, though the two terms showed some correlation, they were not significantly related. The correlation coefficient found between the same two terms in the posttest was 0.57. This number is significant at both the 0.05 and 0.01 levels for 20 degrees of
freedom. Just as with the Introduction to Calculus figures, the correlation coefficient for the writing tests increased from the pretest to the posttest. Although the first coefficient was not significant in this latter test, the coefficient for the posttest was significant. This indicated to the author that as the actual experience of writing became more important, it became a more positive experience, and that as writing became a positive activity it also became more important to the students.

(Pearson r) Correlation of "Clear" and "Valuable". The author calculated the correlation coefficient between the adjectives "clear" and "valuable" using the pretest of the Semantic Differential for Introduction to Calculus. A coefficient of 0.47 which is significant at the 0.05 level for 20 degrees of freedom indicated that the two terms were related in this test. The correlation coefficient found between the same two terms in the posttest was 0.60. This number is significant at both the 0.05 and 0.01 levels for 20 degrees of freedom. This indicated to the author that, as the students experienced clarity in Introduction to Calculus, they found it to be more valuable, and as the students found Introduction to Calculus to be valuable, they were able to more readily clarify the subject matter.

The above procedure was repeated with the Semantic Differential for Writing. The author calculated the correlation coefficient between the adjectives "clear" and "valuable" using the pretest of the writing semantic differential. A coefficient of 0.40 which is not significant at the 0.05 level for 20 degrees of freedom indicated
that though the two terms showed some correlation they were not significantly related. The correlation coefficient found between the same two terms in the posttest was 0.12. This number is also not significant at the 0.05 level for 20 degrees of freedom. In this case the degree of correlation decreased. This indicated to the author that the students perceived little relation between the clarity and the value of writing.

(Pearson r) Correlation of "Successful" in Introduction to Calculus and "Successful" in Writing. The author calculated the correlation coefficient between the adjective "successful" on the posttest of the Semantic Differential for Introduction to Calculus and the adjective "successful" on the posttest of the Semantic Differential for Writing. A correlation coefficient of 0.30 was found. Although this number indicates that the two terms are slightly related, this calculation was not significant at the 0.05 level with 20 degrees of freedom. The author is not surprised to conclude from these numbers that the students do not necessarily associate success in mathematics with success in writing, or vice versa.

The above five relationships were randomly selected by the author. Further time and effort could be devoted to note other significant relationships between the adjectives used in these semantic differential surveys.

The author also inspected the responses given on the two Likert instruments. Two separate charts were compiled indicating the
responses of each individual to each question. A plus sign was used to indicate an answer of YES on the instrument, a minus sign corresponded to an answer of NO, and a zero represented a given answer of UNDECIDED. The total plus, minus, and zero symbols were then tabulated for each respective question. Appendices L and M illustrate the results of these tabulations.

Likert Instrument for Introduction to Calculus. The author was pleased with the positive responses of the students to most of the questions. The author believed in the positive effect of writing in mathematics on the attainment of the Mathematics Course of Study (CSS, 1992) objectives, and this instrument confirmed that the students themselves also perceived this positive effect. Clearly the students affirmed that the integration of writing experiences into their Introduction to Calculus class had helped them to strengthen their basic mathematical foundation by helping them with the following specific objectives:

- to identify the information that is needed in order to solve a mathematical problem (B.8);
- to think logically about a mathematical problem;
- to restate a given mathematical problem in one's own words (B.15);
- to solve mathematical problems involving multiple steps (B.12);
- to decide on a method of solution by examining the structure of a mathematical problem (B.13);
• to recognize how concepts build on or relate to one another;
• to look for a pattern when solving a mathematical problem (B.1);
• to solve a difficult mathematical problem by relating it to a similar problem with which one is familiar (B.14);
• to use a systematic approach to the solution of a mathematical problem (B.13).

On the Likert Instrument for Introduction to Calculus survey, no question had more negative than positive responses. Only one question received more undecided than positive responses: The students were uncertain as to whether the writing experiences helped them to decide whether or not their solution to a mathematical problem was reasonable (G.1).

