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REVISION IN TASKS OF WRITING TO LEARN IN COLLEGE MATHEMATICS: THE CASE FOR INSTRUCTIONAL SUPPORT

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

David L. White

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ABSTRACT

The researcher and two teachers of college developmental mathematics collaboratively planned three tasks of writing to learn in mathematics which involved instructional support and a chance for revising. Given these three tasks, the study was designed to examine students' writings for length, syntactic maturity, and cognitive operations and the teachers' and students' perceptions of these tasks.

Teachers were interviewed and classrooms observed. Students' writings were collected and analyzed. Scores on chapter tests currently in use by the teachers were also collected. Toward the end of the study, students answered a questionnaire about the writing.

Students' second drafts were longer at statistically significant levels than their first drafts on two length measures for two tasks. The syntactic maturity of the drafts was judged to be low, comparable to low-functioning high school students on three measures of syntax for all three tasks. Their revisions in the first and second tasks were made at rather "high" linguistic levels as compared to other studies for both basic and accomplished high school students. In the first and second tasks, students used revision strategies of addition, deletion, and substitution almost exclusively. However, in the third task, the use of the

scheme employed to analyze revisions was judged inadequate to capture the changes students made between first and second drafts. Cognitive operations interacted with task, with students' use of four cognitive operations (contrast, change, time sequences, and logical sequence) statistically different between the three writing tasks. Scores on chapter tests were somewhat higher for students in two writing-aided classrooms as compared to scores of students in two non-writing aided classrooms taught by the two teachers, but these differences were not statistically significant.

Both teachers perceived these tasks as unusual tasks for a college mathematics classroom. They thought the tasks helped students and gave the teachers information about students' understandings of mathematics, information which was more detailed but of a different nature as compared to similar information they might receive from other sources.

Teachers were differentiated in their implementation of the writing tasks, their responses to students' writing, their perceptions of the three writing tasks, and in their perceptions of writing in general by a writing-experienced/ inexperienced dichotomy. Several actions on the part of the teachers characterized their support in instruction for the writing, both in drafting and revising.

Students thought that the tasks, including the chance to revise, helped them in their mathematics class in a number of ways, but saw the tasks as difficult ones to carry out.

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CHAPTER 1

BACKGROUND OF THE STUDY

Introduction

At the K-12 level, most of the writing that students do is brief, often a report of facts or discrete bits of information with little elaboration. Seldom does the K-12 classroom offer students the opportunity for rethinking or revising their writing. Often, there are few supports for the processes of writing in general or for the processes of revision in particular. Most of the writing done in K-12 classrooms is used (1) for the purpose of evaluating the quality of the writing (as when English teachers evaluate writing for its clarity, organization, or conformity to the conventions of standard written English [SWE]), or (2) for the purpose of evaluating the quality of the information contained in the writing (as when teachers in the content areas evaluate term papers or reports for accurate recall of information). In fact, most of the writing done in schools, K-12, is used primarily as a way to examine students. Applebee (1981) found that in American high schools most writing is used to test student knowledge and that little

writing is done for audiences other than the teacher as examiner.

Likewise, at the college level, writing is often used by teachers either (1) for the purpose of evaluating the quality of the writing (as in freshman composition courses), or (2) for the purpose of evaluating the presence and presentation of discipline-related knowledge (as when students write term papers, reports, and essay examinations in the various disciplines). In a survey of 322 post secondary institutions, Griffin (1985) found that only 139 or about one third of these institutions had in operation any form of writing program attempting to implement writing in the content areas for purposes other than writing-as-testing.

This predominance of writing-as-testing is, however, being challenged at the college level by those interested in writing across the curriculum (WAC), and, specifically, by those interested in using writing-to-learn tasks within the framework of WAC.

Background of the Problem

Under the rubric of WAC, some tasks of writing are being used by teachers for purposes other than simply that of writing-as-testing. WAC has become a recognized movement that focuses on non-testing uses of writing in content area classrooms at the college and pre-college level. Several

recent works have attempted to bridge the gap between theoretical calls for non-testing uses of writing and practical classroom tasks of writing. Many have detailed the rationale for WAC, the movement itself, or its application to the classroom (Odell, 1980; Irmscher, 1979; Herrington, 1981; Griffin, 1982; Bader & Pearce, 1983; Griffin, 1985) while others--notably professional writers--have shown how writing leads to the creation of new knowledge on the part of the writer (Murray, 1987) and to enhanced understanding of the topics written about (Zinsser, 1980).

Others have chronicled the assumptions of the WAC movement. Bizelle & Herzberg (1986) trace the movement's ideas about the uses of expressive writing (in which the writer makes sense of experience through the resource of his own personal language) to the London school which includes James Britton (1970) and Nancy Martin (1976), through Janet Emig's (1977) argument for writing to "become a central means to constitute ... knowledge" (p. 342) in all areas of the curriculum, to later WAC programs in the United States (cf. Wilson, 1988). A general consensus seems to have arisen among the various proponents of the WAC movement. This consensus, according to Griffin (1985), centers on three general concepts central to the WAC movement: (1) Writing as a skill must be practiced throughout the entire curriculum. (2) Written discourse is central to academic thought. (3) "To write is to learn" (p. 403). Griffin's notions above center on learning

to write (writing as a learned skill), on writing as a particular way of approaching and sharing academic content (writing to communicate inside the academic community), and on writing as a way to learn. Before we look closely at this third concept--the one that will be central to the argument here--we need to look briefly at the other two concepts of writing as they appear in the practice of writing across the curriculum proponents. The first two of Griffin's notions will be discussed together as "writing to communicate".

At the level of practice, writing to communicate shows up in the college classroom as writing-intensive courses of study, incorporating tasks of writing that use written language, text structures, and forms which are peculiar to specific disciplines (that is, learning to write inside a particular academic discourse in order to communicate with other members of the discourse community). In writing to communicate, students are asked to learn common forms of written discourse typical of a particular discipline in order to communicate to self and then to a known audience within that discipline the contents of that discipline. For example, in a college engineering class, students might write a technical report to a supervisor following up on a class assignment or project and, in so doing, would become "aware of how much their [future professional] welfare depends on their ability to communicate in writing" (Mett, 1987). These classroom tasks of writing to communicate are designed to

mimic the actual writing done by accomplished members of the particular academic community or of the field or profession for which it trains its students. The rationale for writing to communicate comes from the desire to make students a part of a given discourse community. Impetus to have students write to communicate also comes from studies of actual writing done in particular workplaces and the kinds of knowledge (audience awareness, audience demands, text structures, formats and so forth) used by such writing (Odell and Goswami, 1982). Across the writing to communicate approaches, students are asked to learn to write and to act through writing in certain prescribed ways, in effect to learn the culture of a particular academic discourse, what has been called the community of academe or the "larger intellectual/ethical context of a liberal education" (North, 1986).

By contrast, writing to learn asks students to focus not on learning to write, on forms or conventions, or on wider audiences, but on the content being written about. As students are involved in writing-to-learn tasks, they are asked to think about particular ideas and explore those ideas in ways that help them explain the ideas to themselves. Using their own language and personal rather than public forms (that is, expressive writing as it is termed by Britton [1970]), writing to learn takes as its purpose helping students explore connections among bits of knowledge or ideas, or helping students make connections between ideas and their own personal

knowledge and prior world knowledge--to explore, question, connect, contrast, clarify, and define ideas for their own learning. Whereas writing to communicate takes others as the primary audience for the finished written product, writing to learn takes the self or a trusted other as the primary audience for the written product. While proponents of writing to communicate see the written product and conventions of written discourse as important outcomes of the process of learning to write in particular ways, proponents of writing to learn sees learning about ideas as important outcomes of the writing process. And while proponents of writing to communicate see the written product as an important artifact and end result, proponents of writing to learn see as important the processes, thinking, and learning which students engage in while writing.

On a more practice-centered level, Fulwiller (1987) has compiled a useful compendium of essays dealing with classroom tasks of writing to learn at the college level as has Tuchudi (1986). Petersen (1982) gives an early sourcebook enumerating writing-to-learn practices across a wide variety of content fields at the college and pre-college level while Gere (1985) has collected a variety of such practices at the pre-college level. An examination of these volumes reveals the major points of departure between these classroom uses of WAC in its guises of writing to communicate and writing to learn. A useful contrast of the two is given by Wilson (1987).

As WAC and writing to learn grow as tools for learning inside classrooms, teachers and researchers have become interested in formulating tasks of writing to learn that can be used in particular content area classrooms. More and more, interest has grown in using writing to learn inside those classrooms where heretofore such tasks of writing to learn have not been used. One such area of increasing interest is the use of writing to learn in mathematics.

Statement of the Problem

Writing to learn in mathematics is a relatively new area of interest, one that is increasingly receiving attention in the literature of writing and mathematics. Yet much remains to be done to help mathematics teachers use writing to learn, and much remains yet to be learned about writing to learn in the mathematics classroom: its demands, its processes, its outcomes.

Most mathematics teachers have, of course, little experience in dealing with writing in the classroom. Although they may be able to draw upon their own secondary and college experiences of being students and using writing, these experiences probably center on learning to write rather than on writing to learn since writing to learn has not been a typical activity with any focussed or widespread use in any content area classroom during the past few decades. Nor is

it likely that mathematics teachers have been asked to use writing in their own formal induction into teaching since calls for using writing in mathematics education courses have been relatively recent (Watson, 1980) and few (Burton, 1985; Goldberg, 1983). Further, most mathematics teachers do not see themselves as writers (White, 1987), and only recently have workshops or inservice programs been developed to offer mathematics teachers any training in using writing to learn in the mathematics classroom (McMillen, 1986; Turner, 1989). In short, like many practitioners outside the English classroom, mathematics teachers have little training and less experience with writing in general and with writing to learn in their disciplines.

Yet when mathematics teachers use writing themselves, they often gain new perceptions about writing. They find that writing can be a powerful tool for helping them learn and integrate new mathematics knowledge, for helping them reflect on their own teaching practices and beliefs, and for assisting them in clarifying, elaborating, and defining ideas about mathematics and mathematics teaching (White & Dunn, 1989).

Acting upon these perceptions about writing by translating them into classroom action requires a great deal of work on the part of teachers and interveners or collaborators. One reason why translating these perceptions about writing into action in the classroom is difficult is that mathematics teachers have few models and little

information about using writing to learn in the mathematics classroom. Besides being relatively recent, using writing to learn in the mathematics classroom also places many demands upon teachers, demands that are atypical of the usual teacher work in the mathematics classroom. If mathematics teachers are to use tasks of writing to learn, they must formulate writing tasks which are designed to achieve instructional goals that already exist. They must somehow integrate these tasks into their repertoire of classroom routines, teaching actions, assessment and evaluation strategies, and grading practices. And they must do so in such a way as to assure that the writing tasks become integral to the mathematics instruction (Bell & Bell, 1989).

Further, mathematics teachers often need help in exploring the characteristics of the writing processes in general so that they may facilitate student learning; more specifically, mathematics teachers must be assisted if the full range of the processes of writing are to unfold in the classroom and if the full power of thinking and revision possible during the writing processes is to be brought to bear upon tasks of writing to learn in mathematics (Miller & England, 1987; Pearce & Davison, 1987). Several recent reports of using writing to learn in the mathematics classroom have shown that how the writing process is managed greatly effects the learning of mathematics content that takes place (Davison & Pearce, 1988a; Keith, 1988). Assisting

mathematics teachers in taking advantage of the full range of writing processes within tasks of writing to learn thus seems to be a little understood but vital goal of investigation.

Research Questions

The present study was designed to examine several characteristics of students' writing and the perceptions of teachers and students about the use of writing to learn when teachers plan and implement writing-to-learn tasks in mathematics and when revision is involved in the writing. Those characteristics of students' writing to be examined include the length of drafts, their syntactic maturity, the level of revision (whether the revision takes place at the level of the word, phrase, clause, or T-unit [a T-unit consists of an independent clause and its associated subordinate clause(s)]), the strategy of revision (whether the revision takes place by addition, deletion, substitution, re-ordering, or embedding of information) and the cognitive operations that seem to be represented in the writing.

Specifically, the study was designed to examine several questions about tasks of writing to learn in mathematics: (1) What are the lengths of drafts students produce in completing these tasks, both before and after revision? (2) What are the levels of syntactic maturity of the final drafts in these tasks? (3) What are the levels of revision students use when

they revise their drafts? (4) What are the revision strategies students use when they revise their drafts? (5) What are the cognitive operations students appear to use when they write such drafts? (6) What are teacher and student perceptions of drafting and revising for these writing-to-learn tasks in the mathematics classroom?

Significance of the Study

Several teachers and researchers who have undertaken research into the use of tasks of writing to learn in mathematics (Bell & Bell, 1985; Pearce & Davison, 1987) have called for structuring writing-to-learn tasks inside process-oriented approaches (including revising) and embedding these writing tasks more fully in on-going mathematics instruction.

Other researchers have called specifically for the use of revision in tasks of writing to learn in mathematics. Fennell and Ammons (1985) suggest that rewriting and revising assist students when they complete tasks of writing to learn in mathematics and suggest that teachers demonstrate to students revision activities such as adding, deleting, and re-ordering information in their writing about mathematics as part of the teachers' support for the writing process in the mathematics class. Keith (1988) claims that students should routinely be asked to revise their drafts after teacher comments on the

writing and that such support for revision allows students to "reconstruct their own answers" and rethink their original, sometimes faulty notions about mathematics through the writing. Pearce and Davison (1987), investigating the writing tasks used by junior high school mathematics teachers, claim that "increased attention to aspects of the composition process [including prewriting and revision] would result in an increase" (p. 13) in the efficacy of writing-to-learn tasks in mathematics and would promote "more reflective, analytical attitudes" (p. 14) on the part of students towards the mathematics problems they write about. Elsewhere (Davison and Pearce, 1988a), they state that

> if students are expected to write, then they should, at least, be allowed to explore what they ... have written ... [and should be] required to rewrite or revise initial written efforts, especially if those initial efforts are inaccurate (p. 14).

They further claim that, to be an instructional or learning activity, tasks of writing to learn in mathematics should involve revision as part of the instructional support for learning that teachers provide.

However, we still need to know more about the ways such writing-to-learn tasks may evoke the features of writing that have been shown elsewhere to be occasions for learning: elaboration (through length of drafting), revision at a variety of levels, varying revision strategies, and cognitive processing (Martin, 1976; Emig, 1977; Odell, 1977, 1980).

By studying these features of written language used in

tasks of writing to learn in mathematics, we may be able to understand more fully the nature of these tasks and better design such tasks and accompanying instructional support.

If teachers recognize some of the resources from writing that students bring to these tasks (including a range of precesses in writing), they may be able to communicate to students those resources that come into play and thus alert students to making conscious use of these resources for using written language which the students may bring with them to the mathematics class. Similarly, if teachers recognize some of the cognitive operations evoked in certain writing to learn tasks, they may be able to communicate to students the cognitive operations that come into play and thus alert students to making conscious use of these operations. Moreover, as we increase our knowledge of the features of revising that aid students' learning, teachers can alert students to their use and usefulness.

Further, as teachers take advantage of these features of writing to learn, they may be able to structure such tasks of writing in better ways and so foster learning. If teachers come to recognize the power of these features, they may see for themselves the effects these tasks bring about and have a stronger rationale for the use of these tasks and thus be better prepared to begin and sustain their use.

As teachers themselves become more aware of the nature of writing to learn, as they find ways to support

process-oriented approaches to writing to learn including support for revision, as they are able to identify the written language resources and cognitive operations students use in the tasks, and as they find a stronger rationale for using such tasks to foster learning in the mathematics classroom, we may be able to improve the power of certain writing-to-learn tasks in the mathematics classroom and thus aid students and teachers in using them.

Assumptions

In this study I am making several basic assumptions about tasks of writing to learn: (1) Tasks of writing to learn foster students' learning. (2) Writing to learn in mathematics provides mathematics students with opportunities for learning mathematics content. (3) Providing instructional support for tasks of writing to learn, including calls for revision, allows students to handle the demands of writing and provides expanded opportunities to learn mathematics. (4) Students in college mathematics classes bring with them knowledge and abilities in writing that are sufficient for them to focus on the mathematics content rather than on the writing per se during their completion of tasks of writing to learn.

I am assuming that writing to learn, as a part of the WAC movement, fosters learning. Research has demonstrated that tasks of writing to learn call upon students to use language

as a tool for learning and that language provides students with tools that encourage the exploration of ideas, the elaboration of meaning, and the establishment of connections among ideas. These ideas are expanded later in the discussion of Emig's (1977) work. I am assuming that writing itself offers students the use of cognitive operations (Odell, 1977) which may foster these explorations, elaborations, and connections among ideas.

As applied to mathematics, I am assuming that writing provides mathematics students with the opportunity to learn. Initial research suggests that mathematics students may profit from writing about mathematics topics and that writing about mathematics topics allows them to explore ideas about mathematics, elaborate upon their prior knowledge in mathematics, and establish connections for themselves and so actively learn new mathematics information by using the structure of written language to assist in their learning. These ideas are explored in greater detail later (see the discussion by Evans [1984]; Bell & Bell [1985]; and Lesnak [1989]).

I am assuming that as teachers provide instructional support for writing, including support for revision, they allow students to focus more of their attention on the ideas they develop in their writing and, through revision, return to those ideas to rethink and reconsider them. Specifically, as teachers respond to students' writings and encourage students

through written comments on the writing and through calls for revision, students may have additional chances to explore, elaborate, and establish explicit connections among mathematics ideas. As students attempt in second drafts to deal with teacher comments and suggestions, they may have the opportunity to increase mathematics knowledge or to amend faulty understandings through revising their and completing a second draft.

Finally, I am assuming that college mathematics students bring with them sufficient knowledge and abilities to focus in their writing on the ideas they write about rather than on the writing per se. In encouraging students to use writer-based rather than reader-based prose and by encouraging students to produce informal and personal pieces intended for a trusted audience, teachers help students focus on the ideas they deal with in the writing rather than on the form, audience, or the conventions of SWE. By encouraging students in these ways, teachers help reduce the formal demands of tasks of writing and so help students focus on the content of the writing as opposed to the form.

Limitations

The design of the study is limited in several ways and does not control for a number of factors among students, teachers, and tasks.

(1) The study does not control for several student factors which may affect students' learning through writing. There is no control of students' writing abilities, no control of students' mathematics abilities, and no comparisons between writing ability and mathematics abilities. Also, there is no control of student's writing attitudes, no control of students' mathematics attitudes, and no comparisons between ability or attitude in writing or mathematics.

(2) The study does not control for task factors such as the effects of differing writing topics (e.g., it does not set out to compare writing to learn about first order equations with writing to learn about polynomials). It does not control for task factors involving mathematics content (e.g., it does not compare writing to learn about arithmetic topics with writing to learn about algebra topics), for the effects of differing mathematics processes (e.g., the solving or routine exercises versus problem solving), or for mathematics teaching methodologies (e.g., checking homework versus guided practice in class).

(3) The study does not control for the order of presentation of tasks or topics.

(4) The study does not separate out or control for the effects of "composing without writing" (Graves' [1972] designation for the revision that takes place before drafting), the effects of "internal revision" (Murray's [1978] term for the process of altering one's own

understanding of an idea after the writing takes place), the effects of "shaping at the point of utterance" (Britton's [1980] term for revising while drafting), or the effects of other facets of revision, even though the study involves an examination of some aspects of revision in certain tasks of writing to learn in mathematics.

In sum, the design of the study limits the generalizability of the results in a number of ways.

The study is restricted to an examination of three particular revision tasks in two sections of a college developmental mathematics course taught by two teachers. The study was limited to an examination of three writing tasks on three different topics as students generate short, informal pieces of writing inside a mathematics classroom whose teachers collaboratively plan with the researcher to support the writing process.

Definition of Terms

For the purposes of this study, several definitions will be made.

(1) "WAC" (writing across the curriculum) refers to attempts to incorporate writing into classrooms that traditionally have used writing only as a means of testing; that is, WAC refers to attempts to use writing to accomplish specific goals, especially student learning, in the classrooms

of disciplines outside of English and language arts-oriented disciplines.

(2) "Writing to communicate" refers to attempts to use writing to initiate students or novices into a specific discipline in order that they may gain command of genre and other conventions of the written discourse particular to that discourse community.

(3) "Writing to learn" refers to using tasks of writing to facilitate student learning of academic content, especially within the framework of WAC.

(4) "Syntactic maturity" refers to the relative complexity of certain syntactic structures manipulated by students in their writing. The usage of the term here follows that in O'Donnell (1976). (Examples of three measures of syntactic maturity are given below, page 111-114.)

(5) "Revision" is defined as overt written changes between first and second drafts as indicated by the level and strategy of revision used as students revise their drafts.

(6) Again, as stated before, "level of revision" refers to whether revising takes place at the word, phrase, clause, or sentence level (Bridwell, 1980).

(7) "Revision strategy" refers to whether revision occurs by the operation of addition, deletion, substitution, re-ordering, or embedding of instances of revision (Mohanan, 1984).

(8) Length of written products is defined as the number

of words per draft and the number of T-units per draft (Hunt, 1965). Again, as stated before, a T-unit consists of a main clause and its accompanying subordinate clause(s), the term more frequently used in the current literature than Loban's (1976) C-unit, which he applied to both oral and written language.

(9) "Cognitive operation" follows Odell's (1980) usage. Using the term "intellectual processes" in an earlier work, Odell (1977) defined these as the "conscious mental activities involved in thinking [which can be identified by certain] linguistic cues ... in the surface structure of written or spoken language" (p. 108). Odell posits that these cognitive operations are signaled by certain linguistic features ("cues") in the text which students produce. These linguistic cues "help us determine what intellectual processes a writer is using" as he writes and thinks through a topic. These cues in the students' texts include signals of contrast, classification, change, physical context, time sequence, and logical sequence. Most specifically, "cognitive operations" refers in this study to these linguistic cues in the written text that students produce.