**Likert Instrument for Writing.** The students' responses regarding the effect on their writing ability of the integration of writing experiences into their mathematics course were generally positive. The author believed that a secondary positive effect would be noticed in the attainment of the Language Arts Course of Study (CSS, 1993) objectives, and this instrument confirmed that the students themselves also perceived some degree of a positive effect. The students' responses reflected that the integration of writing experiences into their Introduction to Calculus class did help them to strengthen their basic writing skills by helping them with the following specific objectives:
• to explain a process through writing
• to communicate ideas through writing (11-6)
• to explain a concept through writing
• to draw conclusions from given information (11-6)
• to develop an expository style of writing (11-7)
• to compare/contrast characteristics of a topic
• to use precise language in writing (11-6)

Three questions on the Likert Instrument for Writing received more negative than positive responses. The students did not perceive that they were better prepared to (a) develop a paragraph according to a topic sentence; (b) check for correct usage of punctuation; or (c) edit writing to include transitional devices within a paragraph. Half of the students were undecided as to whether they had greater confidence in writing their ideas.
Summary

Many Americans openly express anxiety about the way education shapes its future leaders and citizens. Educational leaders have challenged the professionals in their fields to continue to create and promote excellence in education. The National Council of Teachers of Mathematics (NCTM) has specifically called for a change in the way that mathematics is taught and learned in American classrooms. One current innovation to advance mathematical reasoning and problem solving is the incorporation of writing experiences into the mathematics curriculum. It is suggested that these integrated writing experiences can enhance the learning, retention, and use of mathematical skills and concepts and can bring about additional positive outcomes such as improved ability to communicate through the written word and an increase in self-confidence. The purpose of this study was to analyze the attitudes of beginning calculus students toward the integration of writing experiences into the curriculum of the Introduction to Calculus course at a girls' Catholic high school.

Two hypotheses were made at the beginning of this study. The first was that there would be no significant difference between the pretest and posttest mean attitude scores toward Introduction to Calculus after the students had been exposed to a project which
integrated writing with mathematics. Secondly, there would be no significant difference between the pretest and posttest mean attitude scores toward writing in the Introduction to Calculus curriculum after the students had been exposed to a project which integrated writing with mathematics.

Sixty-three young women from grades 11 and 12 were surveyed. These were the members of the three sections of the Introduction to Calculus course taught at an Academy for young women in Northwest Ohio. At the beginning of the school year each girl completed a semantic differential for Introduction to Calculus and a semantic differential for writing. These forms, consisting of 19 polar adjective pairs, were intended to elicit responses about attitudes toward Introduction to Calculus and toward writing. Writing experiences were then integrated into the mathematics curriculum in the form of journal writings and essay test questions. At the end of the school year, after eight months of treatment, each girl completed parallel forms of the original semantic differential surveys. The marks made on these forms were transformed into numerical statistics in order that the hypotheses could be tested quantitatively. In addition to these last two surveys, the author also administered two Likert instruments in order to further analyze the attitudes of the students toward their writing experiences within the mathematics classroom. Although 63 students were surveyed, in order to curb the limitations of the test, only the 21 from the section of the Introduction to Calculus class held in the middle of the day were used in the actual analysis.
The author made two assumptions in conducting this project. First of all, it was assumed that the responses of the Introduction to Calculus students to each of the given surveys would be honest. Secondly, it was assumed that the testing instruments were reliable in that they measured the attitudes that were intended to be measured.

It must be kept in mind that the design of these experiments, $T_1 \times T_2$ and $T_1 \times T_2$, lent itself to limitations. The internal validity of the project was especially threatened by the effect of history, by the natural process of maturation, and by statistical regression. Two sources of external validity were not able to be controlled: the confounding effects of pretesting and the interaction effects of selection and treatment.

For the hypothesis regarding Introduction to Calculus, the calculated t-value of 2.44 was well above the critical value of 2.086 for significance level 0.05 with 20 degrees of freedom. The null hypothesis was rejected indicating that the results were due to factors other than chance or sampling error. Therefore, there was a significant difference between the pretest and posttest mean attitude scores toward Introduction to Calculus after the students had been exposed to the integration of writing with mathematics.

For the hypothesis regarding writing, the calculated t-value of 1.96 was within the critical value of 2.086 for the 0.05 significance level with 20 degrees of freedom. The null hypothesis was not rejected and the results could probably be attributed to chance or sampling error. Therefore, there was not a significant difference between the pretest and posttest mean attitude scores toward
writing in the Introduction to Calculus curriculum after the students had been exposed to the integration of writing with mathematics.

Although the responses to the Likert instruments neither supported nor rejected the findings of the two hypotheses, the author believed that they contained important information. These surveys confirmed that the students themselves perceived that writing in mathematics had a positive effect on their mathematical as well as on their writing skills.

Conclusions

This research project showed that integrating writing experiences into the Introduction to Calculus class did significantly and positively influence the attitudes of the students toward Introduction to Calculus. The project also showed that integrating writing experiences into the Introduction to Calculus class did not significantly influence the attitudes of the students toward writing. It is important to remember that these findings can only be generalized to include the limited population of the Introduction to Calculus students at the particular girls' Catholic high school in which the experiment was conducted.