The study will employ particular tasks of writing to learn. To describe these tasks and emphasize their differences from tasks of writing in their composition classes, these tasks will be referred to for teachers and students as "informal" writing (cf. Britton's [1975] use of

the terms "informal writing" and "personal writing"). Informal writing is essentially writer-based rather than reader-based prose (Flower & Hayes, 1977). These tasks are to be designed following principles for constructing writing-to-learn tasks in mathematics as detailed in the review of the literature.

Summary

In this chapter were introduced some of the notions underlying efforts in WAC to use writing as a tool for learning in school settings. Workers in WAC have utilized the ideas of writing to communicate and writing to learn and have implemented tasks of writing to learn in content area classrooms to accomplish the learning objectives already in place in those classrooms. Writing has been shown to help writers create knowledge for themselves and enhance their understanding of the topics they write about. Research that has been carried out in writing to learn in mathematics suggests that tasks of writing to learn can foster learning in mathematics. Research also suggests, however, that more attention needs to be given to providing instructional support to mathematics students, including support for revision, as part of implementing tasks of writing to learn.

This study is designed to use tasks of writing to learn in a college mathematics classroom and explores six questions

about students' writing and the perceptions of teachers and students about the use of writing to learn in mathematics when instructional support and calls for revision are included as part of the task of writing to learn.

In Chapter 2 is reviewed the research related to writing to learn in mathematics; an argument is advanced that, although tasks of writing to learn have been shown to foster learning in mathematics, the use of such tasks remains somewhat problematic since most researchers note that tasks of writing to learn in mathematics need to be embedded in instructional support to a greater extent than has been the case in the past. The research also suggests that such support, including revision, would lead to better use of the tasks by teachers and more effective learning of mathematics content by students.

In Chapter 3 is detailed the design of the present study, including collaborative planning of tasks of writing to learn in mathematics and instructional support for the tasks. In the chapter are described the methods of data collection, including an ethnographic strand to document teacher perceptions of the use of writing tasks as well as students' perceptions of the tasks. Also described are three revision conditions and the collection of students' writing, teachers' responses to the writing, and scores on chapter tests.

In Chapter 4 is given the method of analyses for the ethnographic components, including the thematic analysis, and

the method of analyses for the length, syntactic maturity, and cognitive operations evident in students' writings. In Chapter 4 is also given the method of analysis for students' scores on chapter tests.

In Chapter 5 is displayed the results of the analyses. The results chronicle teachers' perceptions of the three tasks of writing to learn in mathematics used in the study, teachers' perceptions of writing in general, the methodological and procedural issues pertaining to the classroom implementation of the writing tasks, students' patterns of revision, the cognitive operations seen in the writing, the greater length of the second drafts, and the relationship of writing tasks to learning outcomes as seen in teacher-constructed chapter tests.

In Chapter 6 is listed findings from the results of the analyses. In it is given conclusions relating to the six research questions and relating to other issues raised during the study. In the chapter is discussed also the findings and conclusions, including procedural writing; ways teachers read, responded to, and used the content of the students' writings; and in it is detailed also the kinds of instructional support for writing and revising given by the teachers during the study. The chapter concludes with seven suggestions for further research.

CHAPTER 2

REVIEW OF THE LITERATURE

Using Language to Learn

James Britton, in his influential Language and Learning (1970), pointed out the strong contribution language can make to learning both inside and outside the classroom. To many, Britton's work has become a central source for thinking about how language users employ of language in the classroom and how teachers can take advantage of this built-in resource for learning that students bring with them to the classroom. In fact, most of the work done in writing to learn begins with the work of Britton and his colleagues. In their work, they argue that language becomes a powerful resource for exploring the world of things and ideas. For educators, their work demonstrates how language becomes a starting point for active, engaged learning in the classroom (cf. Martin, 1977).

In discussing the uses of language, Britton contrasts three principal uses of language. These three uses include the poetic, the transactional, and the expressive. The poetic uses of language are those which involve language for the sake of language, the creation of beauty in language, an aesthetic

to be contemplated for its artistry.

A second use of language that Britton posits is the transactional use of language, that is, uses of language to get things done, to do the work of the world. Here language users use language for pragmatic or practical ends; they participate in the world; they use language to accomplish the ends they want from others: asking for a raise, reporting ideas to a supervisor, writing a letter of complaint to the local newspaper, writing an excuse to a sick child's teacher. The transactional uses of language found early proponents among those who wished to introduce writing into the mathematics classroom (see for example, Kennedy, 1985; Hosmer, 1986).

A third use of language is the expressive use of language; this is the use of language that is most cogent here. In expressive uses of language, language users make sense of the world to themselves and for themselves, exploring the world and attempting via their linguistic resources to categorize, compare, show causality, and in general to explain the myriad facets of experience to themselves through language. This is the use of language which is private, usually not shared publicly, or shared only with a trusted audience, and which is directed to the self or trusted other as a way to explain and discover. In writing, the expressive uses of language include discovering, exploring, capturing thought on paper, investigating, becoming tentative, making

guesses, sometimes exploring blind alleys thereby externalizing the fleeting thoughts of the mind and attempting, in short, to think on paper (cf. Zissner, 1988).

The expressive use of language appears in both oral and written form. While the prime focus of Britton's Language and Learning is the uses of language within a developmental framework, he demonstrates how the poetic, transactional, and expressive uses of language may work as a resource for the learner. But, according to Britton, written (as opposed to oral) language brings additional resources to writers. While both speech and writing can be used for their expressive function, writing allows writers to systematize and codify thought in special ways through those conventions particular to written language. It can capture ideas for later study and thereby enhance thinking (Emig, 1977). Written language as opposed to oral language, then, seems to call forth additional different processes, makes different demands, and provides other resources. The theoretical grounds for these a claims about writing are espoused by Emig, to whom I now turn.

Writing to Learn

The nature of writing is such that writing itself helps in learning. Indeed, writing and learning have many similarities. Noting these similarities, Emig (1977) sees writing as involving processes of "originating and creating a

unique verbal construct that is graphically recorded" (p. 123). Explicating Vygotsky, Luria, and Bruner, she posits that the "higher cognitive functions, such as analysis and syntheses, seem to develop most fully only with the support system of verbal language-- particularly, it seems, of written language" (p. 122).

What exactly are those characteristics of writing that seem similar to learning, which seem to foster learning, or which can be used as resources during learning? According to Emig, writing, like learning, provides feedback and reinforcement in its permanent graphic recording and in the ability of the writer to "re-scan" what he has written (that is, to re-read and, possibly, later revise); it uses propositions, hypotheses and summaries; it is active, engaged, personal, self-rhythmed; it "requires the establishment of systematic connections and relationships [between ideas], whether they be co-ordinate, subordinate, superordinate, causal, or something other" (p. 126); and it involves "the fullest possible functioning of the brain" (p. 125) in its simultaneous use of hand, eye, and mind.

Other educators have suggested that writing can play a vital role in learning in specific content areas. Lehr (1980), reviewing the literature of writing to learn a decade ago, suggests that writing provides students with "valuable tools for thinking and learning" (p. 25) in many content areas and that "writing is a means by which students contend with

new information, discover relationships and clarify their own ideas" (p. 23). Others have agreed with Emig and suggested that learning is enhanced by specific tasks of writing because of its use of learning strategies during the process of writing (Odell, 1979; Irmscher, 1979).

The writing-to-learn approach suggests that students using writing are active participants in the teaching/learning relationship, that students have much to contribute to the relationship and that the process of writing engages students in creating knowledge through the use of written language and that writing, in Herrington's words, "provides at once the way for [students] to discover and communicate" (p. 379) that knowledge. Odell (1980) asserts that "some of the cognitive activities that enable one to understand a subject are the same activities that enable one to formulate and support the assertions one makes in one's writing" (p. 145)-- activities such as exploring, creating, testing, and refining hypotheses. Because of its linguistic and cognitive demands, writing can be "a way of learning about anything and everything" (Odell, 1988, p. 241).

As it brings this wide range of resources, writing offers an important adjunct to learning. Writing can aid learning as writers use the expressive function of written language, since writing brings its own demands and resources, and because it parallels learning in many ways. Writing captures ideas for later reflection. Written language makes possible the

creation of new connections between ideas because writing by its nature emphasizes connections between ideas at the semantic, syntactic, and text levels and allows through re-reading and revision for continued reflection about the ideas captured on paper. Writing allows for later re-scanning and returns to the captured ideas and connections previously established between ideas so that writers may clarify, extend, reshape, re-think and revise their prior ideas. It actively engages learners in content, makes them self-aware, more consciously in control of their learning (Irmscher, 1979), can provide a written record of the entire process of learning, and engages them in meaning-making and meaning-reshaping. In short, writing is, in Emig's words, "a unique mode of learning" (p. 122).

Writing to Learn in Mathematics

Tasks of writing to learn have typically been used in disciplines emphasizing verbal learning (cf. Gere, 1988). However, some reports have begun to suggest strongly that writing to learn can also aid students in the mathematics classroom. These reports argue that some tasks of writing to learn can aid students in understanding mathematics content at a variety of grade levels, across a variety of mathematics topics, and can assist teachers in instruction in a variety of ways.

Early attempts to use tasks of writing to learn in mathematics at the college level often grew out of projects and programs for WAC sponsored by English faculty in collaboration with mathematics teachers. Thaiss (1982), Herrington (1981), and Maimon (1986) describe such projects which included writing to learn in mathematics. In their early attempts, researchers and teachers often found difficulty in adapting writing tasks to the mathematics classroom, all too often favoring the transactional at the expense of the expressive function of writing. However, as these projects began to re-examine the roots of the writing to learn approach, they often re-centered themselves by returning to the work of Britton and his colleagues and the original language across the curriculum movement from the British schools. Parker (1985) reviews the language across the curriculum movement and details its general aims and some of its methods. Soon, as the separate roles of expressive and transactional language were re-emphasized, writing to learn in mathematics gained momentum. (For an example of this grounding in the expressive and transactional uses of language and its effects on tasks of writing to learn in mathematics, see King [1982].)

However, because writing to learn in mathematics constitutes a relatively recent approach, it may be profitable to make the case for its use in mathematics at the college and precollege levels first by referring to the few empirical

studies that have been reported in the literature thus far.

Writing to Learn in Mathematics: Reports of Empirical Studies

Several recent empirical studies have attempted to show how particular tasks of writing can foster learning in mathematics. In a study of elementary classrooms, Evans (1984) found that writing assisted fifth grade students to understand geometry and, to a lesser extent, multiplication. In her study, Evans asked her students to write about mathematics in order to increase their understanding of mathematics. Tasks of writing included (1) explanations of how to solve a problem, addressed to an audience that knew less about mathematics than did the students, (2) definitions of key concepts and ideas which gave "students the chance to describe something new in their own familiar terms" (p. 831), and (3) explanations of "troubleshooting" in which students analyzed their errors on homework assignments and on tests. Evans used textbook-supplied tests as pre- and post measures for instructional units in geometry and multiplication. Results showed high test score gains for her students as compared to students in a comparison group taught by another teacher who had her students use no tasks of writing. Rather interestingly, results seemed to be greater for lower achieving students than for higher achieving mathematics students; Evans states that "those students in the study with

the lowest pretest scores made the most gains" (p. 834).

In a study of ninth grade mathematics students, Bell and Bell (1985) examined the link between tasks of writing and learning mathematics. Like the Evans study, the Bell and Bell study attempted to show that particular tasks of writing could be used to help students learn mathematics content. Unlike the Evans study, however, they focussed on problem solving rather than on computation. In an experimental-control design experiment, Bell and Bell contrasted the learning of mathematical problem solving in classrooms using writing (the experimental group) versus classrooms using traditional mathematics instruction (the control group). Tasks of writing to learn for the experimental group asked students (1) to record the steps and strategies they used in solving particular problems, (2) to evaluate problems and justify their explanations as to whether these problems could be solved or not, and (3) to develop and then to write their own problems from given materials and to write explanations of possible solutions to these problems. Students in the control group did no writing, but other traditional mathematics instructional methodologies were claimed to be fairly consistent between the two groups. Students were then tested in their problem solving ability. The researchers found that students in the writing classroom out-performed students in the traditional classroom on tests of problem solving. The researchers summarize by stating that "students who wrote

about their activities performed better as mathematical problem solvers than those who did not" (p. 219). Bell and Bell hypothesize that writing enabled students to clarify for themselves what they were doing and to develop a greater self awareness (monitoring) of their own processes of problem solving. They also concluded that reading the written products produced by students in the experimental classroom gave the teacher a greater amount and depth of information about students and their mathematics knowledge by communicating to the teacher "when they [students] were having difficulty understanding the material" (p. 219), in effect, assisting teachers in assessing students' knowledge of mathematics.

At the college level, Paik and Norris (1984) studied the effects of journal writing (a kind of expressive writing as we have used that term here) on the final examination scores of students in their intact business statistics course. The two asked for volunteers from the class to participate in their study. These volunteers were randomly and blindly assigned to a control (no writing) or to an experimental (journal writing) group; that is, Paik and Norris did not know which students were in which group until at the end of the study. The students in the control group did no writing but did more of the usual class assignments, while the students in the experimental group were asked to write journal entries and submit them periodically. In a rather unusual situation for

writing-to-learn tasks, no responses were made to the journals, although they were read and returned to students. In the usual final exam for the course, the experimental group scored an average of 13 points higher than did the control group with results statistically significant at the .05 level.

Despite the evidence that writing to learn can assist students in learning mathematics content in many classrooms, some research points out problems encountered in implementing writing-to-learn tasks. In another study (Hirsch & King, 1983), college algebra students were asked to do a series of tasks of informal writing to learn algebra. Students were asked to respond to a number of writing prompts, but teachers were instructed to be "non-directive" and not to respond to the writing produced. Not surprisingly, the researchers found that neither teachers nor students viewed the writing as an integral part of the mathematics class; that neither the writing (experimental) nor the no-writing (control) group differed significantly on a post-measure of mathematics ability (the departmental final examination in the course); but that there were no detrimental effects upon the writing group in terms of learning mathematics. This finding suggests the advisability of making writing-to-learn tasks an integral part of the classroom, especially by responding to students' writings.

When writing was made an integral part of a remedial college algebra course, Lesnak (1989) found that writing

helped students score better on the usual computational tests in the course than did the usual instruction. In his own classroom, Lesnak developed a series of writing assignments centered around the objectives already in place in his college remedial algebra course. These assignments asked students to complete tasks such as the following in a unit on solving arithmetic equations and inequalities:

> Every time students claim that they do not know how to proceed in the solution of an equation, require them to write the four steps they have learned in order to get themselves moving again toward a solution (p. 151).

After each unit, students in both the control (no writing) and experimental (writing) sections completed the usual unit tests in the course. By the end of the course, the average score across all unit tests for students in the control sections was 74%, while the average score across all unit tests for students in the experimental sections was 77%. While the difference was small and while most of the writing was transactional in function, Lesnak states that writing was received favorably by the students and that the

> writing to learn activities not only helped [students'] academic skills but also raised their levels of confidence and created more positive attitudes toward the learning of algebra (p. 155).

While these reports suggest that these particular tasks of writing helped students learn mathematics at both the

computational and problem solving levels, many other reports offer anecdotal evidence and informal support that writing can assist student learning in mathematics. They represent a growing notion of the possible importance of the role of written language in assisting students' learning mathematics content. Notable also is the fact that this set of reports offers what is probably the strongest statements supporting the use of writing to learn mathematics. It is to these anecdotal reports that I will now turn.

Writing to Learn in Mathematics: Reports of Non-Empirical Studies

Among this second set of reports are informal studies of college mathematics classrooms. Bemiller (1987) used learning logs or "notebooks," asking his students to make "constant recordings of observations" (p. 300) of mathematical concepts, which students compiled into course notebooks during a college algebra class. These notebooks consisted of transactional writing of classnotes, responses to writing prompts about mathematics content, and expressive writing including journal-like pieces, focused freewrites, and personal writing in which students were asked, in effect, to reflect on their "entire psychological, physiological, emotional and social" (p. 306) state in terms of the class. Reviewing the notebooks so compiled, Bemiller concluded that these writing-to-learn tasks focused his students' attention on manipulating ideas,

concepts, and symbolic representations of mathematical content; allowed students a personal, constructive representation of ideas so that they could interact with these ideas and so "visualize more interrelationships and better expositions of those ideas" (p. 301); encouraged "attention to the task of learning" (p. 301); and, finally, fostered learning by allowing both teacher and student to monitor the on-going progress of learning and its attendant feeling states in students.

Mett (1987) also used tasks of writing to learn in a college classroom, in this case a college calculus class. She used expressive writing tasks which she termed "learning logs" (essentially mathematics-oriented journals of the learning students saw themselves doing while carrying out the usual classroom mathematics assignments); in addition, she used focused freewrites before, during, and after class presentations to assist students in formulating and explaining to themselves the mathematics content from out-of-class assignments; and formal writing tasks in assigned, out-of-class projects. She found that these writing assignments assisted students in becoming "better problem solvers" (p. 534), "prepare[d] minds to be receptive to a new and difficult concept" (p. 535-6), increased students' ability to talk about mathematics content with other students, and increased communication between students and teachers. Similarly, Nahrgang & Peterson (1986) asked students to keep

private journals in their college algebra and calculus classes and found that they allowed students "the opportunity to work informally and personally on mathematical concepts, using their own language and real-world experiences" (p. 461).

In addition, teachers and researchers at the precollege level have lent their support to the usefulness of expressive writing tasks in the mathematics classroom. Several have shown how tasks of expressive writing assist high school and junior high students in learning mathematics through tasks of journal writing (Healy, 1981), through writing their own problems at the elementary level (Hosmer, 1986) or at the high school level (Johnson, 1983), through writing real-world scenarios corresponding to geometric expressions and proofs (Gesslin, 1977), or through writing real-world scenarios corresponding to two-variable, two equation expressions (Venne, 1988). Still others have used mainly transactional writing tasks to assist students in learning mathematics through writing letters at the elementary level (Kennedy, 1983) and at the secondary level (Schmidt, 1985). Yet others have used a combination of both expressive and transactional writing tasks to assist students in learning mathematics (Keith, 1988; Shaw, 1983).

In reviewing these reports of anecdotal and informal studies supporting the usefulness of tasks of writing to learn mathematics, Madigan (1987) has compiled a detailed list of resources which use both transactional and expressive tasks at

the college level and Kenyon (1989) has done likewise at the pre-college levels. In a summary of the effects of these tasks, Madigan summarizes that "writing is an effective way to teach [mathematical] content, not just to learn it" (p. 245) and that tasks of writing to learn in mathematics "can be used to teach course content in every class room" (p. 245) while Kenyon states that writing to learn mathematics aids students as they "begin to gather, formulate, and organize old and new knowledge, concepts and strategies, and to synthesize this information as a new structure that becomes a part of their own knowledge network" (199).

Writing to Learn in Mathematics: Instructional Support for Tasks of Writing

It seems, then, that many researchers and practitioners have found that using tasks of writing to learn mathematics can be an effective practice that mathematics teachers may use to foster learning of mathematics content in their classrooms. However, several investigators and practitioners have shown that difficulties attend the planning and subsequent implementation of writing-to-learn tasks in the mathematics classroom.

Part of the difficulty in planning and implementation lies in the use of supportive instructional approaches when writing to learn is brought into the mathematics classroom. Keith (1988) gives what is possibly the most forceful argument

that mathematics teachers must provide strong instructional support for their students as they begin to use tasks of writing to learn. She states that in her early work with writing tasks she provided little help to students in producing drafts and few occasions for re-working the writing; however, as she worked with these tasks in the classroom, she found that it was more productive to "approach writing as part of a process" (717), that is, to approach writing by embedding it in what is typical in instruction--supplying students with needed help in initial attempts and then later lessening some of the support as they internalize new strategies and structures and become more confident in performing new tasks and interconnecting tasks so that old learning re-enforces new. Keith argues that writing to learn in mathematics, if it is to be successful in terms of learning, must be surrounded by instruction such as (1) discussion of the content of the writing, (2) peer evaluation and response to the written products, (3) revision of the ideas and the writing itself, and (4) what she terms "anticipation" in which the writing serves as a prelude to deeper analyses of the mathematics topics being considered.

Conversely, when the process of writing is given little attention and when the instructional support surrounding tasks of writing to learn in mathematics is faulty or absent, the results are often disappointing. Pearce & Davison (1987) studied writing tasks taking place in the classrooms of 31

junior high mathematics teachers. Using teacher interviews, reviews of lesson plans and student work, and some classroom observation, they found little writing taking place: they found that in these classrooms "writing appeared to be an infrequently used technique," that the writing which did in fact take place was mostly at what they termed the translation (copying) level, and that instructional support for "the writing process (e.g. prewriting and revision) were rare to non-existent" (p. 13). However, they argue that "the attainment of instructional objectives [in mathematics] would be enhanced through increased use of writing in mathematics classrooms" (p. 13) and call for more collaborative work with mathematics teachers to enable them to better use tasks of writing-to-learn. The two suggest that the teachers in their study "would profit from inservice efforts in ways that could incorporate writing into their classroom" (p. 13) and that the incidence of writing activities would increase if teachers were given such help. They further state that such efforts would promote a more reflective, analytical attitude towards the study of mathematics by mathematics students. Additionally, Fennell & Ammons (1985) state that mathematics teachers need to know much more about the process of writing than they presently do if they are to support such tasks and implement them effectively into the classroom. Indeed, Hirsch and King (1983) found that writing is not helpful to students and teachers when little instructional support was

built in, especially when prewriting, drafting, and revision, reading and responding to the writing are absent; they further argue that teachers must "integrate [tasks of writing] into the math class" (14).

Despite these calls for using writing to learn in the mathematics classroom and calls for helping teachers offer instructional support for these opportunities to learn from writing, little help now exists for mathematics teachers. In looking at the textbook series mathematics teachers commonly use, Davison & Pearce (1988a) found that this situation obtains even in textbooks and the accompanying teachers' guides. In a review of five textbook series widely used at the junior high level, Davison and Pearce examined textbooks at two grade levels; they found the textbooks they examined offered a median of only 17 to 18 writing activities per text, representing fewer than one writing activity for every two weeks of instructional time. Often those writing activities, however, were brief and report-like, allowing--it would seem--little chance for the expressive functions of writing and learning from writing. The two conclude of the texts they examined that "there was a scarcity of activities calling for longer ... [or] original writing" (p. 497) on the part of students, that teachers were offered little help in implementing and supporting activities suggested in the texts, that there was "relatively little assistance or structure given to students through the use of prewriting activities or

revision opportunities", that there was "little or no instructional support, and no assistance for teachers on how to use writing in their mathematics classes in either the form of explanation or additional references" (p. 498). Because of the paucity of such help for mathematics teachers to incorporate writing to learn activities, other reports have noted the need for outside collaboration when mathematics teachers attempt to incorporate tasks of writing to learn even when teachers are willing and eager to do so (cf. Thaiss, 1982; Maimon, 1986; Davison and Pearce, 1988a, 1988b).

One successful effort at collaboration, however, has been reported. Miller and England (1989) worked with high school algebra teachers. They found that careful planning for instructional support for writing was an important component of their undertaking and that tasks of writing to learn must be carefully embedded in instruction. They argue that while the tasks of writing to learn in their study greatly aided student understanding and affect, "teachers need time and assistance in planning a writing-to-learn program" (p. 309). Notably, they say, this collaboration needs to include careful consideration of the prompt for writing, of which they say "the simpler and more direct..., the better" (p. 310). Interestingly, Miller and England note that writing had many unexpected benefits including (1) a greater insight on the part of teachers into the teaching of algebra, (2) improved student attitudes towards mathematics, and (3)better academic

performance by students. They also claim that

> [i]f teachers learn how to become better teachers of algebra through the analysis of students' writing in algebra, then the benefits of improved instruction will follow (311).

Writing to Learn in Mathematics: A Summary of Principles for Constructing and Implementing Tasks of Writing to Learn

Much of what we know about writing in academic settings suggests that what students learn while engaged in any task of writing (including tasks of writing to learn) is sensitive to the context (including instructional support) in which it takes place (Langer & Applebee, 1984). Similarly, what students learn while engaged in tasks of writing to learn is sensitive to the particular tasks which are chosen for students to complete (Langer & Applebee, 1987; and cf. Gere, 1985). What we know of writing and tasks of writing to learn suggests that this sensitivity to context and task holds true for tasks of writing to learn mathematics just as it does for writing to learn in other disciplines (for a review of such notions of context-sensitivity see Ackerman [1993]). Thus, to choose particular tasks of writing-to- learn and to embed them into mathematics instruction, the teacher or investigator must keep in mind several principles which are evident from the work in this area as discussed above.

(1) Teachers and students must see tasks of writing to learn in mathematics as part of the on-going instruction in mathematics already in place.

(2) Teachers must plan these tasks of writing to learn in mathematics so that they address those goals and objectives already in existence in the mathematics classroom.

(3) The writing tasks must focus on mathematics content rather than the formal aspects of writing.

(4) The instructional support for these tasks (including planning, implementation, evaluation and assessment of them) must continue to address mathematics content (writing-to-learn) rather than formal aspects of writing (as is the case in approaches centering on writing-to-communicate or learning to write).

(5) The writing must begin as writer-based prose if it is to allow students to explore, be tentative, and take chances to learn content rather than forms.

(6) The audience for the writing must begin and remain the self or trusted other before additional shaping is done.

(7) To allow for the full resources of writing to be brought to bear (resources which the student already brings with him to the mathematics classroom), students need to engage in a variety of writing processes and strategies including pre- writing, drafting, and revising processes.

When these principles are followed, research suggests,

students are able to take advantage of a fuller range of resources available to them when they complete tasks of writing- to-learn.

Summary of the Review of Literature

Research is beginning to suggest that tasks of writing to learn in mathematics aid students and teachers in many ways: in learning new concepts; in exploring and linking new ideas to old; in interweaving and exploring connections between ideas, experience, and feelings; in monitoring the learning that takes place; and in helping teachers and students monitor these and other processes and outcomes of the entire instructional context. However, in order to implement such tasks effectively, mathematics teachers and collaborators need to embed these tasks into instruction. Doing so calls for careful efforts in planning and implementation with much attention to the tasks themselves and to a wider range of writing processes students engage in while writing, including prewriting, re-reading, responding, and revising. How this may take place in the college mathematics classroom is the object of this study.

Chapter 3

METHOD OF DATA COLLECTION

This study examined the use of tasks of writing to learn in college developmental mathematics classes when students revised their writings about mathematics topics and were aided in their writing by their mathematics instructors.

Research Questions

The research questions guiding the study include the following: (1) What are the lengths of drafts students produce in completing these tasks, both before and after revision? (2) What are the levels of syntactic maturity of the final drafts in these tasks? (3) What are the levels of revision students use when they revise their drafts? (4) What are the revision strategies students use when they revise their drafts? (5) What are the cognitive operations students appear to use when they write such drafts? (6) What are teacher and student perceptions of drafting and revising for these tasks of writing to learn in mathematics?

Overview of the Study

Participants in the study were two college mathematics instructors and their students in four sections of a college developmental mathematics course. Two college mathematics instructors were selected on the basis of each instructor's (1) willingness to participate in the study, (2) interest in and willingness to plan and implement tasks of writing to learn mathematics, and (3) willingness to open her classrooms to observation during the study. Two sections, one from each instructor, were selected as "writing-aided" sections while two other sections of the same course, one from each instructor, were designated as "non-writing aided" sections. Two case study students, one from each writing-aided section, were nominated for informal interviews based on teacher recommendations of students who (1) were "average" in that classroom, (2)were able to verbalize well, and (3)were willing to cooperate in six informal interviews, each lasting approximately thirty minutes.

The researcher and instructors cooperatively planned three tasks of writing designed to help students learn the mathematics topics currently being addressed by these teachers. Each task so planned was used in the two writing-aided classrooms of the two teachers. Each task was planned so that (1) the tasks directly addressed the topics currently being taught in the classes, (2) the tasks were seen

by the teachers and students as part of the on-going instruction in the classes, (3) the tasks were focused on learning mathematics topics rather than on formal aspects of writing or learning to write, and (4) each task was written by students during a portion of one class session, responded to by the teacher, and revised by students during a later class session.

A total of four classrooms were visited and fieldnotes and tape recordings made. Later, transcripts of tape recordings were made of those sections of interest (general classroom patterns of instruction, mathematics topics addressed and developed, teachers' references to mathematics topics or thinking addressed in the writing, and how writing is incorporated into the on-going instruction in the classroom).

Teachers were interviewed and fieldnotes and tape recordings made of each interview. Teachers were interviewed before the tasks of writing to learn were used, as the teachers and researcher cooperatively planned the tasks, as each teacher read and responded to the writing produced by the students, and after each class session in which the writing tasks were used. Later, transcripts of tape recordings were made of those sections of interest: (1) teachers' perceptions of general classroom patterns of instruction, (2) mathematics topics addressed and developed, (3) how the writing does or does not address the teaching and learning of particular

mathematics topics, and (4) how the writing was incorporated into the on-going instruction in the classroom.

Two case study students were selected as described above, interviewed, and fieldnotes and tape recordings made. However, these were later abandoned because the two student eventually dropped out of their mathematics classes. An ad hoc questionnaire concerning student perceptions of the writing tasks was substituted. The questionnaire, like the writing tasks, was collaboratively developed during interviews with the two teachers and was administered to students in the two "writing-aided" classrooms; then, a classroom discussion led by the researcher was held in each of the two classrooms after the questionnaire was completed by students. The interviews with the instructors to develop the questionnaire were pooled with other teacher interviews and used as additional interview information.

Writings done by the students were also holistically rated by teachers as they sorted student papers into four stacks representing the teachers' judgment of students' understanding of mathematics content.

Test scores were collected from "chapter" tests that were currently in use by teachers in the four classrooms during the time of the study.

The writing produced by students was collected to be analyzed later.

Selection: Setting and Participants

The college selected for the site of the study is a community college at which I am currently employed as a faculty member in the English department. For purposes of reporting here, I will call the college Lakeridge Community College. (This and all names of persons reported in the study, including names of teachers and students, are pseudonyms.) After securing approval from appropriate administrative officials at the college, I contacted the chair of the mathematics department and asked for nominations of full time faculty members in the department who might be interested in collaborating with me in the study. From the five persons she suggested, one taught only one section of a developmental class. Of the four remaining, two faculty members met the criteria for selection as discussed above.

The Setting

Lakeridge State Community College is located in the upper East Tennessee area, in the region south of the Tri-Cities and north of Knoxville. Geographically, the college is situated within the ridge and valley system of the tributaries of the Tennessee River. Students are drawn from within a seven county service area bounded on the east by the Smokey Mountains and on the west by the northern stretches of the Cumberland Plateau. As were other Tennessee community

colleges, Lakeridge State was located, at its inception in 1970, so as to be accessible within a 30-40 mile commuting distance of students.

Economically, the area is dominated by the tourism, chemical, furniture, and small electronics industries. According to the college's estimates, the average income of households in the area was approximately $13,000 in 1990.

According to the college's Assistant Director of Minority Student Development, the student body of the college reflects the demographics of its service region in terms of minority student enrollment. In the service region, slightly more than 5% of the adult population is of African-American descent. The college's student enrollment, approximately 5,400 full time equivalent in the Fall of 1992, is 95.4% white, with blacks making up 3.24% of total enrollment and accounting for almost all of the non-white students enrolled. Most students receive some sort of financial aid. Most students major in technical, non-transfer degree programs. The average age of students on campus is 28, indicating the large proportion of non-traditional age students in the student body.

Since the college is a part of the Tennessee Board of Regents (TBR) system, its admissions requirements follow an "open door" policy. In 1985, the TBR instituted its Academic Admissions and Placement Procedure, which actively places most Lakeridge students as they enter the college's admission

process. Under this TBR policy, all students who are 21 years of age or older and all younger students who score 19 or lower on any section of the ACT test are remanded for academic testing and placement upon admission. Because of the make up of the student body, approximately 95% of all students are currently tested upon admission in the areas of mathematics, writing (English composition), and reading. Housed under the umbrella of the Developmental Studies Program, testing and placement remands about 98% of all the students who were tested into one or more courses in the mathematics requirement, about 80% in the writing requirement, and about 40% in the reading requirement. These data are estimates given by the college's Director of Developmental Studies and are based on 1990 enrollment figures.

Students who are required to enroll in developmental mathematics may be remanded into one or more of the following courses: arithmetic, elementary algebra, or intermediate algebra. These courses are taught within the mathematics department, primarily staffed by teachers whose major assignment is teaching such courses, although a significant portion of other full- and part-time mathematics faculty teach in this area also.

The mathematics department uses evaluation and grading procedures in the developmental mathematics courses at Lakeridge State based upon modified principles of mastery learning. In traditional mastery learning arrangements,

students receive instruction in course content until they can make a passing grade (in this case, 70%) on tests. If students fail a test, they re-study the material and re-take tests until they reach a satisfactory grade on the test and then proceed to the next unit of instruction. In the developmental mathematics courses at Lakeridge, students who do not receive a passing score on a test must retake that test but may do so only once. The score on the second test is used in computing grades for the course.

The department-wide course syllabus at Lakeridge State lists the following topics for instruction in "intermediate algebra," the course which was used as the focus of the present study: (1) factoring algebraic expressions and using factoring to solve equations, (2) simplifying or solving rational expressions and equations, (3) graphing and applying the various forms of linear equations and linear inequalities, (4) solving and graphing systems of equations and inequalities, (5) simplifying or solving radical expressions and equations, (6) solving and graphing quadratic equations and inequalities, and (7) identifying functions and relations.

In the present study, the two teachers who cooperated in the project have their primary teaching assignment within the developmental mathematics courses although they each usually taught at least one 1000-level (college freshman) mathematics course every academic year. Both taught two sections of intermediate algebra during the Spring term of 1993.

The Participants

The participants in the study included two college developmental mathematics teachers, selected as described above, and their students in four sections of a course in intermediate algebra.

One teacher, J, is a mid-career teacher, a white mainstream professional. She was educated in public institutions in East Tennessee. She grew up in White Pine, Tennessee, a small largely-rural community which is located in the foothills of the mountains and within the present service area of Lakeridge State. She attended public schools in that community through the ninth grade. As a junior and senior she attended a consolidated high school in a nearby county, where, as she says, she "went from a high school where there was probably 250 students in the school to a high school where there were 2,000." As an undergraduate she attended the University of Tennessee, Knoxville, from 1970 to 1974, graduating with a BS in education, majoring in mathematics and related sciences. She began teaching in the Fall of 1974, and returned to school part time and summers to work on an MS in education which she completed in 1978. While working on her masters degree, she continued teaching high school mathematics and science for a total of eight years.

In 1980, she began teaching developmental mathematics for Lakeridge State in the evening school. In 1982, she resigned her high school position and, after the birth of two children,

returned to teaching part time for Lakeridge until 1987. In 1987, she was hired as a full time faculty member and is currently assistant professor of mathematics. At Lakeridge she has taught developmental mathematics and freshman-level courses in mathematics for six years and was, in 1990, made supervisor over the developmental mathematics program. This year, she also received an award from the Lakeridge President as the Distinguished Faculty Member for 1992-93.

In 1990, J and I collaborated in using tasks of writing in the mathematics classroom. In that earlier collaboration, J used a few tasks of writing that I suggested to her since she had approached me about doing so from hearing me speak on the topic at a state professional meeting. She says that she has used writing tasks once or twice since then but found the mathematics curriculum too "full" to find time to use them consistently or on any regular basis.

The second teacher, L, is also a mid-career, white, mainstream teacher. She was educated in the public schools of Magnolia, Mississippi, a small town in the southern part of the state. As an undergraduate she attended the University of Southern Mississippi from 1962 until 1966, graduating with a BS, with a major in mathematics and a minor in education. She began teaching in a junior high school, teaching algebra in Huntsville, Alabama. She taught there for one year then took a five year leave upon the birth of a child. She returned to teaching at Donelson Junior High School in Nashville,

Tennessee where for five years she taught in an individually-paced mathematics classroom. She and her family then moved back to Mississippi to the same area where L grew up. There she taught Title I mathematics at the local junior high school for a year before moving within in the same system to teaching high school mathematics, which she taught for the next 11 years. While in Mississippi, L took a master degree in education, also at the University of Southern Mississippi.

L was hired at Lakeridge as a full time instructor of mathematics in 1989. She has taught there for the last four years and is currently instructor of mathematics.

Prior to this study, L and I were professionally acquainted as fellow faculty members teaching on the same college campus but had not collaborated professionally and knew each other only in passing. In one of the interviews, L did state that she had tried some "writing across the curriculum" assignments in one of her classroom when she first came to Lakeridge but that her students didn't 'like' them, so she abandoned those assignments.

Students in the four classrooms were predominately first and second semester freshmen at Lakeridge. Like most of their classmates in developmental mathematics, most were also required to take one or more courses in developmental or basic writing and/or reading. The ages of students were about evenly divided between traditional freshmen (who come to college recently or immediately after graduating from high

school) and non-traditional freshmen (who come to college after a rather lengthy hiatus, or who come after taking the GED).

Enrollment in the four classrooms decreased significantly during the 12 weeks of the study, a common occurrence, according to both teachers. Table 3.1 gives the data for the enrollment changes during the time of the study. In the table, "beginning" data apply to mid-January enrollment while "ending" data apply to late-April.

In all of the four classrooms, females outnumber males by about 2 to 1.

Procedures of the Study

Once the instructors and classrooms were selected, I spent approximately twelve weeks interviewing teachers, visiting classrooms, and talking informally with students. I became both a participant (as a student in the classrooms) and an observer (as a relatively disinterested third party in the classroom and interviewer with the teachers) in order to observe and participate in the "details of daily life and activity enacted by people who have become relatively indifferent to, and unabashed by, the presence of a foreigner" (Pelto and Pelto, 1970, p. 68). This time span approximated the middle twelve weeks of the fifteen-week semester.

Table 3.1
Beginning and Ending Enrollment
in the Classrooms During the Study

class meeting time	beginning enrollment	ending enrollment
J's Classes		
Monday-Wednesday-Friday (writing aided class)	25	20
Tuesday-Thursday (non-writing aided class)	36	22
L's Classes		
Monday-Wednesday-Friday (non-writing aided class)	36	20
Tuesday-Thursday (writing aided class)	30	21

Teacher Interviews

Fieldnotes and tape recordings of teacher interviews were made for each interview during the study. The fieldnotes themselves took two forms: (1) handwritten fieldnotes taken during the interviews and (2) several reconstructed and reflective pieces written about the interviews immediately after the interviews took place. These two forms of the fieldnotes served to "flesh out" the picture of each interview as it emerged from the tape recordings.

Most of the interviews were unstructured in the sense that we had no written agenda for discussion, but, in general, the interviews centered on what had occurred in the classrooms since the interviews took place immediately after class sessions for both J and L. In a few instances, I did prepare written questions for the interview in response to my having reviewed fieldnotes or tape recordings of classrooms or earlier interviews, but in most cases the interviews focused on the give and take of classrooms, planning for classrooms, and making sense of classrooms.

In the early weeks of the study, teachers were interviewed before the tasks of writing were planned. In these interviews, the instructors and I discussed the general design of the study, the purpose of tasks of writing-to-learn in the mathematics classroom, the mathematics topics under study in the classrooms, plans the instructors had for

teaching particular topics, and students in general and in particular. Early on in the interviews, we discussed the criteria I had established for selecting case study students, the criteria for constructing topics for writing about mathematics, and revision conditions. Both J and L agreed to these criteria. These first interviews occurred about every other day and spanned about the first two weeks of the study. Later, the interviews centered on planning the three writing tasks to be used in the study. We collaboratively planned tasks of writing which we thought would address the needs of the instructors in helping students master mathematics content. Planning sessions, in addition to their primary function as ways to co-operatively plan the writing tasks, also were used as occasions for exploring teacher perceptions of using writing in general and in the particular tasks we planned. During the time when the planned writing tasks were implemented, the interviews consisted mainly of de-briefing sessions. De-briefing sessions took place after most of the classroom sessions I visited and after each writing task took place. De-briefing sessions centered on attempts to understand from the teacher's perspective the writing and the context in which it took place. When the writing tasks were implemented in the classroom, de-briefing sessions also included a sorting task (Pelto & Pelto, 1970) of the students' writing. In the sorting task, teachers were asked to sort each set of writings into two stacks: those representing high

understanding of the mathematics at hand and those representing low; a second, similar sorting of each stack was then made, resulting in four stacks of papers ranging from representations of high to low understanding of the mathematics topics as judged by the instructors. From time to time, interviews took place on other occasions also, with topics centered on my attempts to clarify my understandings of what the instructors were doing in the classrooms I visited as a participant or in planning sessions or had said in interviews. I conducted a total of 36 interviews with the two teachers. These interviews ranged in length from 20 minutes (the shortest) to 95 minutes (the longest); most interviews lasted about 30 to 40 minutes.

Each interview was captured in fieldnotes and tape recordings. Later, the fieldnotes and tape recordings of the interviews were used to produce transcripts of the interviews. Table 3.2 presents a summary of the teacher interview data. Also, as the study progressed, I attempted, as far as time permitted, to listen to each tape recording and re-read the fieldnotes of the interviews so as to refine my emerging understanding of the teachers' perceptions as stated in the interviews by questioning teachers about their earlier statements. During the interviews, this took the form of reporting back to them what they had said earlier and juxtaposing seemingly contradictory statements. At other times, this took the form of my offering my own conclusions,

Table 3.2
Summary of Data Sources for Teacher Interview Data

Data Source	Count
With L	
interviews conducted:	17 interviews
fieldnotes of interviews:	26 pages, handwritten
transcripts of interviews:	88 pages, typed single-spaced
With J	
interviews conducted:	16 interviews
fieldnotes of interviews:	20 pages, handwritten
transcripts of interviews:	58 pages, typed single-spaced
Totals	
interviews conducted:	33 interviews
fieldnotes of interviews:	46 pages, handwritten
transcripts of interviews:	146 pages, typed single-spaced

inferences, and interpretations for the teachers to respond to.

Classroom Observations

Fieldnotes and tape recordings of classrooms were made of each of the class sessions I visited while participating in the four classrooms of the study. These fieldnotes, too, took two forms: (1) handwritten fieldnotes taken during the class session, and (2) reflective pieces written later about the classroom. These fieldnotes served to guide my use of the tape recordings of the classrooms.

As I visited the classrooms, I participated to an extent as a student myself. The material under discussion was sometimes a review of mostly-forgotten topics and sometimes an introduction to topics new to me, and I often saw each of the two instructors present the same topics twice. As a participant in the classrooms I visited, I completed some homework assignments, did all in-class problem sets, took tests, and wrote all the planning and "unplanned" writing tasks implemented in the writing-aided classrooms. In L's writing-aided classroom, which met for two and a half hours twice per week, I also went on class breaks with students.