The responses on the Likert instruments also led the author to conclude that the writing experiences integrated into the mathematics curriculum were a positive means of attaining curriculum objectives in the fields of both mathematics and language arts.
Recommendations

This project has confirmed the author's belief in the benefits of introducing writing into the mathematics curriculum. The author will continue the use of journal writing and essay testing with future Introduction to Calculus classes and will continue to experiment with other types of writing experiences, especially that of freewriting. The author also intends to introduce these experiences to the students of the other mathematics classes that she teaches.

In studying the responses to the Likert instruments the author noted specific areas that might be improved if given greater emphasis. For example, many students were undecided about whether or not writing in Introduction to Calculus helped them with the objective of judging the reasonableness of an answer. The author will take this result as a suggestion to assign specific journal writings in which students are to compute an answer and then judge its reliability or reasonableness. Similarly, in studying the results of the Likert Instrument for Writing, the author believes that modeling examples of student journal entries and essay test responses could improve student confidence in some areas. In particular, the objectives concerning development of a paragraph according to a topic sentence and the use of transitional devices within a paragraph could be strengthened through modeling.

The author recommends that other professionals teaching in mathematics integrate writing experiences into their curriculum. She urges them to experiment to find the methods of writing and
assessment that will fit their personal teaching style and their time limitations.

The author further recommends continued collaboration between professionals of language arts and mathematics. The sharing of expectations, experiences, and results could surface new ideas and practical suggestions to benefit both the students and the teachers of both subject areas.

This study was inspired by the NCTM Standards and publications. With this in mind, the author recommends that mathematics teachers keep abreast of the challenges and enthusiasm of the NCTM.
REFERENCES


science (pp. 48-55). New York: Teachers College, Columbia University.


## Semantic Differential for Introduction to Calculus—Pretest

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<thead>
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<td>Rigid</td>
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59
## Semantic Differential for Introduction to Calculus—Posttest

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Numerical Values Used to Quantitatively Measure Attitudes

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APPENDIX D

Differences, Means, and t-Value for Introduction to Calculus

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100  2070
t-Value Calculations

Semantic Differential for Introduction to Calculus

\[ t = \frac{D}{\sqrt{\left(\Sigma D^2 - \frac{(\Sigma D)^2}{N}\right) / N(N - 1)}}^{(1/2)} \]

\[
\begin{align*}
\Sigma D &= 100 \\
D &= 4.76 \\
\Sigma D^2 &= 2070 \\
(\Sigma D)^2 &= 10000 \\
N &= 21
\end{align*}
\]

\[ t = \frac{4.76}{\sqrt{\left(2070 - \frac{10000}{21}\right) / 21(20)}}^{(1/2)} \]

\[ t = \frac{4.76}{\sqrt{1593.81 / 420}}^{(1/2)} \]

\[ t = 4.76 / 1.95 \]

\[ t = 2.44 \] (Calculated t-Value)
## Semantic Differential for Writing—Pretest

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### APPENDIX G

**Differences, Means, and t-Value for Writing**

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Total: 158 for 7342
t-Value Calculations

Semantic Differential for Writing

t = \frac{D}{\left[ \left( \Sigma D^2 - \frac{(\Sigma D)^2}{N} \right) / N(N - 1) \right]^{(1/2)}}

\Sigma D = 158 \quad D = 7.52 \quad \Sigma D^2 = 7342 \quad (\Sigma D)^2 = 24964 \quad N = 21

t = \frac{7.52}{\left[ \frac{7342 - \frac{24964}{21}}{21(20)} \right]^{(1/2)}}

t = \frac{7.52}{\left[ \frac{6153.24}{420} \right]^{(1/2)}}

t = \frac{7.52}{3.83}

t = 1.96 \quad \text{(Calculated t-Value)}
APPENDIX H

Likert Instrument for Introduction to Calculus—Pilot Test

CIRCLE

YES if you agree with the statement
NO if you do not agree with the statement
UNDECIDED if you cannot agree or disagree with the statement

Integrating writing experiences into our Introduction to Calculus class has DEFINITELY helped me...

YES NO UNDECIDED 1. to look for a pattern when solving a mathematics problem.

YES NO UNDECIDED 2. to solve mathematical problems involving multiple steps.

YES NO UNDECIDED 3. to examine the structure of a given mathematical problem in order to decide on a method of solution.

YES NO UNDECIDED 4. to use a systematic approach to the solution of a mathematical problem.

YES NO UNDECIDED 5. to decide whether or not my solution to a mathematical problem is reasonable.

YES NO UNDECIDED 6. to identify the information that is needed in order to solve a mathematical problem.