As stated above, two of the classrooms were designated as non-writing aided classrooms, indicating that the instructors agreed not to use any writing tasks in those classrooms. The

purpose of my visits to these classrooms was to ensure that such was the case. For that reason, fieldnotes sufficed in these classrooms, although some of these classrooms, too, were tape recorded to provide substantiation that no writing took place, if such substantiation were needed, or to record the use of these tasks should they be used. In the writing-aided classrooms, each classroom I visited was tape recorded and fieldnotes made. The primary purpose of visiting the two writing-aided classrooms was to note general patterns of instruction, to watch how the two instructors implemented the writing tasks we planned, and to gather information about the classroom context in which those tasks were implemented.

I visited a total of 36 class sessions in both the writing centered and non-writing centered classroom for a total of approximately 25 clock-hours in J's classrooms and a total of 38.5 clock-hours of observation in L's. Table 3.3 presents a summary of the classroom observation data.

As both participant and observer in the four classrooms, I was introduced to the students in the two writing-aided classrooms. To one of the students in J's classroom (the case study student) and to four of the students in L's classroom, I was already known: I had taught these five students in a developmental composition course one semester earlier. These students, especially, and others too provided me with insights into the classrooms, insights that prompted me with further questions and material for the teacher interviews.

Table 3.3
Summary of Data Sources for Classroom Observations

Data Source	Count
L's Classrooms	
visits to classrooms:	19 visits
clock hours of observation:	38 hours
fieldnotes of classrooms:	81 pages, handwritten
J's Classrooms	
visits to classrooms:	17 visits
clock hours of observation:	25 hours
fieldnotes of classrooms:	91 pages, handwritten
Totals	
visits to classrooms:	36 visits
clock hours of observation:	63 hours
fieldnotes of classrooms:	172 pages, handwritten

Planning the Writing Tasks

The two teachers and I cooperatively planned a total of three writing tasks to be used by them in their classrooms. These three tasks were planned to conform to several previously-established criteria and to follow the principles for constructing tasks of writing to learn in mathematics as detailed in the review of literature, above, and as discussed by several writers in the field of using writing in mathematics (Keith, 1988; Miller & England, 1989; Pearce and Davison, 1988a). Each task was to involve (1) predrafting such as note-taking, listing, or brainstorming of ideas, (2) drafting of informal written pieces in the classroom, and (3) one of three revision activities: (a) a simple call by the teacher for students to re-read and then revise their first drafts, (b) teacher-modeled reading and revising of a student draft at the whole-class level with class discussion of the process followed by independent revision of their first drafts, or (c) peer response followed by revision. Since the instructors were asked to respond to the drafts after they were written and collected, and since writing and revising typically evolve over time (Bridwell, 1980), predrafting and drafting occurred in one class session followed by revision during a second class session. Schematically, the design of

the three writing tasks may be represented in the manner summarized in Table 3.4.

Table 3.4
Drafting Scheme for the Writing Tasks:
Task and Drafting and Revision Conditions

Task	Drafting and Revision Conditions		
	first session		second session
task 1	predrafting activity	drafting	self-directed revision
task 2	predrafting activity	drafting	teacher-modeled revision
task 3	predrafting activity	drafting	peer-response revision

After each drafting session, teachers read, responded to, and sorted students' writing. Plans for the three writing tasks evolved from the co-operative efforts of both teachers and researcher.

Planning the First Writing Task

After having watched J's and L's classrooms for three weeks, where they were working with students in solving and graphing linear equations and inequalities, I proposed that we

plan a writing assignment on graphing.

The textbook in use in the course presents graphing in general, graphing via the number line, and graphing via the Cartesian plane and then sets about presenting three methods for solving then graphing linear equations and inequalities. Those three methods are presented in the following order: (1) solving via a table of values, (2) solving via the intercepts method, and (3) solving via the slope-intercepts method. In the interviews, both L and J had said that they intended to take up these topics in the order in which they are presented in the text (that is, as listed above). In my talk with L, I found that L had definite ideas that these methods were each preferable one over the other according to the shape of a given equation to be graphed. J, on the other hand, felt that by the end of the chapter on graphing students should use the slope-intercept method with any equation, but later said that any method that "made the most sense to them [students]" would be fine for her students to use. Because of these differences, and because each of the teachers planned to spend about three weeks on solving and graphing linear equations and inequalities, I suggested to them that we plan a writing task that would help students learn these three methods.

On one particular Friday I had watched J present the second of these methods after she had focused three class session on introducing graphing and solving and graphing via the tabular method. We decided that we would ask students to

compare the first two methods of solving a linear equations (table of values versus intercepts) by asking them which they thought would be "better" to use and then asking them how to do the intercepts method, since that would be the method currently under study when the task was implemented. J was ready to use this writing task, but L was not since her writing-aided classroom had not yet reached the point in instruction she deemed necessary. Nevertheless L was agreeable to use it at an appropriate time, and so J and I decided that she would put the task in final form herself and would use it in the classroom on the following Monday.

On that Monday, J brought into the classroom the following questions and wrote them on the overhead projector. Her questions read: "Why would you prefer to use the intercepts method? How do you use the intercepts method to solve a linear equation?" This prompt was later used verbatim by L in her classroom.

Planning the Second Writing Task

At about the time that J was composing the final draft of the prompt for the first writing task and as I talked with L about how the first writing task was faring in J's class, L suggested that we lift out three linear equations from the textbook and have students say how to solve each. Knowing that we were working on a task that would not be used by students until about two weeks later, we talked about several

different equations and which methods students might use to solve each. The equations we finally chose are those depicted in Figure 3.1. The prompt for the second writing task asked students to examine each of the equations, tell which of the three methods they would use to solve the equation and then tell how they would solve each for later use in graphing.

1. $2x - 5y = 20$

2. $y = -3/4\ x + 5$

3. $y = 2x$

Figure 3.1
Equations Used in the Second Writing Task

For L, the method of choice for solving the first equation was the intercepts method, for the second the slope-intercept method, and for the third the table of values method. After L and I worked on this task in two planning interviews, L typed up a handout for students that displayed a prompt for writing followed by the three equations. Too, it was important for me to see that J did not think the prompt L composed was too "slanted" in the direction of L's notions of the "correct" procedure that students should use on each equation. This was important for several reasons: (1) J had essentially composed the details of the prompt for the first writing task, (2) I

knew that J's and L's notions were very different in terms of the "correct" procedures that students should use on each equation, (3) I sensed that L felt strong ownership of the task she had composed, and (4) J, being "ahead" in instruction, would be the first to use the second (and, as it turned out, third) writing task. For these reasons I listened carefully as J talked during the interview in which I presented L's prompt for the second writing task. What she had to say at that time suggested to me that she did not feel that the prompt compromised the collaborative nature of our efforts. I also listened carefully during the interview in order to understand J's perceptions about what student responses should be to the prompt and the equations and the appropriateness of the task for her students. In the interview, her statements suggested that she was comfortable with both how students might respond and with our continued collaboration, although she said neither explicitly. The following excerpt from the transcripts of the interview supports my claim. In the following interview (labeled J02-22 in the transcripts), I pointed to the three equations that L had listed, and said,

> D: It's one of each of the kinds. Is that true?
>
> J: It's not the way I want mine to do it, no. I want them always to use slope-intercept. I think slope intercept is the easiest and the quickest. But it's good that they have the other methods. I think all the answers [to each of the three problems given] should either be the intercepts or the slope-intercept.

D: Let me remember [what the kinds are]. Their answers to each of those should be one of those.

J: To each of mine. Now I know what L's saying. But if they'll look at this [y = 2x] as 2x plus zero, you've got it. So it would just be great to see what they answer.

D: Will you want your students to answer slope/intercept and talk about deriving y form first?

J: That will be fine. That would be just as acceptable to me.

D: Or the other possibility is intercepts?

J: But see, this one [2x - 5y = 20] is nice because the intercepts are 10,0 and -4,0. If on a test I gave them 2x - 5y = 8, then there are no nice intercepts. It would be much easier to do the slope/intercept. When my people see this problem on a test, immediately I want them to put it in y form and graph it. Whereas the intercepts aren't going to be nice. If x is going to be 0, y is negative 8/5; and if y is 0, then x is 4. So this [2x - 5y = 20] is nice, and this [y = 3/4 x + 5] isn't. But if they put it in y form, the y form is not going to be a whole lot better.

***

D: If on any of these, your students answered a tabular method, what would you think?

J: Fine if that's what they understand. I don't have a pat answer. They have three choices, and the one that they choose for them is fine.

D: OK.

J: Do you want us to have pat answers?

D: Not at all. I'm just trying to anticipate your understanding of how students will respond to this.

J: I would be thrilled if they all just said, I would put them in y form and graph. I think that would be wonderful. But if they broke it down into intercepts, it would show that they are using a little more intuitive thought because they are thinking, what's the easiest for this problem.

Having determined that J saw this as an appropriate task for her students, I asked J if she would be comfortable with the handout. So, both J and L used the handout that I had prepared for the second writing task.

Planning the Third Writing Task

During the second week of March, J was still "ahead" of L in instruction and J had begun working with students on simplifying radical expressions and solving equations with radicals. On Monday of that week, J discussed squared numbers, perfect squares, the perfect square numbers between 1 and 169, square roots, using a calculator to find square roots, and adding and subtracting expressions with square roots. After class that day, we started the usual interview, this time in the classroom. As J and I talked, we discussed plans for another writing task to take place that week. We decided that we would pick a problem from the textbook on simplifying radicals that would involve both adding and subtracting radicals (which she had discussed during class that day) and multiplying radicals (which she planned to discuss during the next class meeting). Although we agreed that students would be asked to solve the problem and tell how they solved it, we left the exact problem and prompt up to J. As we departed the classroom to continue the interview in her office, J said,

Yeah, I think that would be excellent. Then we write

> that Wednesday and do the rewrite on Friday. OK. Let's do that. We can come up with something. I can pick one [of the radical expressions] out of this assignment that wasn't even one that we did. Let's go with that.

Figure 3.2 displays the prompt and the radical expressions that J devised.

Solve by simplifying and tell

how you did it.

$3\sqrt{8x}$ $2\sqrt{50}$

Figure 3.2
Prompt and Expression
Used in the Third Writing Task

Later, as L and I discussed the details for task number three, we decided that she seek out J and copy the prompt for the task from J. In an interview two days later, I followed up on arrangements and found that L had gotten the details from J, and we did not discuss the prompt further even though it was a week later still before L implemented the third writing task.

"Unplanned" Writing Tasks

Both J and L used additional writing tasks that are not discussed above and which were not a part of this study

proper. These tasks are called "unplanned," because we spent much less time in working with these tasks and because the written products did not become part of the later analyses. J implemented one such task without our having collaborated on it at all and one which both the instructors used after our having discussed it; we decided, however, not to revise it. Unfortunately, these assignments were written in the midst of classes being cancelled campus-wide because of snow. In addition, J was absent due to illness, and L was absent in order to attend a conference. Due to these unforeseen delays, we agreed that revision would have to take place too long after the initial writing. The "unplanned" writing task both J and L used called for students to pick a problem which they had missed from their test on chapter 12 and to copy the problem on a separate sheet of paper, solve the problem (hopefully, this time, correctly) and then tell how they solved it. The "unplanned" writing task which J used occurred on a day before a review for the test on chapter 12. In this task, J directed students' attention to six particular problems in the textbook practice test and four linear inequalities she had written on the overhead projector. Her prompt to students was,

> As you look over this chapter test and as you think about these inequalities in class today, I want you to tell me what you think your weakest area is. And if you have a weakest area, what don't you seem to understand? As you look at the different areas that will be on the test, tell me what you think you have trouble with. Now if you don't think you are going to have trouble tell me, "I

> think I feel confident about this test; I think I'll do fine," and why. But if you think one of the things we just looked at, you think, "uh oh, I might panic if I saw this," I want to know what it is and why. And then on Friday I can address these at the first of the class. You can write me three or four sentences or a paragraph.

Again, neither of these two "unplanned" tasks were used in the analyses of written products although students' writings were collected and the interviews surrounding the "unplanned" tasks were used in the teacher interview analyses.

Student Response: Written Products

Students in the two writing centered classrooms wrote in response to the three tasks of writing planned for the study. They wrote first drafts which the teachers read, responded to, and sorted and returned to students and, later, second drafts which teachers again read, responded to, and sorted and returned.

Written Products: First Drafts

As explained above, students wrote in the two writing-aided classrooms in response to the tasks presented to them by their instructor. All drafts, including the first drafts, were written in the classrooms. Because the two instructors covered different topics at different times (although usually the same topics and usually in the same order), J and L often asked students to write on different

days. After students wrote the first draft, the instructor collected the drafts from her class, and she and I together went to her office for the usual interview after class.

Written Products: Reading, Responding, and Sorting

Immediately after each class session of writing, the instructor and I met in the instructor's office to read the student writing as part of the usual interview and de-briefing. As stated earlier, instructors were asked, after they had read the drafts, to do a sorting task, ultimately sorting papers into four stacks. Also as stated earlier, the sorting corresponded to the instructor's judgment of the accuracy of the mathematical content reflected in the student's writing.

Because J was the first of the two to implement the first writing task, she was also the first to read and sort papers for her students. Because she felt that students should know what was taking place and how they performed, J asked that we put numbers on the papers corresponding to the "stack" the particular paper was sorted into. In the first sorting process, J divided the papers into a high stack and a low stack, and again divided each stack into high and low, as planned, and then wrote numbers (a "score") on each. In the second and third writing task, she "scored" papers as she read them. L literally sorted until the third writing task when she, too, "scored" papers as she read. Both J and L turned to

"scoring" on their own, rather than sorting, without prompting from me to do so and without discussing the process with me beforehand.

After each draft was returned, J discussed with students the meaning of the "scores" from sorting but emphasized that there was no grade involved. When she returned second drafts of the first writing task to students, L informed her students that the "score" represented the number of points they received as a daily grade on this assignment. As J verbalized it to her students,

> A four would mean that everything is right. And a one would mean that everything is wrong. Now, a three would mean that it's sort of right, it needs a little bit of revision. And a two would mean it's somewhat wrong and it needs to be a little bit better to make it right,

or as L stated to her students, "I have them marked from zero to four as to how much you would have gotten." Coming as these "scores" did from the sorting task, no claim can be made about them except as to the relative ranking by teachers' judgments of the perceived mathematics content of students papers. Since we did not share sorting "scores" between teachers and did not attempt to establish explicit criteria for teacher ratings or judgments, no claim can be made as to the meaning of the scores other than to say that they represent a rough approximation of teacher judgment of the mathematics content of the writings. In L's classroom, the sorting in effect ultimately involved grading of student performance and thus evaluation of students.

Also at the instigation of J, the instructors wrote notes to students on their drafts, both first and second. As J said in one of the interviews, speaking about writing comments on a student's paper, "I just wanted to tell him something." Because writing comments seemed a real and understandable concern to both instructors, the instructors consistently wrote comments on all student drafts, both first and second drafts, on all the writing tasks.

Written Products: Second Drafts

After the instructors read, responded to, and sorted the first drafts of student papers, those papers were returned to students on the following class meeting. In the first writing task, students were given their papers and asked to revise and write another copy. (In her class, J also gave students a description of the scores from the sorting and told students some ways to revise.) In the second writing task both J and L used the overhead projector and a fabricated "student" paper to model some possibilities for revision. Then students were given their papers and asked to revise and make another copy. In the third writing task, students were put into groups of two or three and asked to read each other's papers and discuss possible revisions. They were then asked to revise their papers and make another copy. (In J's class, students were assigned partners for this activity; in L's class, they picked their own.) Instructors then took up all the second

drafts and read, responded to, and sorted the second drafts. Second drafts were then returned to students at the following class meeting.

As stated before, all interviews surrounding the planning of these writing tasks (including the reading, responding, and sorting) were pooled as teacher interview data.

Student Response: Questionnaire

Two case study students, one from each of the writing-aided classrooms, were nominated by J and L. J nominated Darrell, an older adult male student who was in his second semester at Lakeridge. He was a former student of mine, and I knew him to be verbal and articulate. J assured me several times that he was, in her words, "average Joe" in her class; in fact, at one point in the interviews as J was reading one of his papers she became somewhat frustrated with his answer; she laughed and said, "You wanted an average student and that's just what you got." L nominated Robyn, a young female student who was in her third semester at Lakeridge. She was co-operative and much more verbal in the interviews than she was in the classroom, and according to L, an average student in the class. Each case study student was interviewed and fieldnotes and tape recordings made. An informal schedule of questions was used in the interviews. (See Appendix 1 for the schedule of questions used.) Later,

transcripts of the interviews were made.

I met with Darrell four times before he was unable to come for further interviews and with Robyn three times before she was unable to come for further interview. Unfortunately, Darrell took a position as manager of the college's baseball team and Robyn's job hours were abruptly changed; thus, both of the case study students suddenly ceased to be available. Eventually, both dropped out of their mathematics classes. Because of this situation, because of the small number of interviews, because of the inability of the case study students to meet --even when they did meet-- immediately after each of the writing tasks, and because the interviews ceased before the writing tasks were implemented, the case study student interviews were abandoned.

In their place was substituted a student questionnaire that the two instructors and I developed together. I began my talk with each of the teachers by bringing to them questionnaire items formulated from the items on the schedule of questions for the case study student interviews. As we talked about the difficulties coming about in the case study student interviews, I asked J if she would mind helping me formulate a few questions to ask students that would stand in the stead of the "lost" interviews with case study students. J was eager to suggest items. In an interview, she told me that if she were making out the survey she would ask,

Did you think that the writing helps you clarify ideas or

> concepts in this course? Yes or no and why or why not. Did you enjoy the writing? Did you find the writing to be worrisome or a waste of time or something relating to what you were doing?

These ideas are represented in the questionnaire we constructed as was the idea, from L's suggestion, that we ask students an open-ended question in which we give students the chance to make any suggested changes that they felt warranted in how the writing proceeded. (A copy of the student questionnaire appears as Appendix 2.) Essentially, the questionnaire includes eight questions that ask for a yes or no response and then requests that the student tell why he thinks that way. The questionnaire concludes with two open ended questions.

Immediately after students completed the questionnaire, I led the students in a classroom discussion of their responses to the questions in a further attempt to understand student perceptions of the writing. I opened both discussions with open- ended prompts such as, "Well, what did you think about the writing in general?" In both classes, students seemed relatively free to comment. In J's class students participated, and most students contributed to the discussion. In L's class, the discussion was dominated by two particular students, although several other students also participated in the discussion to a lesser extent. In L's classroom, relatively fewer students contributed to the discussion as compared to J's classroom. In J's classroom several students

came up to me after class to continue to talk about the writing and in L's classroom I talked to individual students during a class break after the discussion of the questionnaire.

Tape recordings were made of the classroom discussions, and I made fieldnotes immediately afterwards.

As with other interview material, the collaborative work on the survey between the teachers and me was pooled with all the other interview data.

Interviews and Observations: Tape recordings and Fieldnotes

As stated already, the classrooms and teacher interviews were tape recorded and fieldnotes made. Because the teacher interviews followed immediately after the classroom observation, tape recordings contain both classroom and interview recordings. A total of 98 tape recordings (45 minutes maximum, each) were collected as follows: of classrooms and interviews with L, 52 tapes; of classrooms and interviews with J, 46 tapes; of total classrooms and interviews, 98 tapes.

In addition to the fieldnotes and tape recordings of the classrooms, I collected written materials distributed during the classes. These documents included syllabi, handouts, tests, practice sheets, exercises, my own writing done in response to the planned and "unplanned" writing tasks, and

other written artifacts from the classrooms.

Student Response: Chapter Tests

Already in place in the four classrooms of the study --both in the writing-aided classrooms and in the non-writing aided classrooms--were typical chapter tests over the mathematics topics covered in the textbook. During the study, writing tasks one and two addressed topics covered in Chapter 12 of the textbook, one of the "unplanned tasks" used by both J and L addressed a topic covered in Chapter 12, one "unplanned task" used by J addressed topics covered in Chapter 13, while writing task three addressed a topic covered in Chapter 14 of the textbook. Although the textbook provided practice tests, reviews, and supplementary tests, both J and L created their own chapter tests. J used one set of chapter tests in both of her classrooms; L used another set in both of her classrooms. J's tests were similar but not identical to L's; thus, they can not be used for comparisons between teachers, but all sets of tests emphasized computation and algorithm. Because of the modified mastery learning arrangements in the course department-wide, all students were allowed one re-take if their scores on the tests fell below 70%. All scores collected were those based on any "re-takes" of the tests. Scores for students in all four classes on Chapter 12, 13, and 14 tests were collected.

Summary

Two college mathematics teachers and four of their sections were selected for the study. Two classrooms were designated writing-aided and two designated non-writing aided. The researcher and teachers collaboratively planned and the teachers implemented three tasks of writing to learn in their writing-aided classrooms. Teachers nominated two case study students, both of whom later dropped out of the classes. After students wrote in response to each task, students' writings were collected, read, responded to, and sorted by the teachers. Teachers returned the papers to students, and students wrote in one of three revision conditions. Students' second drafts were collected, read, responded to, sorted, and returned to students. All drafts were collected and photocopied for later analyses. Teacher interviews and classroom observations continued throughout the study. Because the case study students dropped out of the classes, a questionnaire was formulated and substituted for the case study student data; questionnaires were administered to students in the two writing-aided classes. Also, the scores on chapter tests (already in use by the teachers) were collected during the time that teachers used the writing.

Available for analyses were (1) teacher interview and classroom data in the form of fieldnotes and tape recordings, (2) students' writings, (3) the results of teachers' sorting

of the writing, (4) results of the questionnaires administered to students, and (5) students' scores on chapter tests.

Chapter 4

METHOD OF ANALYSES OF DATA

Research Questions

As stated before, several research questions guided the study. These questions center on using tasks of writing to learn in mathematics when teachers support the writing and have students revise as part of the support for writing. Those questions include: (1) What are the lengths of drafts students produce in completing these tasks, both before and after revision? (2) What are the levels of syntactic maturity of the final drafts in these tasks? (3) What are the levels of revision students use when they revise their drafts? (4) What are the revision strategies students use when they revise their drafts? (5) What are the cognitive operations students appear to use when they write such drafts? and (6) What are teacher and student perceptions of drafting and revising for these writing-to-learn tasks in mathematics?

Overview of the Analyses

From the work of interviewing teachers, fieldnotes and tape recordings were collected and catalogued by teacher and date. From the observation of classrooms, fieldnotes and tape recordings were collected and catalogued by teacher, classroom, and date; documents from the classrooms were similarly collected and catalogued. The interviews and observations became the basis for a narrative that attempted to capture each of the planned and "unplanned" writing tasks as they unfolded (in planning interviews, classroom implementation, de-briefing and sorting session, planning of revision and second drafting conditions, classroom implementation, de-briefing and sortings, and any follow-up questions). They also became the basis for a separate narrative that attempted to portray the teachers' perceptions of writing in general. Each of these narratives was then available for further analyses.

Students wrote in response to three planned writing tasks. Students' writing, both first and second drafts, were collected from each writing session and read, responded to, and sorted by teachers. After the de-briefing and sorting sessions, each set of student writings was collected and photocopied before the originals were returned to students. Photocopies were catalogued by classroom, draft (first or second), and student. These writings were then available for

further analyses.

After the three writing tasks were finished, students in the writing-aided classrooms responded to a questionnaire concerning their perceptions of the writing. These responses were collected and catalogued by teacher, classroom, and student. Immediately after students completed the questionnaire, I led a class discussion in each writing-aided classroom about the writing that students had done; tape recordings and fieldnotes of the discussion were made for later analyses.

Students' scores on chapter tests were collected from all four classrooms.

Teacher Interviews

After the teacher interviews were conducted, tape recordings and fieldnotes were collected and catalogued by teacher and date. A transcript of the tape recordings of each teacher interview was then made in the following fashion. J's interviews were transcribed first. The tape of each interview was transcribed, with an initial transcript of the entire tape recording made using word processing. Each transcript was then placed in a separate word-processing file. As the transcription proceeded, reference was made to the fieldnotes of the interviews and any pertinent documents collected from the classroom (such as problem sets, textbook pages, tests,

etc.). After an entire interview was transcribed, the entire tape was listened to again and refinements made in the transcript as needed. This last step proved very beneficial since some portions of the tapes--which on first hearing were unintelligible--became clear during a second hearing.

The transcriptions of the interview tapes are partial; extraneous material (personal exchanges, discussion of topics of college-wide interest, etc.) was summarized inside brackets.

When all the interviews were transcribed, copies of the interview transcripts were made and an initial coding of topics was conducted, using broad categories (teacher perception of the writing task, teacher perception of writing in general, planning the writing task, responding to papers, project-level plans and concerns, extraneous material, and other). These initial codings helped to describe and clarify the interview transcripts in relation to the study. These initial codings were later modified and refined and subcategories developed and assigned. After working with the transcripts and the modified codings of J's interviews, the transcripts were again refined. The same procedure was repeated with the tapes of L's interviews.

In all, a total of 146 pages of typed, single-spaced transcripts resulted from the interviews with the two teachers.

Because the coding was intended to illuminate the

thematic content of the teacher interviews, the codings were used merely to identify and locate particular themes in the interviews. However, to give the reader a flavor of the codings, Table 4.1 is given to exemplify the coding scheme used. The line count is given for illustrative purposes only here and was not carried out on any other interview. In the table, numbers to the left indicate "turns" or chronological sequence of themes in the interview, the center column indicates the coding for theme (with the material in parentheses below the theme gives the subcategory of or a comment on the themes), and in the far right column indicates the length (in terms of lines of type in the transcript) for that "turn" of the theme. In addition to giving a "flavor" of the coding, Table 4.1 also illustrates the recursive nature of themes in the interviews.

After the interviews with both teachers had been transcribed and coded, they were then available for further analyses.

Classroom Observations

After the tape recordings and fieldnotes of classrooms were taken, they were collected and catalogued by teacher, classroom, and date. The fieldnotes were then read for mathematics topics, instances of implementing the writing assignments, and references to writing. Pertinent areas of

Table 4.1
Codings of Teacher Interviews
Interview #L02-22

turn	theme	count
1	planning writing task (task 1)	31
2	responding to papers (J task 1, draft 1)	27
3	planning writing task (task 1)	5
4	responding to papers (J task 1, draft 1)	7
5	project level concerns (responding to papers)	4
6	planning writing task (task 1)	5
7	planning writing task (task 2)	7
8	planning writing task (task 1)	20
9	project level concerns (revision)	3
10	planning writing task (task 1)	13

the fieldnotes were used as reference points to transcribe tapes of the classrooms. For purposes of this analysis of classroom observation, pertinent areas refer to those portions dealing with implementing the writing and any later references to the writing that teachers might make. The tapes of all writing-aided classrooms were listened to and initial transcripts of pertinent portions made. Each transcript was placed in a separate word processing file. Working first with J's writing-aided classroom, I transcribed the tapes making a first transcript of the pertinent portions of the tape in a fashion similar to that outlined above for the tapes of teacher interviews. After the pertinent portions were transcribed, I listened again to the tape and made refinements in the transcripts. As before, reference was made to fieldnotes and collected documents to refine and detail the transcripts. As a result, I transcribed a total of 10 classroom episodes of implementing writing in J's classrooms along with accompanying classroom references to the writing. After working with transcripts of J's writing-aided classroom as detailed above, I repeated the process with L's writing-aided classroom and found eight classroom episodes of implementing writing tasks and accompanying references to the writing.

Because the non-writing classrooms were observed merely to ascertain that no writing occurred there, those tape recordings and fieldnotes were not transcribed.

Interviews and Observations: Narratives of the Writing Tasks

After the transcripts of interviews and classrooms were produced and refined, I attempted to draw as full an account of the development of each writing task as possible, given the above materials (tape recordings, fieldnotes, coded transcripts, and collected documents) as data. First, the planning of a given writing assignment was pulled from the coded transcripts of teacher interviews, then the classroom transcripts were consulted and the implementation of the first drafts of each writing task pulled. As expected, the implementation of the writing assignment was fairly easy to identify and pull from the classroom transcripts, but additional care was taken to pull any and all references made by the teacher in the classroom to writing in general or to the particular writing task. Next, pertinent areas were pulled from the subsequent interviews during which the teacher read, responded to, and sorted students' writing. Again, the coded interviews were consulted to pull all references to the particular writing task made by the teacher throughout the interviews. Then all planning for the second draft and all references to that particular task were pulled from the teacher interviews. Again, as students' writings were taken back into the classroom for revision, the classroom transcripts were consulted for implementing the revision (that is, the second draft of each writing assignment), and

pertinent classroom transcripts were pulled. After the revision, teachers read, responded to, and then sorted the revised (second) drafts of the writing during interviews; pertinent transcripts again were pulled. In addition, the coded interviews were once again consulted to pull any other pertinent portions of the transcripts from classrooms and interviews, as it did happen that teachers sometimes referred a week or so later to writing done earlier. All these transcripts were "pulled" into one word processing file. From this compiling of transcripts, each writing task was then captured in a document that I will call Narratives of the Writing Tasks. In the Narratives of the Writing Tasks, I also produced some prose to link parts of the transcripts together, especially to show the chronology of the development of each task and interview and classroom transcript data and to give context and referents to the talk captured in the transcripts. This prose was produced by reference to the transcripts themselves, and to the tapes and fieldnotes from which they were extracted and produced. The word processing files, when compiled, resulted in five files for J and four for L, including their planned and "unplanned" writing tasks. There was a total of 94 pages, typed and single spaced, of the Narratives of the Writing Tasks for the two teachers, 43 pages for J and 51 pages for L.

The Narratives of the Writing Tasks then were used as the basis for drawing conclusions and inferences about the

development of the writing tasks and teacher perceptions of using these tasks of writing to learn inside the mathematics classroom.

These conclusions and inferences were arrived at by the following method. First, I read the narrative of each task and drew initial conclusions about significant portions of each writing task; these conclusions were then fleshed out in prose. Second, these conclusions were then sent to an outside reader for substantiation and modification. This outside reader was an informed faculty member currently teaching English at Lakeridge and pursuing a Ph.D. in English. As a result, some modifications were made. Sample conclusions are given below. These conclusions come from examining the narrative developed for the first writing task, the first draft, in J's classroom.

1. J introduces the task as having the purpose of being "so I can see where you are as far as these two methods are concerned." This statement suggests to students that the purpose of the assignment is informal assessment of their knowledge of these two procedures.

2. The writing task comes after the introduction of the two procedures, guided practice in the procedures during class, practice in the procedures in homework, and additional guided practice by going over most of the homework problems together in class. Thus the writing is firmly situated in the midst of instruction rather than in preliminary instruction, or in introductory instruction, or in evaluation. The placement of the writing task in this way suggests that J believes that students have had sufficient time and practice to know the procedure fairly well before the writing takes place.

3. The immediate goal J sets for students in the task is to "Just try to tell the very best you can what you are thinking" and "in your own words, your own language, I

want you to explain it to me." Both of these statements to students suggest the importance of thinking and language in the writing task at hand. As such, they also lend credence to the task as one worthy of the "work" in mathematics that students have done.

The copy of the conclusions from the Narratives of the Writing Tasks for J amounted to 16 pages, typed single space. For L they amounted to 13 pages, typed single space.

Also, to aid in "triangulating" data, sections of the Narratives of the Writing Tasks and the conclusions about them pertaining to J were sent to J; the sections pertaining to L were sent to L. Along with this narrative and conclusions about it, J and L were given a list of questions about the narrative and the conclusions. (Those questions appear as Appendix 3.) In brief, both J and L were asked to comment on the accuracy of the Narratives of the Writing Tasks themselves and on their perceptions of the conclusions drawn from it.

Interviews and Observations: Narratives of Writing in General

With the material for the Narratives of the Writing Tasks removed from the word processing files of the transcripts of the teacher interviews, I was left with a good deal of interview material remaining which had been coded as teacher perception about writing in general. From this remaining material, I extracted those portions of the transcripts that had been so coded. This material was extracted from the files

of the transcripts and was used to develop a second document, the Narratives of Writing in General, in a manner identical to the method used to produce the Narratives of the Writing Tasks. Less chronologically and thematically connected, the Narratives of Writing in General was also given added prose to show some thematic context and the interview date. There were a total of 18 pages, typed single spaced of the Narratives of Writing in General, 5 pages for J and 13 pages for L.

The Narratives of Writing in General was then used as the basis for drawing conclusions and inferences about the teachers' perceptions of writing in general, rather than as applied to the specific tasks. These too were sent to an outside reader and resulting modifications made.

The copy of the conclusions from the Narratives of Writing in General J amounted to 4 pages, typed single space. For L they amounted to 3 pages, typed single space.

The section of the Narratives of Writing in General pertaining to J was sent to J; the section pertaining to L was sent to L. Along with the narratives and the conclusions about it, J and L were given a list of questions about this narrative and the conclusions. (Those questions appear as Appendix 4.) In brief, both J and L were asked to comment on the accuracy of the Narratives of Writing in General and on their perceptions of the conclusions drawn from it.

Interviews and Observations: Thematic Analysis

The Narratives of the Writing Tasks and the Narratives of Writing in General were analyzed along a number of lines. The original plan called for the analyses to include examining these teacher interviews and class observations thematically for (1) references to length, syntactic maturity, revision level, and revision strategy related to writing made by the teachers, (2) references to the cognitive operations in writing made by the teachers, (3) references to the learning that takes place during the writing, (4) classroom patterns of instruction, and (5) methodologies and procedural issues surrounding the use of writing. An additional analysis was (6)teacher perception of writing.

References by Teachers to the Writing

References to length, syntactic maturity, revision level, revision strategy, learning, and cognitive operations were examined by noting instances when the teachers mentioned these ideas or ideas related to them during the class as they were connected to the writing. These references were culled from the narratives and pooled. Each reference was then coded as to kind (length, syntactic maturity, revision level or strategy, learning, and cognitive operation), teacher making the reference, and position of occurrence (before a first

draft, after drafting, or not occurring in proximity to the drafting).

Classroom Patterns of Instruction

Classroom patterns of instruction for each task of writing were examined by locating the mathematics subject matter focus immediately preceding each task, noting the amounts of time devoted to writing each task (both first and second drafts), the written prompts for each writing task delivered by teachers in the classroom, and the center of activity immediately preceding and following the writing task (either teacher-centered or student-centered). The center of activity was coded as teacher-centered when students' attention was called for by the teacher to be directed at the teachers' actions (such as when J used the overhead projector to display the step-by-step procedures for solving a linear equation by the slope-intercept method); the center of activity was coded as student centered when students' attention was called for by the teacher to be directed at action the student performed himself (such as during individual practice of a problem set) or toward an action that students performed together (as when, for example, students discussed a handout in small groups in L's class). The center of activity before writing was coded as "none" if no instructional activity preceded the writing (that, if the

writing was the first instructional activity of the class session). Likewise, the center of activity after instruction was coded as "none" if there were no instructional activities after the writing (that is, when the writing was the last instructional activity of the class session).

Methodologies and Procedural Issues

The methodologies and procedures by which teachers implemented each task of writing were examined along a number of lines. The analyses included the following. (1) Placement in the instructional unit. The writing tasks were coded as occurring in "initial" placement if they took place during the class session in which their mathematical subject matter focus was introduced. For example, L used the third writing task (simplifying a radical expression) in the class session when she first demonstrated how to multiply and collect terms involving radicals. The writing tasks were coded as "culminating" if they were placed during or explicitly linked by the teacher to a review of the chapter. They were otherwise coded as "development," that is, placed in the development in instruction of the mathematics subject matter focus. (2) Announced function in instruction. The announced function in instruction examines those statements the teacher makes in her remarks prefatory to the task that seem to give students a purpose or rationale for the teacher's use of the

writing task. These statements or announcements are here merely excerpted and quoted, not coded. (3) Inferred function in instruction. The inferred function of the writing tasks involves the researcher's inferences as to the instructional purpose of the task. Inferences were made by examining the Narratives of the Writing Tasks for statements and actions by teachers surrounding the tasks. The inferred functions were coded "learning" when the tasks were inferred to have the purpose of demonstrating new mathematics knowledge, relating new mathematics knowledge to old, or consolidating knowledge. Inferred function was coded "assessment" when the purpose seemed to be to allow teachers' insight into their students' knowledge of mathematics, and coded "evaluation" when the task's purpose seemed to be to assign grades to students. (4) Contentless goals (Flower and Hayes, 1977). Contentless goals involve sub-goals and routines relating to the composing process when a goal does not refer to specific linguistic or mathematics content; that is, contentless goals refer to goals for action that involve a <u>how</u> rather than a <u>what</u> to mean or to write. These goals are excerpted and quoted here, not coded. They are further divided into those used during the first draft, those used to link the second draft back to the first, and those referring to revision processes. (5) Time allocation. Time allocation was noted in the fieldnotes and in the Narratives of the Writing Tasks. Fieldnotes noted significant times for directions and drafting, and tape

recordings were timed for directions and drafting where possible. "Directions" involve the time taken by teachers for all their prefatory remarks beginning with the announcement of the particular writing task and lasting until the teachers' directions and talk ended to allow students to write, either by drafting prose or by drafting planning notes. "Uninterrupted drafting" refers to the time allotted to drafting when no talk takes place by the teacher for the class as a whole. "Total drafting" refers to the time allotted beginning with the "uninterrupted drafting" and ending when the teacher announces that all papers should be in or when the teacher collects or receives all papers. The time allotted was noted for both first and second drafts.

Teacher Perceptions

Teacher perceptions of the writing tasks and of writing in general were examined by a thematic analysis of the perceptions reported by teachers for each writing task and for writing in general. This thematic analysis was carried out in the following fashion. First, working with the conclusions from the Narrative of the Writing Tasks, I drew conclusions and inferences and sent them to the outside reader. Modifications were made based on such input. At any point where the outside reader felt conclusions or inferences were only weakly substantiated, the conclusion or inference was

dropped. Also, if teachers strongly objected to a conclusion or inference as inaccurate or untenable, it too was dropped. Second, these conclusions and inferences concerning the Narrative of the Writing Tasks were gathered and joined to the supporting context from which they were originally drawn (i.e., transcripts of interviews or classrooms). Third, they were then re-written to make connected prose. Later, the conclusions and inferences from the Narrative of Writing in General were similarly analyzed. The results of these two groups of analyses (of perceptions of the particular tasks and of writing in general) will be reported separately.

Student Response: Written Products

After each session of writing and after the instructors read, responded to, and sorted the student writing, the drafts were collected and photocopied. Only that writing was analyzed which was completed by students who wrote both first and second drafts inside a particular planned writing task. In other words, the analyses of written products do not include the writing produced in the "unplanned" tasks nor does it include writing of single drafts within each task by students who were not present to complete both drafts. During the course of the study, it was possible for each student to produce two drafts in each writing task, for a possible total of six drafts for each student present across all planned

writing tasks. The number of drafts produced by students and then used in these analyses is given in Table 2.

Table 4.2
Numbers of Drafts Used
in the Analyses of the Written Products

	Task One		Task Two		Task Three	
	draft 1	draft 2	draft 1	draft 2	draft 1	draft 2
J's class	8	8	18	18	14	14
L's class	16	16	16	16	12	12

Because these drafts were extremely informal and written for a known and trusted audience (i.e., they are essentially writer-based prose), the handwriting and drafts were sometimes difficult to read. Figure 4.1 displays a sample of the drafts. For these reasons and to ensure standardized analyses of the drafts, the drafts were typed using word processing. These typed copies of drafts were then proofread and modified as necessary. These typed copies then served as the objects of analyses for the analyses of the written products.

Analyses of the written products include analyses for length, syntactic maturity, level of revision, revision strategy, and cognitive operations.

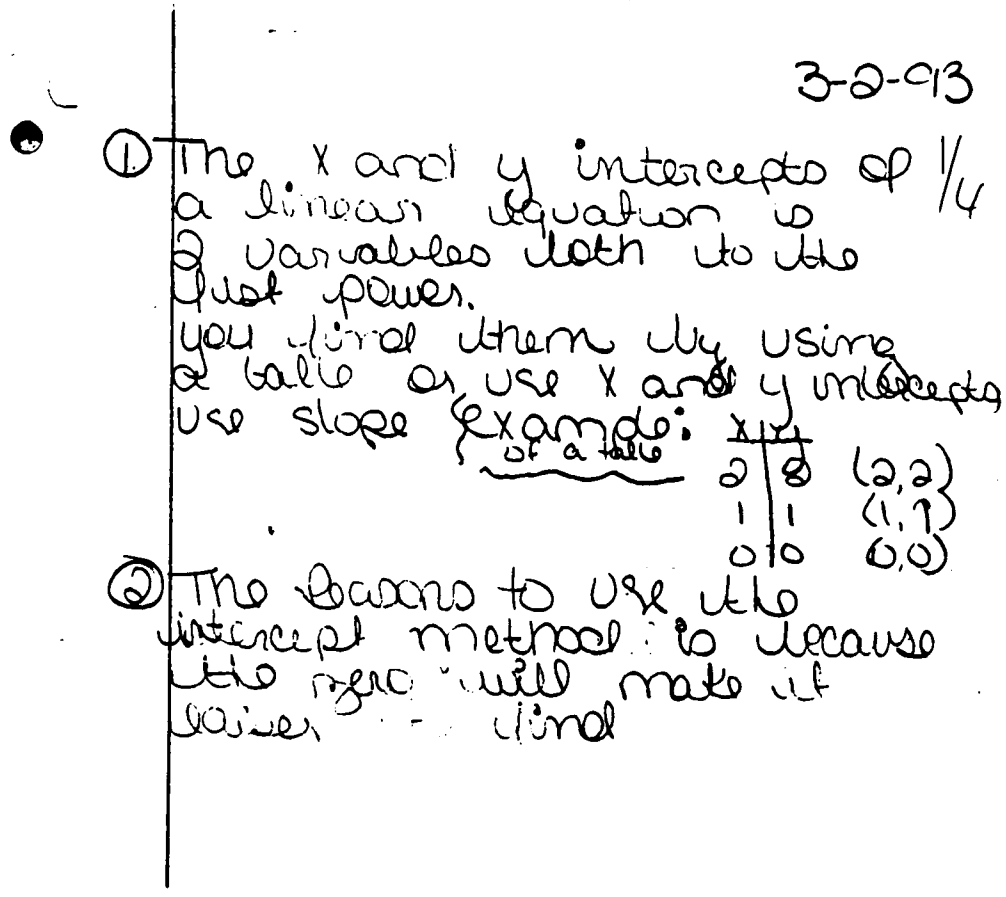


Figure 4.1
A Sample from the Drafts

Length

Both the first and second drafts of students' writing were analyzed for length. Two measures were used in the analyses of length: (1) the number of words in each draft, and (2) the number of T-units in each draft. (Hunt, 1965) suggest that this measures are to be indicative of differences in the writing ability of students at various levels while Hillock (1986) suggest they may be and indicative of the relative amount of information available in a text. An increase in the length of the drafts in the second draft would suggest that students have an increased opportunity to display in writing a greater number of ideas that they are able to say about the mathematics content. An increase in length thus is suggestive that the opportunity for a second draft enables students to incorporate into their writing more ideas about the mathematics content as compared to the opportunities in a shorter first draft. Of course, the argument could be made that from their English classes students expect to be asked to make second drafts longer than first in order to make them "better." However, this may not have taken place for a number of reasons. First, obviously, the students were writing in a mathematics class, not an English class. Secondly, in both classes the sorting took place in terms of the understanding displayed, not the length. Third, sorting scores and comments reflect this attention to content and not form. Finally, in

fact, in J's class, students were explicitly told not to worry "about the English" of their drafts.