YES NO UNDECIDED 7. to account for all possibilities when solving a mathematical problem.
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<td>to solve a difficult mathematical problem by breaking it down into simpler problems.</td>
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<td>9.</td>
<td>to solve a difficult mathematical problem by relating it to a similar problem with which I am familiar.</td>
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<tr>
<td>10.</td>
<td>to restate a given mathematical problem in my own words.</td>
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Please give your honest response in a few sentences.

What suggestions would you give the teacher to improve learning through the process of writing in a mathematics class?
APPENDIX I

Likert Instrument for Introduction to Calculus

CIRCLE

YES if you agree with the statement
NO if you do not agree with the statement
UNDECIDED if you cannot agree or disagree with the statement

Integrating writing experiences into our Introduction to Calculus class has DEFINITELY helped me...

YES NO UNDECIDED 1. to look for a pattern when solving a mathematical problem.
YES NO UNDECIDED 2. to solve mathematical problems involving multiple steps.
YES NO UNDECIDED 3. to decide on a method of solution by examining the structure of a mathematical problem.
YES NO UNDECIDED 4. to use a systematic approach to the solution of a mathematical problem.
YES NO UNDECIDED 5. to decide whether or not my solution to a mathematical problem is reasonable.
YES NO UNDECIDED 6. to identify the information that is needed in order to solve a mathematical problem.
YES NO UNDECIDED 7. to account for all possibilities when solving a mathematical problem.
YES NO UNDECIDED 8. to solve a difficult mathematical problem by breaking it down into simpler problems.

YES NO UNDECIDED 9. to solve a difficult mathematical problem by relating it to a similar problem with which I am familiar.

YES NO UNDECIDED 10. to restate a given mathematical problem in my own words.

YES NO UNDECIDED 11. to think logically about a mathematical problem.

YES NO UNDECIDED 12. to be less dependent on the use of memorized formulas in order to solve mathematical problems.

YES NO UNDECIDED 13. to understand a whole concept rather than only fragments of it.

YES NO UNDECIDED 14. to recognize how concepts build on or relate to one another.

YES NO UNDECIDED 15. to strengthen my basic foundation in mathematics.

Please give your honest response in a few sentences. *

What suggestions would you give the teacher to improve learning through the process of writing in a mathematics class?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

* This question was answered by each student but did not influence the outcome of this study.
APPENDIX J

Likert Instrument for Writing—Pilot Test

CIRCLE

YES if you agree with the statement
NO if you do not agree with the statement
UNDECIDED if you cannot agree or disagree with the statement

Integrating writing experiences into our Introduction to Calculus class has DEFINITELY helped me...

YES NO UNDECIDED 1. to write my ideas with fluency.
YES NO UNDECIDED 2. to write my ideas with confidence.
YES NO UNDECIDED 3. to develop a paragraph according to a topic sentence.
YES NO UNDECIDED 4. to write with a vocabulary directed toward a particular audience.
YES NO UNDECIDED 5. to use precise language in relating my ideas through writing.
YES NO UNDECIDED 6. to check for correct usage of punctuation.
YES NO UNDECIDED 7. to draw conclusions from given information.
YES NO UNDECIDED 8. to compare/contrast characteristics in writing.
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<td>10.</td>
<td>to edit writing to include transitional devices within a paragraph.</td>
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Please give your honest response in a few sentences.

What suggestions would you give to future students to help them learn through the process of writing in their math class?
Likert Instrument for Writing

CIRCLE

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Integrating writing experiences into our Introduction to Calculus class has DEFINITELY helped me...

YES NO UNDECIDED 1. to communicate my ideas through writing.

YES NO UNDECIDED 2. to communicate my feelings through writing.

YES NO UNDECIDED 3. to write my ideas with fluency.

YES NO UNDECIDED 4. to write my ideas with confidence.

YES NO UNDECIDED 5. to develop a paragraph according to a topic sentence.

YES NO UNDECIDED 6. to write with a vocabulary directed toward a particular audience.

YES NO UNDECIDED 7. to use precise language in relating my ideas through writing.

YES NO UNDECIDED 8. to check for correct usage of punctuation.
YES  NO  UNDECIDED  9. to draw conclusions from given information.

YES  NO  UNDECIDED  10. to compare/contrast characteristics of a topic.

YES  NO  UNDECIDED  11. to explain a process through writing.

YES  NO  UNDECIDED  12. to explain a concept through writing.

YES  NO  UNDECIDED  13. to edit writing to include transitional devices within a paragraph.

YES  NO  UNDECIDED  14. to develop an expository style of writing.

Please give your honest response in a few sentences. *

What recommendations would you give to future students to help them learn through the process of writing in their mathematics class?

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

* This question was answered by each student but did not influence the outcome of this study.
APPENDIX L

Data for Likert Instrument for Introduction to Calculus

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# APPENDIX M

## Data for Likert Instrument for Writing

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