Comparisons were made between draft one and draft two inside each of the tasks. For each student, the number of words per draft for draft one was subtracted from the number of words per draft for draft two. Similarly, for each student the number of T-units per draft for draft one was subtracted from the number of T-units per draft from draft two. These differences were calculated for each student within each task. A positive difference in this analysis would represent greater length in draft two while a negative difference in this analysis would indicate that draft one was longer. Mean differences were then calculated for each task inside each classroom. Mean differences were tested for statistical significance by constructing a 95 percent confidence interval around each mean. A confidence interval for these mean differences not including zero would thus indicate a statistically significant difference, either positive or negative, between draft one and draft two within each classroom.

Length: Words per Draft

The coding for number of words proceeded by counting words in each draft for each student who wrote two drafts within a particular task. Because the students were writing about mathematics content, they often incorporated mathematics

symbols in their drafts. As the coding proceeded, a number of operational guidelines had to be developed to address the use of mathematics symbols in the writing. Other guidelines were developed in response to the tasks themselves and the nature of the writing that students produced. Those guidelines include the following: (1) copying the question or a simplified form of the question was not counted in any way in this analysis; (2) carrying out a mathematics procedure [i.e., "solving the problem"] was not counted in the word count; (3) spelling was standardized to preserve meaning and to regularize word count between students so that, for example, the word "setup" in the written statement "I would setup the problem" was counted as two words and the words "out side" in the written statement "out side the radical" was counted as one; (4) if a draft used listing as an organizational principle, each numeral and associated punctuation were counted as one word; (5) two often-occurring symbols [#, =] were counted as one word each if they occurred in the text and could be verbalized as the word "number" and "equals," respectively; (6) if a mathematics expression were included in the text, it was counted as one word [e.g., the statement "when I saw 2x + 0" and the statement "then I added 6 + 4 - 6" were both coded as containing 4 words].; (7) if a mathematics equation were included in the text, it was counted as one word [e.g., the statement "then you get y = 2x" was also coded as containing 4 words]; (8) when the text was faulty in terms of

omitted words, even in the case of obvious omissions and their values, no words were counted; and, (9) contractions were counted as one word.

Length: T-units per Draft

As stated earlier, the coding for number of T-units per draft proceeded by counting T-units in each draft for each student who wrote two drafts within a particular draft. A T-unit (Hunt, 1965) is any main clause and its associated subordinate clauses. As with the word count, a few guidelines were developed in carrying out the analysis of T-unit counts. Those guidelines include: (1) copying the question or a simplified form of the question was not counted in any way in this analysis; (2) carrying out a mathematics procedure [i.e., "solving the problem"] was not counted in the T-unit analysis in any way.

Syntactic Maturity

Syntactic maturity was measured in three different analyses. Again, for these analyses, only those writings in each task were analyzed which were completed by students who wrote both a first and second draft. Only second drafts of these writings were examined for syntactic maturity since these analyses attempt to capture and describe the syntactic maturity of the final, "finished" (i.e., second draft)

writing.

In general, research suggests that the development of syntactic maturity is one measure of writers' ability to use written language. In some studies, gains on certain measures of syntactic maturity have been associated with increased subjective ratings of overall effectiveness of the writing of college students (Faigley, 1979), although this finding is sometimes contested. Hillocks (1988) contends that the ability to manipulate syntax may be one indicator of writers' repertoires --"a knowledge of lexical, syntactic or rhetorical forms which writers call upon in their writing" (p. 63).

No tests of statistical significance were performed on these measures since they are meant to be descriptive of the writers' repertoire which students bring with them to tasks of writing.

Syntactic Maturity: Words per T-unit

In his critique of the various indices available to characterize students' syntactic maturity, O'Donnell (1976) asserts that "T-unit length is still the most useful and usable index of syntactic development" (p. 138) and so indicative of students' syntactic maturity. Research has shown the number of word per T-unit sensitive to differences in mode of writing (exposition versus persuasion) among secondary students (Crowhurst, 1977), indicative of growth in syntactic maturity of students in a college freshman

composition course receiving instruction in sentence combining (Faigley, 1979), and useful in demonstrating differences in the length of revision instances of college basic writing students using word processing versus pen and paper in studies of revision (Owston, Murhpy, & Wideman, 1992).

From the results of the analyses of the number of words per draft and the number of T-units per draft, a calculation of the number of T-units per draft was possible. This was accomplished by totaling the total number of words in all students' writings inside a particular draft and classroom. This number was divided by the total number of T-units in all the students' writings in that draft and classroom. This resulted in the mean number of words per T-unit for students inside a particular draft and classroom. This calculation follows the procedures described by Hunt (1965) and Wolk (1970).

Syntactic Maturity: Clauses per T-unit

In another analysis of the students' writings, all subordinate clauses were counted. In this count, elliptical clauses were included as a clause. For example, the statement "It's much easier than the chart" was coded as containing one T-unit ("It's much easier") and one subordinate clause ("than the chart [is easy]"). From this count, a total number of subordinate clauses was reached. To this number was added the number of T-units inside each draft and classroom. The

resulting number was then divided by the number of T-units. This resulted in the average number of clauses per T-unit inside each draft and classroom. Again, this calculation follows the procedures described by Hunt (1965), Wolk (1970), and O'Hare (1973).

Syntactic Maturity: Percent of Words in Final Free Modifiers

In a separate analysis, all final free modifiers (FFM) were located in the students' writings. A final free modifier is any modification structure at the word, phrase, or clause level which occur following the verb in the sentence base (main clause) and which is set off from the sentence base with punctuation. For example, the statement "Since my 6 was negative it gives me a negation so I subtract this from 5, leaving 11" contains the phrase "leaving 11" which was coded as a FFM. Here that FFM was coded as containing two words.

This analysis follows that described by Wolk (1970) who found this measure sensitive to syntactic differences between writing at the college student versus professional levels. In his analyses, following the work of Christiansen (1963), Wolk states that all FFM must be set off from the sentence base by punctuation; that provision was followed in this analysis despite the fact that these students were writing what was essentially writer-based prose.

All FFM's were identified and isolated from the second draft within each classroom. Second drafts were chosen for

this analysis since the second drafts represent the "finished" thinking of students in this study and since initial counting of FFM in first drafts was zero. The total number of words found in the FFM's was counted for each draft and classroom. This total number of words in FFM's was then divided by the total number of words in all the students' writings within that draft and classroom. This resulted in a percent of words in FFM's for each draft and classroom.

Revision Level and Strategy

Revision offers students the opportunity to use a wider range of the processes of writing than does drafting with no opportunity for revision. As part of the processes that students may engage in during writing, revision and support for revision also becomes part of the instructional support that teachers may give in their classrooms.

The drafts that students produced were analyzed for the revisions that student made between draft one and draft two. Revision here is defined as the changes students make when in second draft as compared to the first draft. Analysis of revision was carried out by analyzing drafts for the level of revision and the strategy of revision. Coding for revision level and strategy proceeded after first identifying instances of revision from draft one to draft two. Each revision instance (called simply a "revision" here) was isolated by

comparing drafts word by word; then each revision was coded twice: once for level of revision and once for strategy of revision. Within each classroom and task percentages of revisions at each level and strategy were computed by expressing each as a percentage as the total number of revisions made.

Level of Revision

In the coding for level of revision, no coding was done for "surface" level features such as punctuation, capitalization, spelling, and so forth; although Bridwell (1980) and Monahan (1984) used this level in their coding, it was not included in this analysis since the study did not focus on learning to write or meeting the conventions of SWE but on writing to learn and since surface level issues are usually assumed to be of little importance to writers in their production of writer-based prose.

Each revision was coded for level of revision at the word, phrase, clause, T-unit, or multi-T-unit level. A revision was coded as "word" level when it involved a single word. For example, when Tracy moved from writing in his first draft, "Leave this the same because it is in y form" to saying in draft two, "Leave this the same because it is already in y form," the revision was coded as the addition of a word. The level of revision was coded as "phrase" level when the revision contained more than one word but was not a clause.

For example, in his first draft Shannon wrote, "work two separate problems from the one" and in the second draft wrote, "work two separate problems." This revision was coded as the deletion of a phrase. In another example, Darrell wrote in his first draft, "You let x be 0 to find y"; in his second draft he wrote, "You have to let x be 0 to find y." This revision was coded as the addition of a phrase. The level of revision was coded as "clause" for all subordinate clauses. For example, in his first draft, Shannon wrote, "lose the x if it is attached" and in his second draft wrote "lose the x." This revision was coded as the deletion of a clause. These levels (word, phrase, and clause) follow the usage of Bridwell and Monahan. Another of their levels, which they refer to as the "sentence" level, they recognized from the punctuation students used in their papers. The "sentence" level was deemed not adequate to a representation of the students' writings in these tasks. Instead, that level is designated here as the "T-unit" level since punctuation conventions were not standard in students' writings, as explained above. A revision was designated as a "T-unit" level when it qualified as a T-unit as defined previously, that is, if it contained a main clause or a main clause plus its subordinate clause(s) regardless of punctuation by the writers. For example, Laura wrote in her first draft, "X is vertical. Y is horizontal."and replaced that in her second draft with "The x and y intercepts are where two points cross on the x and y

axis;" this was coded as the substitution of a T-unit since a T-unit in draft two replaced the content of draft one. Another of Bridwell's levels, which she refers to as the "multi-sentence" level was likewise replaced here with the "multi-T-unit" level.

Revision Strategy

In a second coding of each instance of revision, the revision was coded for strategy of revision. In this coding, a revision was coded as exemplifying the "addition" strategy if it did not appear in the first draft but did appear in the second. A revision was coded as a "deletion" strategy if it appeared in the first draft but did not appear in the second. Examples of codings of these two strategies have been given above. A revision was coded as a substitution if the revision in the second draft was put in the place of another word or word string which had appeared in the first draft and when either the meaning or the surrounding structure was preserved. For example, in Shannon's first draft he wrote, "Lose the x if it is attached and then divide if you must." In his second draft he wrote, "Lose the x lose the y and use division if you must." The revision "if it is attached" was coded a deletion of a clause while "then divide" was replaced with "use division," and the latter was coded as a substitution of a clause; "lose the y" was coded as an addition of a T-unit. A revision was coded as reordering when the revision appeared at

one position in a T-unit in the first draft and then appeared at another position in the same T-unit in the second draft. For example, Lisa wrote, "I would use the intercept form to solve the problem" in her first draft and in her second wrote, "To solve the problem I would use the intercept method." The revision "to solve the problem" was coded as the reordering of a phrase. A revision was coded as embedding if two T-units were joined by making one subordinate to another. This coding for strategies essentially follows that used by Monahan (1984).

The coding proceeded throughout the written products for task one and task two for both classrooms. However, coding became problematic in task three for both classrooms. In this task, most students produced second drafts which differed from the first draft so greatly that there were almost no verbatim reference points for analysis of revision to take place. A sense of the extent to which students wrote second drafts in task three that differed from the first drafts can come from a comparison of two drafts of a student's paper. The student took a changed way of articulating her ideas in draft two as opposed to the way she conveyed them in draft one. The paper comes from Lisa, a student in J's class, as she writes in response to the third writing task (simplifying a radical expression).

> Draft One: I looked at the first radical and noticed that it couldn't be simplified. I then went to the second radical and simplified the radical into two separate ones, one of which was a perfect square and the second,

> not a perfect square. I simplified the perfect square and got my answer.

In her second draft, Lisa again gives a detailed answer and includes ideas from her original draft, but she does so in a way different from the first draft.

> Draft Two: You need to simplify the radical and make them the same by pulling out the perfect squares. Take the perfect square and multiply the number by the number outside the radical. Then add or subtract (according to the signs) the numbers outside the radical to get your answer.

The analysis of revision scheme used in this study relies on students maintaining a preponderance of their drafts in identical, verbatim fashion from draft one to draft two. Because of this, the scheme fails to allow the researcher to capture the changes that are evident from draft one to draft two of Lisa's paper. Lisa's second draft, and those of her classmates, were largely "uncodeable" for this reason, using the present analysis of revision scheme. For these reasons, then, the revision coding for the third task was dropped.

After the initial coding, all the previous coding for tasks one and two were checked again and some adjustments in coding made. This final coding was used for calculating results of the analysis. The results were pooled inside each draft and classroom and totals calculated by level and strategy; then each level and strategy was expressed as a percentage of the total number of revisions.

Cognitive Operations

Students' writings were analyzed for the cognitive operations evident in their writing. The purpose of this analysis was to capture, in some way, the thinking represented in students' writings. The final or second draft thinking represented the "completed" thinking students did as represented in the drafting. As a result, this set of analysis was carried out only on the second drafts of students' writings. Again, however, only those second drafts of students who had done both a first and second draft in each task were included in this analysis.

This analysis follows Odell's scheme, which he posits as indicative of the thinking students do while writing, which has been shown to be indicative of such in tasks of writing to learn from literary texts (Marshall, 1987), and which is considered here as representative of the thinking that gets written down in students' papers. Following the Odell scheme, the second drafts were examined for the linguistic cues which seem to be indicative of the cognitive operations underlying the written language.

These cues are divided into six categories: (1) cues of contrast, including connectors (such as "or," "but," "on the other hand"), comparative and superlative forms, negatives (such as "no" and "not"), negative prefixes (such as "in-" and "un-"), and lexical items of contrast such as "contrast,"

"distinction," and their synonyms; (2) cues of classification including the syntax of linking verb followed by predicate nominative, phrases such as "for example," and lexical items such as "similar," "resemble," and their synonyms; (3) cues of changes including "change" and its synonyms and verb phrases that can plausibly be rewritten so as to include "become"; (4) cues to physical context such as geographical location or properties of a physical setting, (5) cues of time sequence such as "then," "when," "already"; and (6) cues of logical sequence including words implying cause-effect relationships such as "because," "therefore," "consequently," and their synonyms, and the phrase "if ... then". Cues for change (item 3 above) were here interpreted to include the mathematical operations of change: divide, multiply, etc., in their verb forms. (Appendix 3 displays a fuller description of the coding system.)

In addition, cues were counted in elliptical constructions for each part of the construction: for example, the statement, "I would use this problem in y form because it is already in y form and you can graph it without having to work the problem" was coded as having two instances of logical sequence cues ("because") since the word stood as a two-fold connector between the sentence base and the two subordinate clauses.

All second drafts were coded and the coding totaled within categories for each task. Because in this sample the

use of cues of physical context was zero, this category was not used in further analysis or data presentation. For comparison purposes, the totals were expressed as a ratio of cues per 100 words within each category for each task.

Within each category and task, totals for category were then compared to the total number of words in the task, with words not in any of the six categories counted in the category "other." To test for statistical significance, the chi-square test for independence of observations was used to determine if categories of cognitive operations were independent of task. The confidence level was set at 95 percent. To carry out this test, proportions of observed and expected values within each category were examined. This initial analysis showed category of operation was not independent of task, so a further analysis to test for statistically significant differences among proportions in each category was carried out. In this further statistical test, proportions of cognitive operations in each category was examined separately to test which cognitive operations were dependent upon task. This second test was carried out using the test of differences among proportions, with the confidence level again set at 95 percent.

Teacher Response: Sorting

As stated earlier, teachers sorted the drafts during the

debriefing interviews immediately after the class in which the writing was produced. The sorting resulted in each paper being given a rating or "score" of 1, 2, 3, or 4 where 1 represents low understanding of the mathematics and 4 represents high. "Scores" from the results of the sorting could be gathered, of course, only from the writing-aided classrooms. The scores for only those students who were present for both drafts within each task were used in this analysis. Comparisons were made between first and second drafts within each of the three planned writing tasks.

Student Response: Questionnaire

A total of 18 students completed the questionnaire in J's writing-aided classroom, while a total of 18 students completed the questionnaire in L's writing aided classroom. An analysis of the questionnaire was made for each question for J's classroom and for each question in L's. For each of the first eight items of the questionnaire, student responses (either "yes" or "no" to the question) were tallied. In the tallies, students who marked both "yes" and "no" responses on an item were coded as giving a "not codeable" response for that item; students who marked neither "yes" nor "no" on an item were coded as giving a "not codeable" response on that item. Responses coded as "not codeable" were dropped from the analyses. For each item, all students' comments on

questionnaire were collected and then transcribed. This resulted in comments and a tally of "yes" and "no" responses for each question inside each classroom. For the 2 open-ended questions, students' comments for each question were collected and then transcribed and analyzed for the support they lent the yes/no responses. The tally of yes/no responses was averaged for class means and means across the two classrooms.

Tape recordings and fieldnotes were made of the discussion that followed the questionnaire in each classroom. Because of the poor technical quality of the recording in J's classroom, only portions of the tape of the discussion were judged usable. The usable portions of the tape recording in J's classroom and the tape recording from L's classroom were transcribed. The transcription was analyzed thematically to support the issues raised in the analysis of the questionnaire.

The compiled transcripts of comments to the questionnaire for J's classroom yielded 8 pages of typed single spaced text. The compiled transcript of comments to the questionnaire and the ensuring discussion in L's classroom yielded 14 pages, typed single space.

Student Response: Chapter Tests

Students' scores on the chapter tests were collected for

both J's and L's tests on Chapters 12, 13, and 14 in both her writing-aided and non-writing aided classroom; thus, scores were collected from all students in all four classrooms. From the non-writing aided classrooms, test scores were used only for those students who completed all three tests administered during the time of the planned writing tasks. From the writing-aided classrooms, test scores were used only for those students who completed all three tests and who completed at least one draft on each of the three planned writing tasks. The decision was made to include scores for all students who wrote at least one draft of each of the three planned writing tasks for two reasons: first, this inclusion makes the stronger case for using writing if all who wrote at least once are included; second, the number who wrote twice was much smaller and would have yielded unreasonably small numbers in one of the writing tasks.

Table 4.3 presents the number of the writing task, the mathematics subject matter addressed by the writing task, and the applicable chapter test. As stated before, these were teacher-made tests emphasizing computation and algorithms.

Comparisons were made between J's writing-aided classroom versus her non-writing aided classroom and between L's writing-aided classroom versus her non-writing aided classroom. Because both J and L constructed and administered different tests, scores could not be compared for the analysis of both writing-aided classrooms versus both non-writing aided

Table 4.3
Relationship Between Writing Task,
Mathematics Topic, and Chapter Test

writing task	mathematics topic addressed by the writing topic	chapter test
task one	intercepts method of solving linear equations	12
task two	solving 3 linear equations	12
J's "unplanned" task	"what are you uncomfortable with for the chapter test"	13
task three	solving a radical expression	14

classrooms.

These comparisons were made between mean scores on chapter tests within each of the three tasks for J's classrooms. Likewise, these comparisons were made between the mean scores on chapter tests within each of the three tasks for L's classrooms. Thus, there were six sets of mean scores compared (three sets of two for each teacher). These comparisons of class means were tested for significance using the t-test for differences in means of independent observations. The confidence levels was set at 95 percent. In these comparisons, class sizes varied, so pooled variances were calculated for data sets of unequal size.

Summary

Three tasks of writing to learn were planned and implemented. Tape recordings and fieldnotes of teacher interviews and classroom observations were made during the time the tasks were used. These tape recordings and fieldnotes were analyzed for references made by teachers in the classrooms to the writing, classroom patterns of instruction pertaining to the writing, methodological and procedural issues pertaining to the writing, and teacher perceptions of the three writing tasks and of writing in general. The students' writings were analyzed for length, syntactic maturity, revision level and strategy, and cognitive

operations. Teachers' sorting of students' writings, students' responses to the questionnaire, and scores on chapter tests were also analyzed.

The results of these analyses are reported in Chapter 5.

Chapter 5

RESULTS OF THE ANALYSES

Overview of the Chapter

From the analyses of the teacher interview and classroom observation data, results were drawn for classroom patterns of mathematics instruction (including the mathematics subject matter focus and center of classroom activity); methodological and procedural issues surrounding the tasks, (including the instructional context, drafting and revising focus, and the use of time in drafting and revising); references made in the classroom by teachers to the length, syntactic maturity, revising, and cognitive operations in the writing; and teacher perceptions surrounding each of the three planned tasks and of writing in general. From the analyses of the written products, results were drawn for length, syntactic maturity, cognitive operations, and teachers' sorting of students' writings. Other results were drawn from the analyses of the student questionnaire and students' scores on chapter tests during the study.

Results: Classroom Patterns of Mathematics Instruction

The teacher interview data were examined by analyzing the Narratives of the Writing Tasks. A summary of those results are found in Table 5.1.

Relationship of Writing Tasks to Chapter Tests

Each of the writing tasks was directly related to the mathematics subject matter that was being discussed by teachers at the time of the first drafts and followed the presentation of those mathematics topics. The teachers and I worked to design a task that--in addition to meeting the other criteria established for constructing writing tasks--addressed the mathematics topics they were working on with students at the time. The tasks' being directly related to the mathematics was, after all, an objective we were attempting to accomplish in our planning for the writing tasks. The particular day that teachers implemented the writing tasks differed from teacher to teacher, and that too was a part of our planning. We took it as a given that each teacher would use the same task but would implement it in the classroom at a point in instruction when it was deemed most appropriate by the teacher. Given our working with planning and implementing the tasks, then, it is hardly surprising that the writing

Table 5.1
Classroom Patterns of Instruction:
The Context for the Writing Tasks

Task One

Subject Matter Focus: Using the intercepts method to solve and graph linear equations.

Writing Prompt: "What is the intercepts method of solving a linear equation and why would you prefer to use it?"

draft one		
1. Center of Activity Before Writing:	J: Teacher Centered	L: Teacher Centered
2. Time Devoted to Writing:	J: 7:06	L: 7:00*
3. Center of Activity After Writing:	J: Teacher Centered	L: none
draft two		
1. Center of Activity Before Writing:	J: none	L: Teacher Centered
2. Time Devoted to Writing:	J: 10:12	L: 6:10*
3. Center of Activity After Writing:	J: Teacher Centered	L: none

Table 5.1 (cont.)

Task Two

Subject Matter Focus: Solving three linear equations for the purpose of graphing.

Writing Prompt: "Of the three methods to graph that we have used, for each equation, tell which method you would use and why. 1. $2x-5y = 20$
2. $y = -3/4\ x + 5$
3. $y = 2x$ "

draft one

1. Center of Activity Before Writing:	J: Teacher Centered	L: Teacher Centered
2. Time Devoted to Writing:	J: 10:33	L: 13:51
3. Center of Activity After Writing:	J: Teacher Centered	L: Teacher Centered

draft two

1. Center of Activity Before Writing:	J: none	L: Teacher Centered
2. Time Devoted to Writing:	J: 13:10	L: 6:00*
3. Center of Activity After Writing:	J: Teacher Centered	L: none

Table 5.1 (cont.)

Task Three

Subject Matter Focus: Solving expressions involving radicals.

Writing Prompt: "Solve the following expressions by simplifying
3\/x2 \/8x2y3 "

draft one

1. Center of Activity Before Writing:	J: Teacher Centered	L: Teacher Centered
2. Time Devoted to Writing:	J: 5:45*	L: 9:40*
3. Center of Activity After Writing:	J: none	L: Teacher Centered

draft two

1. Center of Activity Before Writing:	J: Student Centered	L: Teacher Centered
2. Time Devoted to Writing:	J: 11:25*	L: 9:30
3. Center of Activity After Writing:	J: none	L: Teacher Centered

Note: Times with asterisks (*) represent approximate times since these drafts were completed at the end of a class session and student left the classroom as they finished.

tasks follow and directly relate to the subject matter focus in instruction.

These results suggest that college teachers of developmental mathematics can collaboratively plan writing tasks that grow directly out of the mathematics topics they are addressing in the classroom and then implement those writing-to-learn tasks in their classrooms. They also suggest that with planning, the teachers can tie the writing-to-learn tasks directly to the instruction from which they grow, at least in terms of timing and sequencing of instruction.

Differences in the Time Devoted to Writing

Within each of the three writing tasks, J and L differed in the use of time devoted to drafts, and these differences resulted in observable patterns.

In J's class the first task took about 6 minutes total for the first draft, about 10 minutes for the second; the second task took about 10 minutes total for the first draft, about 13 total for the second; the third task took about 6 minutes for the first draft, about 11 for the second. Clearly, according to the data for J's classroom, second drafts (including the revision activities) were accorded more time than were first drafts. From my impressions of the classroom and the narratives of the classroom, my hunch is that J responds to the need for students to accomplish a

longer, more complex task by giving them more time to do the revisions. This impression is supported by her assertion in the interview after the second draft of the second task that

> I didn't want to press them. I want them to feel that it's [writing] an integral part of what we do now. That it isn't something superfluous, or that it's going to press us for time as far as the class is concerned.

These results suggest that J is aware that first and second drafts make different demands on students in terms of time devoted to writing, and so she gives students more time in the second drafts. As stated earlier, J and I had worked with writing in the mathematics classroom before, and so she may be using that experience with writing to guide her here. Alternatively, J may also be unusually sensitive to students' needs in many areas, writing just one among them.

In L's class a different pattern emerges for the use of time for the second drafts across the tasks. In L's class the first task took about 7 minutes for the first draft, about 6 minutes for the second; the second task took about 13 minutes for the first draft, about 6 minutes for the second; the third task took about ten minutes for the first draft, and ten minutes for the second. Thus, second drafts take about the same amount of time or no longer than the first drafts. From my impressions of the classroom and the narratives of the classroom, L did not act as if she saw the second drafts as making more demands upon students than did the first drafts. In other words, she made little differentiation in the amount

of time she devoted to first versus second drafts. However, she seemed to be aware that she gave students little time for their second drafts. In the interview after the first draft of the first task, L says,

> I feel like I rushed them. All of a sudden it was 10:30 and time for a break. And I wanted to do it before break, so I just stopped and said, do this now.

In an interview after all the writing tasks were completed, L said that she didn't think that students took much time to revise, that some did only a very little revising and, in fact, she wondered if students even took time to read the comments she had written:

> I was disappointed that they didn't seem to have read it because they didn't really do anything about it the second time sometimes.

In short, L seemed to give little time for revising as compared to initial drafting, seemed to recognize this disparity and its results in students' revising activities, but seemed somehow unable to change this pattern.

Taken together, these results suggest that J and L perceived the demands of revision differently or perceived student performance of revision differently or were acting out of more or less experience with using writing. It may very well be that L is correct about her perception that students took her comments little to heart. Indeed, as we will see in the discussion following the student questionnaire, at least

one of L's students found L's comments difficult to respond to in revising.

The Placement of the Writing Tasks in Classroom Activities

By examining the center of activity in instruction and the placement of the writing tasks inside instruction, we can see several patterns that emerge from the data.

J took a variety of approaches to placing the writing tasks inside classroom instruction while L did not. In J's class, of the six drafting sessions noted here (two drafts for each task), J placed writing tasks in the midst of teacher-centered activity twice, ended the class session with writing tasks twice (once following student-centered activity and once following teacher-centered activity) and began the class with writing tasks twice. On the other hand, of the six drafting sessions noted here, L employed two basic patterns of placing the writing tasks in instruction: inside teacher-centered activities (three times) or at the end of the class session following teacher-centered activities (three times).

This difference in patterns of classroom activity and their variety in terms of placing the writing tasks in classroom activities suggests that L sees no way yet available to her to find a variety of placements for the writing tasks or that she feels less comfort or competence in how the tasks

are placed and so places them in less of a variety of positions inside each session of classroom activity. This second notion --that L feels less comfort or competence in how she places the writing tasks-- is supported by several statements that L made during the interviews. After the first draft of the first writing task, as we talked about the time spent on the writing task, L stated that how she placed the task (so that the break would immediately follow the task) actually rushed the students in the task and that such a placement "wasn't really a good way to do it. So I guess we could do it at the beginning of the period." However, as the facts show, L never did do that. Later, in an interview about midway through the project, L says, "See, I'm not good at this writing at all. I would need to get better." I probe, asking what she means by "better"; she says, "better with my questions, better with my comments." Later still, again in discussing planning for writing tasks, L says, "I need to work it [writing] into my lesson plans better if I'm actually going to do it [use writing] later."

These results suggest that the two teachers, J and L, made different plans or decisions about the placement of the writing in the flow of classroom activities and demonstrated differing levels of comfort about how they placed the tasks. L seemed to think that a placement of the tasks different from the ones she used might give students more or better opportunity for writing. These results also suggest that

those who work with teachers in their use of writing-to-learn tasks in mathematics need to be sensitive to possible differences in the amounts of time devoted to drafting and in where these tasks are placed in classroom activity.

These results also seem to reflect the fact that J has had more experience in working with writing than has L, at least as far as first drafts are concerned. The different levels of experience with using writing and the concomitant differences in how each teacher managed time devoted to drafts and the differences in the placement of the writing tasks in classroom activities suggest that as teachers have experience with using writing in the mathematics classroom they make different decisions about writing and show changed patterns of using writing relative to mathematics instruction.

Center of Activity in the Mathematics Classes

Most of the classroom activity that surrounds writing here is teacher-centered activity. Granted that, within the context of this study, the writing tasks themselves are new interventions into their classrooms, but of all the centers of activity noted here, all but one of the 24 are centered on the teacher. This is consistent with my impressions from classroom observation. In all the hours of visiting classrooms, the teachers were the center of activity with two exceptions: when students were completing the solutions to

problem sets or tests, and once, in L's class, when students talked in small groups to answer questions from a teacher handout.

Results: Methodological and Procedural Issues

From the analyses of the Narratives of the Writing Tasks a number of results were obtained. Table 5.2 summarizes the data from these analyses.

Instructional Context of the Writing Tasks

The first drafts of the writing tasks were placed at several different positions in the instructional unit by the teachers.

J placed the first and third tasks in the development portion of her instructional units, that is, where she was attempting to consolidate ideas and procedures already introduced. She placed the second writing task near the culminating point in the unit under study. This second writing task, in which students were asked to write about three different equations (which L saw as demanding the three different methods for solving linear equations), J placed immediately before the practice test on the chapter covering those three methods of graphing and stated to students that, like the review, she hoped that the writing task would "tie

Table 5.2
Methodological and Procedural Issues:
The Task Environment

Issues	J's classroom	L's classroom
Writing Task One		
1. Instructional Context of the Task		
-placement in instructional unit	development	initial
-announced function in instruction	"so I can see where you are as far as these two methods are concerned"	"I have a writing assignment for you"
-inferred function in instruction	assessment	evaluation
2. Writing Focus: First Draft		
-contentless goals	none	none
3. Writing Focus: Revision		
-contentless goals of the task	"write down these verbal meanings to these things that we talked about"	none
-contentless goals of revision	"rewrite them and dress them up a little bit more carefully"	"I'll give some points, like three points, on the daily grade"

Table 5.2 (cont.)

Issues	J's classroom	L's classroom
4. Time Allocation: First Draft		
-directions	2:05	0:50
-drafting, uninterrupted	3:07	5:25*
-drafting, total	4:01	6:00*
5. Time Allocation: Revision and Second Draft		
-directions	3:08	2:10
-drafting, uninterrupted	3:50	4:00*
-drafting, total	7:04	5:00*
Writing Task Two		
1. Instructional Context of the Task		
-placement in instructional unit	culminating	culminating
-announced function in instruction	"to know which method you would use and why"	"I have a writing assignment for you"
-inferred function in instruction	assessment	evaluation

Table 5.2 (cont.)

Issues	J's classroom	L's classroom
2. Writing Focus: First Draft		
-contentless goals	"write the method, refresh your memory on the board, write a sentence or two"	"tell briefly about the question"
3. Writing Focus: Revision		
-contentless goals of the task	"describe it as if you were trying to teach someone who wasn't here"	none
-contentless goals of revision	"read my notes, read what you wrote and see what your response would be"	"You want to definitely try to make it better"
4. Time Allocation: First Draft		
-directions	1:20	0:45
-drafting, uninterrupted	5:40	9:00
-drafting, total	9:33	13:06

Table 5.2 (cont.)

Issues	J's classroom	L's classroom
5. Time Allocation: Revision and Second Draft		
-directions	3:30	1:00
-drafting, uninterrupted	9:40	2:00*
-drafting, total	9:40	6:00*
Writing Task Three		
1. Instructional Context of the Task		
-placement in instructional unit	development	development
-announced function in instruction	to determine "if you are going to be OK in the chapter"	"I want to go back and give you a problem to do and write about it"
-inferred function in instruction	assessment	evaluation
2. Writing Focus: First Draft		
-contentless goals	"write the problem and then I want you to explain what you were thinking as you went through"	"write it, and tell how in words"

Table 5.2 (cont.)

Issues	J's classroom	L's classroom
3. Writing Focus: Revision		
-contentless goals of the task	"to be sure you know what you are doing"	none
-contentless goals of revision	"incorporate what people have told you"	"Do that and tell how you did it" better"
4. Time Allocation: First Draft		
-directions	1:01	0:40
-drafting, uninterrupted	4:46*	5:31
-drafting, total	6:00*	9:01
5. Time Allocation: Revision and Second Draft		
-directions	1:26	0:30
-drafting, uninterrupted	3:02	7:00
-drafting, total	10:00*	9:00

Note: Time with asterisks (*) represent approximate times since the indicated drafts were done at the end of the class session and students left as they finished.

together everything we have learned".

L placed the first task in the introduction portion, the second in the culminating portion, and the third in the development portion. This placement may suggest that either J felt very comfortable with placing these tasks at any of these positions, that the position in the instructional unit did not enter into her planning at all, or something else entirely. But taken with her statements, already quoted, of needing to plan the writing better, it is more likely that the placement of the writing tasks in the instructional unit probably either did not occur to her at all, or was of minor importance given all the other demands the writing seemed to place on her.

These results demonstrate that these writing-to-learn tasks were more often placed by teachers in non-initial position in the instructional unit. This suggests that the teachers may have seen the tasks' "fit" into the instructional unit as ways to develop or culminate the instructional unit rather than as ways to introduce mathematics topics in an instructional unit.

Functions of the Writing Tasks in Instruction

For J, the tasks seemed to function as a way to assess the understanding of particular students about particular bits of mathematics knowledge. Every time she implemented the

writing tasks in the classroom, she told students that she wanted them to write so that she could have a better grasp of their understanding. Indeed, the one task that J implemented on her own without prior discussion with me--and therefore a task I have referred to as "unplanned"--came on a day before a class session devoted to a review for a test on chapter 13. J asked students to review six problems in the chapter review in the textbook and four problems she had written on the board; students were asked by J to

> write and tell me what you think your weakest area is, and if you have a weakest area, what don't you seem to understand about the area.

J further underscored the assessment function of this "unplanned" writing task as she told students, "and then on Friday I can address these [weaknesses] at the first of the class." During the interviews, too, the assessment function of the tasks seemed of paramount importance for J. On the day she implemented this "unplanned" task, she told me,

> At first, I thought, we've got too much to do. Then, I thought, no I need them to write. I need them to write.

Pressed as to why she thought so, J responded, "because I want to know who feels comfortable and who doesn't." When I asked what she was going to do with the writing, J stated,

> I'm going to pull out the people. I will go over the homework. But I'll address probably more specific questions to those people. Like, I'll say, Lynette, now do you have a question here? Do you understand? Without

referring to the writing.

Indeed, during the class session that followed the "unplanned" writing task, J addressed Cindy, Sandra, Lynette, Shannon, and Gary by name in referring to particular mathematics ideas and procedures. Asked afterwards if she had been working out of information obtained in the writing when she did address these students, J agreed that such was the case and that the writing helped her "know where they were coming from."

Too, as we will see in the student questionnaire and the subsequent discussion, several students seemed to feel that the basic function of the writing in J's classroom was to let J know what students understood and what they did not understand so that she could provide assistance.

For L, the inferred function of each of the tasks was evaluation. In the classroom, she told students that she would give them points for the writing tasks in the same way as she gave them points for the infrequent short quizzes on solving problem sets in class: both were unannounced before hand, both were completed in the classroom within five to fifteen minutes, both could be completed by students with reference to notes and textbooks, and both were done without assistance from the teacher. Students often seemed to feel that one of the functions of the writing tasks was evaluation: during the second writing task, while L was out of the room, one student asked aloud if this were for a grade and another answered, "Probably." At one point, L had told students the

tasks would not be graded and at another point she told them they would. In each of the writing tasks, L returned the first draft papers with the sorting score marked on them and announced to students that the score represented "what you would get" as a grade on that paper if the grades were taken. When L returned second draft papers she told students that the score was the number of points they received on the activity out of a possible four.

In contrast, J was quite firm immediately in the first draft of the first writing task when a student asked if the tasks would be graded. "No," she said, "No grades." The point, however, is that these teachers used the tasks for functions of their own.

These results suggest that writing-to-learn tasks, while they may be planned for one purpose (learning) by the researcher or intervener, may be used by mathematics teachers for their own purposes, which may or may not be centered on learning and developing mathematics knowledge.

Goals of Drafting as Set by Teachers

The contentless goals the two teachers gave to students in the first draft of the writing tasks differed. As contentless goals, these were goals that the teachers set for students seemed to be for the purpose of assisting students in producing the drafts. As such, they inform us about the

support in instruction that teachers gave students as the students wrote.

In the first writing task J gave no goals that, if accomplished by students, might assist them in writing the first draft. During the second and third writing tasks, however, she did suggest to students some actions they could take that might assist them in drafting. During the second writing task, in which students wrote about how to solve three linear equations, she told students to "refresh" their memories about the three different methods of solution, to call the name of the particular method they would use, and to write a sentence or two about it. In the third writing task, she told students in the first drafting session to "write the problem" and do the solution and then to write "what you were thinking as you went through" the solution.

L offered no such goals but announced to students that they should write to answer the question in the written prompt.

Clearly, teachers differ in the extent to which they are ready to present goals to students for drafting. This result suggests that mathematics teachers who are not experienced in using writing in the classroom may need assistance in implementing drafting in ways that may assist students in the task by establishing goals for students to accomplish inside the tasks.

Goals of Revision as Set by Teachers

The contentless goals of revision that the two teachers gave to students differed also. As goals of revision that the teachers set for students to accomplish, these also are occasions when teacher may assist or support writing in instruction.

In the first writing task, J told students to revise by answering the comment(s) or question(s) that she had made on their papers and include that answer in their second drafts. She also gave example comments she might have made, explained their meaning, and told students what they might do to respond to the comments and questions. In the third task, J referred students back to what their partners in revision groups had said and told students to "incorporate what people have told you" in the second draft.

In the first writing task, L told students that she would give them points for their revised papers. In the second writing tasks she told students about their drafts, "you want to make it better." In the third writing task she told students to do the problem again and "tell how you did it."

As seen above, the two teachers both gave goals in reference to the larger task of revising, but the quality of J's goals seems to present more potential for leading students to success in their second drafts: they are specific and detailed, they relate to incorporating a larger amount or

changed knowledge in the papers, and they are communicated in simple, non-technical terms. The goals she suggests to students suggest actions that students might take in order to make more use of her comments and those of their peers. Seen from another perspective, J more closely controls or influences the revision that students made. Even though both gave comments and questions in response to student drafts, J enmeshed those comments and questions to a much greater degree in teacher talk and guidance of the revision.

Use of Time in Drafting

As noted earlier, J and L differed in the amounts of classroom time that they allotted for first versus second drafts, with J allotting more time for revision and second drafting across all tasks as compared to L. Other differences are also evident between the time the two teachers devoted to writing as seen in the results of this analysis. When the time for "directions" (that is, from the announcement of the task until students actually begin drafting) is pulled out of the total time for the tasks, other differences emerge between how J and L allot time in their classroom for writing.

In each of the three tasks, J spent more time in "directions" than did L. Again, "directions" include the time from the announcement of the writing task until the time students begin drafting or written planning. In the first and

second drafts of the first writing task, for example, J spent 5:11 in directions versus L's 3:00. Combining all tasks and drafts, J spent more than twice as much time in "directions" as did L, a total of 12:28 for J across all drafts and tasks as compared to a total of 6:01 for L. This is time when the teachers' talk to students may provide instructional support for the tasks. Part of that instructional support, as discussed above, includes goal setting for drafting and revising. Other important talk during "directions" included some instances of linking present mathematics knowledge and tasks to previous mathematics knowledge and tasks.

If sheer duration of teacher talk indicates a richer context from which students may write, then J provided such. Of course, no such claim can be made for duration; however, that amount of talk does give teachers the opportunity for providing students with instructional support. Taken with the greater amounts of goal-setting J provided, the greater amount of talk that J did suggests that she may have been providing students in some way with the instructional support they needed to accomplish the writing in ways consistent with her plans for the writing. Another possibility is that during her talk J somehow was able to transfer her feelings of comfort, confidence, or competence in using writing to her students. Indeed, as we will see later in looking at the class discussions following the student questionnaire, L's students felt that the writing tasks were difficult for them to do.

"It was hard," they said. "It was really hard." J's students, on the other hand, were not so preoccupied with the degree of difficulty of the tasks as we talked in the discussion after students completed the questionnaire. No cause-effect link can be made here among the duration of talk in directions, the degree of difficulty of the task, or the quality of instructional support in the task. Although that is the case, these pieces of information are suggestive that teacher talk around the drafting and revision may help students perceive the writing tasks as less difficult than when teacher talk around the task is of less duration and contains fewer goals for students to use in drafting and revising.

Across all drafts of the three planned writing tasks, the combined time J spent on writing in the classroom (from announcement of the task until papers were collected) amounted to 58 minutes, in L's class about 54. Although they each spent about the same amount of classroom time on these drafts, as we have seen above, the manner in which they used that total time varied a great deal.

Results: References to Writing from the Classroom

Teachers made relatively few references in the classroom to the length, syntactic maturity, revision, and cognitive operations concerning the writing that students did. Only 14

such references were made.

The Kinds of References

When examined by the kinds of references, the references to length were dominant. Most of these references (8 out of the 14) were references to length of the writing made by J. For example, J told students that they should write "two or three sentences or a paragraph" in their drafts.

There were two references to syntactic maturity. Although these two references made by J were surely about the writing, they were somewhat oblique in their being references to the syntactic maturity. They were: "You don't have to worry that the English is proper" and "In your own words, your own language, I want you to explain it to me." Both references signal students that they should not focus on the formal aspects of writing which may or may not include such issues as syntax for conscious control by students. When asked later about what she meant by these two statements, J said that she didn't want the students to worry about how their writing "looked".

There was one reference coded as being a reference to cognitive operations. But just as the reference coded syntactic maturity was so coded with no high degree of confidence, so too this one reference coded as being a reference to cognitive operations is only rather obliquely

about cognition. The one reference to cognitive operations was made by J: "Just try to tell me the very best you can what you are thinking."

In short, the teachers --mostly J-- made a few references to length of the writing as they talked about the writing. Of all these references, most were made by J and concerned the length of the writing, and most pertained to the first drafts rather than the revising.

Other Characteristics of the References

The references were overwhelmingly made by J. She made all but one of the 14 references examined here.

Most of them occurred immediately before drafting (13). One was made after a draft was completed.

References to Writing Not Associated with the Drafting

There were four references to writing--not included in the above discussion--that occurred in the classroom but not in proximity to the drafting. Each of these references concerned the content of the writing. Because they did not occur in proximity to the drafting, these references were not included in the above analyses.

These four references are given below because they demonstrate a linking by the teacher from instruction back to

writing. The writing that the references link back to had taken place much earlier, sometimes up to a week earlier. The teachers made these references when they were ostensibly not talking about writing per se but about the mathematics. In parentheses is given the approximate distance from the drafting at which the reference was made.

> 1. J: (later in same class session) I noticed some real interesting answers on this paper, but most of you just in a nutshell, Darrell put his in a real nutshell, why would you prefer to do intercepts? [Darrell replies that he would prefer to use the intercepts method because "it's easier".]
>
> 2. J: (a week later) You got real good at intercepts because we wrote about that last week. And everybody came up kosher on the last writing.
>
> 3. J: (in the next class session) There were three ways that we could graph straight lines. And that's what we've written about this week.
>
> 4. L: (later in the same class session) And what are those points called? What you wrote about? [One student replies, "Intercepts."]

These four references were the total that were found in all the classroom transcripts in which teachers talked about the writing after the writing took place. They each refer to the content of the writing but are not in proximity to the drafting. They are instances of the teacher linking the content of instruction at one point in the classroom to the content of the writing at an earlier point. Three of the 4 were made by J. Their small number shows that the teachers did make some links back to the drafting, but did so relatively few times during the course of instruction.

Results: Teacher Perceptions of The Three Writing Tasks

From an analysis of the Narratives of the Writing Tasks several results were obtained about the three planned writing tasks. Those results are discussed in turn for each of the teachers in each of the three planned tasks.

Task One

In the first writing task, students were asked to write in response to the prompt, "why would we prefer to use the intercepts method to graph and how do you do it." After their drafting and the teachers' reading, responding to, sorting, and then returning the papers, students were asked to revise.

Task One: J.

First draft. In implementing the first draft, J gives students the entire design of the task as she gives the directions: students will write, she will respond, and students will rewrite. When students ask her a question about the writing, she is quick to respond with a definite answer, suggesting to students that this is her assignment, that she has taken ownership of it, and that she understands the parameters of the task she has set for them. Her response also situates the task into prior mathematics knowledge and firmly enmeshes it in that knowledge by comparing the present

method (intercepts) with the tabular method, the last-taught method of solving linear equations. After students have drafted and handed in their papers, J gives an encapsulated possible answer to the question "why" (because it is easier) and "how" (as she reviews the intercepts procedure in the abstract). This action parallels other daily practice in mathematics procedures and activities J engages in with her students.

Second Draft. When J implements the revision in the classroom, she gives directions to the class about the revision and then recognizes by name those students who did not write a first draft of the paper and then adapts directions on the spot to meet their needs. This shows students that J does, in fact, keep tabs on them--at least, who was present and who was not--and so lends credence to her claim to students and in the interviews that she wants to know where each student "is" in the classroom work. This also implies that, as with all her work in the classroom, J wants to keep tabs on students and their responses to her assignments for them: what they think, do, and feel. In other words, this is one more of her assignments as she sees it. She gives the students revision specifics: they should "re-read what you wrote and look at any notes I might have written down;" if their answer was right, they should dress it up "a little bit;" and students should remember that the

goal of the revision remains the goal of the entire task, that is, to answer the original question. Here J again takes ownership of the writing task, supplying students with a relatively rich series of procedural goals they may follow. Her talk also demonstrates to students that she will not leave them on their own to accomplish the assignment; she will emphasize to them the procedures and/or processes they may engage in to accomplish the task in a way she judges as successful. Her recurring phrase of "a little bit," spoken four times in the talk surrounding the revision, implies that she is actually trying to diffuse any fear of writing or rewriting that students may harbor. But this is also a phrase that recurs throughout all her talk with students and points to a dominate need she has in the classroom: to soothe students, to make them "feel comfortable" with the classroom and what they do there. J also sets the revision directions inside a fictional-world scenario of a classroom:

> write it like you were trying to explain it to someone that perhaps was not in the class when we tried to learn how to do intercepts.

This scenario taps personal experience and may assist some students who might otherwise have trouble in completing the task. It draws on their own personal experience and gives a classroom audience, if a fictional one, for the writing. J also addresses directions to students about how to proceed in their revision depending on the comments she made on their

papers: whether she wrote question marks beside particular parts, wrote notes, or asked questions. Then she tells students to re-read what they had written. These directions further support the revision by again suggesting procedures and/or processes students may engage in to carry out the task of revision

In the interview after the second draft, J says of her students' performance,

> I think they're receptive. I didn't get any groans, like, oh, you know. And I didn't get any of those like, I wonder why we're having to do this.

This statement implies that J sees the drafting and revision as successful in the sense that she "pulled it off" by enmeshing it all in her talk and/or instruction and by making students feel comfortable with the task. Mainly, this was accomplished by her talking students through parts of the task and linking parts of the task back to prior-taught mathematics content. J seems to perceive her task in having students write as one in which she must "pull it off" for it to be successful. J also perceives the task as one that culminated instruction:

> And I think ... it helped pull everything back together. Where were we on Monday, where are we now, and where do we want to be next Monday.

Again, for a task to be successful for J, it must fit into the

instructional unit in a way that links it to much that comes before and that which will follow. For J, apparently, this is as important an aspect of the writing as it is of any other task in the mathematics classroom.

Task One: L

First Draft. In implementing the first draft, L shows the students the prompt for the task written on an overhead projector and asks that they "in your own words, answer this and turn it in." These directions are much more abrupt and abbreviated than are J's with little teacher talk surrounding L's giving the assignment. L mirrors such in her comments during the interview after the class: "I just stopped and said do this now." This suggests that using writing, including planning and implementing writing, seems unfamiliar territory to L; this would be a natural outcome for mathematics teachers using writing tasks for the first time in their classrooms. L gives no encapsulated answer to the expected content of the writing and makes no reference back to the writing in the class session after the break.

Second Draft. When L implements the revision in the classroom, she gives directions by saying,

> So you have about 10 minutes to write it again. I told you some little pointers there about what I want you to do. And I will give you some points, like 3 points, towards the daily grade on this time of doing it.

Thus, students are doing the writing and revising to be graded and may treat it similar to a testing situation.

In the interview, before reading the papers, L states,

> I didn't handle this very well. I didn't give them instructions like, do it again. I didn't remember what I was supposed to do. I didn't think about it either.

Again, this suggests that using writing is unfamiliar territory to L and that she thinks that she has trouble in planning the details of implementing the task. Before she reads papers, L says of them,

> I'm worried about it. Some of them had so little carry over. We have been out of class for so long. I'm worried they won't remember what they were talking about.

As she read papers, she remarks of Betty's paper, "it [the writing prompt] says 'what are'. And she says 'they occur when.' Which doesn't flow together." This suggests that L is concerned with both what is said and how it is said in the student writing. This relates to L's earlier statement that she didn't know what to expect in the student writing, that maybe her expectations were unrealistic, that she was expecting students to "write an essay or something." As she reads, she puts check marks on papers beside what she thinks is wrong. This parallels the method L uses to mark tests. Underscoring the relationship between her responding to papers and marking tests, when she returns the revised papers to

students she says,

> I'm going to give you back your paragraphs, your writings from the other day. I was trying to let everybody try to write them again for some daily points.

Again, this suggests that L sees the writing as part of the testing that students do for grades in her class. Later that same day, L makes the only reference to writing outside of the drafting and revising sessions that she makes during the study. She asks students to tell her the name of the method they had just been studying, "And what are those points called? What you wrote about?" This is the only such reference L makes to the writing during all three tasks, and it refers students only to a label, not the content of that label. This lack of reference back to the writing again indicates that L is less comfortable with and may feel less competent in dealing with the writing as compared to J and that she attempts many fewer linking of ideas from instruction to writing tasks or from writing tasks to instruction.

Task Two

In the second writing task, students were given a list of three equations ($2x - 5y = 20$; $y = 3/4\ x + 5$; and $y = 2x$). They were asked, "which method would you use to solve each equation and why?"

Task Two: J

First Draft. As J begins implementing the second writing task, she enmeshes the directions for it in the flow of her talk. Again, J shows her ownership of the task, showing to students that the task is a seamless part of the on-going talk J engages in and the on-going tasks they complete in the classroom. J gives students the time parameters for drafting saying, "maybe about a five or ten minute writing if you need to." This emphasizes that students can take the time they need, that they can complete this task at a speed appropriate to them. Again, this harkens back to J's need for students to "feel comfortable" with the tasks she poses. As she direct students she says, "I want to know, I want to see where you are coming from individually on this" and "There are no right and wrong answers. I just want to know which method you would use and why you would use it." Again, J suggests to students that the purpose of the assignment is to help her assess student knowledge of procedures. The implication is that this will somehow help students. J wants students to write "the method, the word for the method, not just the number." This seems to indicate that the name, the word must be significant to J. For her, this may be the role language plays in the task: The label must be connected to the procedure or category of solution.

Later, after students write and during instruction, she makes another reference back to the writing: "You got real

good at intercepts because we wrote about it last week." This may mean that students are to infer that they learned from the task. But students get the message, too, from this talk that in some way the writing helps. This suggests again that the writing task must be a part of the students' overall perception that what they do at J's behest is for their benefit in the classroom.

In the interview, J reads and responds quickly and seemingly easily with the exception of one student. J pauses long and gives to Jayson, who wrote what J thinks L wanted in the writing, a score of 3. When asked her rationale, J says she is basing this score on his general performance, not just the performance on this particular writing task. This brings up a thorny issue for J: whether to respond to students based on what is absolutely seen in the writing or to take into account other factors when she responds. J opts to take in all factors she is aware of. This suggests that J makes use of all available information she has about a student in responding to (or, at least here, in sorting) students' papers.

Second Draft. When J returns papers and models a revision process, she then gives directions based on the "why" in the original prompt:

> 'Why' is not some kind of generic answer that you think all teachers would give. 'Why' is more of a personal

> answer. 'Why' is saying why would you use it? Why would you use it?

Here again, J focuses students on their individual responses to the question and their choice of methods in solution. This may be to encourage students to develop their own sense of why they use a particular method in solving a linear equation. It also underscores the notion that J perceives this as an analytic task. For the task, students are told to take about five minutes, but she allows more than ten. This difference suggests that J will allow the writing to take longer if she sees students need the time and again suggests her desire to make students "feel comfortable" in completing the task she has set.

In the interview, J gave her rationale for why she spent quite a bit of time in the classroom discussing the meaning of the scores from sorting:

> I wanted them to understand they were trying to focus in on how right or wrong their descriptions were. I think that one reason why several of them improved is that they thought, I know what I'm thinking, she knows what I'm thinking, but I need to express it in more English, and some of them did. They just elaborated a little and made some improvement.

Here lies the tension between what is said and what is known. Did students who scored less than four merely omit knowledge they had or did they need to acquire it before they could include it in their writing? J seems to think that a 4 is given to a paper that shows the writer knows and can express

the appropriate amount of accurate, relevant knowledge while a 3 is given to a paper that shows the writer knows but can't express or expresses in a faulty manner. Herein J also states that she thinks students responded to her comments and that this is one of the reasons many of them improved their scores from the first draft to the second draft. This demonstrates her perception of the efficacy of her comments in that students demonstrated in the appropriate written language a greater or more accurate knowledge in the second draft. Overall, of the task and of the writing, J says,

> I want them to feel that it's an integral part of what we do now. That it isn't something superfluous or that it's going to press us for time as far as the class is concerned.

J realizes the need to make all assignments her own in the classroom and to have students independently arrive at the perception that the tasks are integral so that they, the students, think that everything is interrelated, nothing is wasted or disconnected in what they do in her classroom.

Task Two: L

When students return from a break, L turns on the overhead projector which has on it a transparency that displays the writing prompt. She says,

> I have another writing assignment for you. Use your notes. I don't want you to actually graph anything. I

> want you to tell about it. Tell briefly the answers to these questions here. Tell the method you would choose and why you would choose it. And it's not that only one method is right. I mean you could use more than one. Nobody would have to say, I would use this one or this one and that's it, and everything else is wrong. Just tell which you would use and why. You can use your notes to do that.

This is more talk surrounding the writing than previously seen in L's implementing task one. Here L gives students possible parameters, additional ways that they could write in response to the prompt. This suggests that L feels some need to give a greater amount of talk that will somehow help students in the task.

As we begin the interview, L says of the writing,

> Very few of them got the idea that they could use slope/intercept on $y = 2x$. Most of them said table of values here. Which you can do; that's fine. But I don't know whether to bring it to their attention. At this point I don't want to confuse them. If they know how to do it like this, I think maybe just leave it.

This suggests that L was unaware of this as a possible answer before students engaged in the writing. Later, she says, "I said, 'How would <u>you</u> do this and why? Maybe my question wasn't right." This suggests that L was surprised that students took so many different approaches to the solutions. And, this suggests that L has been focused on a preconceived notion of the answer and was not expecting students to interpret and/or understand in many different ways. It also suggests that L feels this is a difficulty, a difficulty which

lies in the question that she asked, that if she had asked a different question she would not have had to deal with divergent student answers and would not have been taken unawares by divergent understanding as seen in the papers. That L is also surprised for other reasons by what students had to say in their papers is revealed as she states of one particular student,

> My idea of his understanding didn't match the way his paper looks. This is enlightening to me. I'm finding out a lot about my students that I didn't-- I don't always have them pegged like I think I do. Just by looking at them doing problems, I read more into it than is really there. I can tell here that they really don't know. Which is what you expected? [Later, she continues,] What I guess I'm saying is that I'm sort of beginning to understand that my trying to teach concepts and the way I tested don't match up. I test, do this algorithm. And I say I want to teach concepts. And maybe I'm beginning to understand that I've gotten myself at cross purposes here.

The writing, she says, "just points it out." Here the writing has given L different information about the performance and/or knowledge of students than what she usually finds on tests or in the interaction in class between her and students. The writing also suggests to L a contradiction between concepts and procedures in mathematics as intended, as taught, and as tested. And, of course, L is still concentrating on testing (evaluating) rather than teaching or learning.

In the classroom, after modeling a revision process for students on the overhead projector, L states,

> I hope you had time to think about how you could make your answers better or what was wrong with your answer before. Everybody needs to write it and make it clearer or something you've learned since you wrote it the first time. If you didn't know how to do the graphing at the beginning of the period today, you probably didn't know how to answer this question very good the other day. So now you should know better.

This suggests that L believes that students have taken in some information from some source during class that will allow them to perform better on the writing. This better performance will be because of more mathematical knowledge, not because of the writing, as L seems to perceive it.

In the interview, L says of the writing task,

> Maybe I need to set up a question and maybe be more specific and have points that I look for. They need to have this in there or they don't have it. Find a question that I could do that with.

When asked to do so on what she has been teaching, L says,

> What if I put an equation like this one and said, 'Name them.' I want them to name three ways they could graph it and then tell, in each case, how, what that would mean to do.

Despite the fact that this statement fits in well with the general discomfort she voices with most of what she does in the classroom, this suggests that L is responding to what she sees in the writing students have done in order to change future assignments, an occurrence I have not noted before about any other assignment--writing or non-writing--in her class. This also suggests that L's perception of the results

of writing are at cross purposes to my own: she is trying to find a prompt that will elicit writing that she can respond to in a kind of checklist fashion, writing as giving the "correct" answer, as on tests. Again, this underscores L's attempts to use writing as a means of testing and evaluation.

Second Drafts. Back in the classroom, as students return from a break during the next class session, L hands back the second drafts students had written, and as she does so she tells students that the grades are on the papers and are expressed as the number of points students received out of a possible four. L states that she expected something better in the writing the second time students wrote, implying to students that she didn't see "something better" in their revised papers. After distributing the papers, L hands back the tests students had taken the same day as the writing. She asks students if they would have liked to have told her something about the test in writing, and one student says of the writing, "It was hard."

Later, in an interview, L tells me about the relationship she sees between the writing task and student performance on the test over the chapter under study (that is, Chapter 12). She says, "Pretty much the people that couldn't write about it didn't do well." This suggests a direct relationship between student performance on the writing and their performance on typical mathematics tests: there is some positive, direct

relationship between the two, in L's mind, at least on this task and this test.

Task Three

In the third writing task, students were given the an equation with a radical expression and asked to "solve by simplifying and tell how you did it."

Task Three:J

As we planned the third and final writing task, J told me in the planning interview,

> This one, I was thinking about on the way to school this morning. I think I have dealt with this one a where are you, where do we need to be kind of level. You want to say, 'how do you do this process so that maybe it can help me see where you're going wrong.'

Thus J contrasts her perception of these tasks ("where are we and where do we [the class] need to be") with her perception of my notion of the tasks ("how do you do this process so that maybe it can help me [the teacher] see where you're going wrong"). In volunteering this information, J seems to be seeking validation from me that her perceptions are right and validation that her own notion of the purpose of the tasks is an accurate one also.

First Draft. In the classroom, J introduces the directions to the writing task by saying, "If I understand

that you understand this problem, then I think you are going to be OK in the chapter," asks students to "spend about five minutes or so writing," and then tells students,

> I want you to work the problem and then I want you to explain how you did it. Explain what you were thinking as you went through.

In the interview, as she is sorting papers, J gives Gary a 3 on his paper because he could do the mathematics procedure but couldn't explain a significant portion of it:

> Down to here is fine. But he didn't finish. He did not know from here to here how to explain what he was doing.

She knew that was true, she said, because he came up and asked her how to explain what he had done. Again as with Jayson, this suggests that sorting for J is based on more than just what is seen in the writing; the score is based on a sort of sum total of J's knowledge of the student and her assessment of the student's total knowledge of the mathematics involved including her interactions with the student. This is also again suggestive that some students can do the procedure but cannot explain it in writing, that the procedure is somehow "automatic" and not completely under the conscious control of the student. As she read Darrell's paper, J says,

> I think he really understands how to find the square root of the exponent, but he doesn't understand what a perfect square numeral is.

J gives him a 3 instead of a 4 because of this lack of knowledge, and says, "I'll explain it again at the beginning of class and give them another one at the end." Here, again,

J uses the knowledge she gains from the students' paper to her own benefit as a guide in planning the next segment of instruction. Again, as she has said before, this suggests that not only does J use the writing for assessment of what individual students know ("where are we") but she also uses it to assess what she needs to do next ("where do we need to be"). About midway in the sorting process, J says,

> I wonder what we are looking for. Are we looking for the truth expressed in an accurate way or are we looking for the proper procedure?

This juxtaposition of procedure and truth hints at J's perception that truth and procedure are not synonymous in mathematics, a notion she does not pursue and one she has not mentioned before. After having read, responded to, and sorted all the papers, J says that she is very frustrated from reading the papers: frustrated to know how little some students know, frustrated to understand the reasons for why they know so little, frustrated to find that those reasons are often beyond the control of the student (finances, home problems, family demands, social stumbling blocks, and so forth). To J, this frustration could become one potential source of teacher resistance to using tasks of writing to learn mathematics. By using these tasks, teachers thereby gain a greater knowledge of the students' understanding, an understanding which is sometimes faulty or misconstrued, lacking in links between ideas, or totally absent. What teacher will then revamp her entire course syllabus after

learning all this? In effect, she seems to say, many mathematics teachers may not want to know all the things about the students they teach, which they will find out if they have students write. J also comments on this particular task:

> This writing is much more specific [than the "unplanned" task she had implemented immediately before this one]. It gives me different information because it's procedural and I think the other writings, especially the last one, were more emotional.

She labels the kind of writing that we are talking about here as

> writing in the mathematics curriculum: let me explain to you what I think I know and see if I know it. That kind of writing would be more readily accepted than the other.

Speaking of the resistance of mathematics teachers to using writing, she says that mathematics teachers say they don't have time to have students write, "but like today, it took maybe five minutes, even if it was at the very end of class." J also says that the procedural writing of this task provided her with helpful information:

> If I had read the writing [before students left the class], I probably would have just talked to Lynette [one of the students who wasn't doing well.] So that's a very positive kind of outcome. You know who's having trouble. You could even ask them to stay" [after class for help after having read the papers].

Second Draft. In the classroom, when J has put students in groups of two's and three's to complete a problem set, she asks them to revise their papers in groups. After explaining

the scoring rubric again, J puts up the writing prompt on an overhead projector and says,

> Work it out and then explain to me how you did it. What you did when you did that. Some of you related that perfectly to me on Wednesday. The rest of you I was able to tell where you were having trouble. Write two or three sentences or a paragraph to tell me how did you work it. If you were trying to explain to somebody else, what would you say.

Here, again, J gives students subgoals or subroutines to accomplish inside the larger task of revising and writing, she focuses students' attention on their display in writing of the correct procedure for solution, and she established a fictive audience for composing.

Back in the interview, J reads, responds to, and scores the papers quickly. She says of the papers,

> Even though some people went down a numerical score from last time, I feel like they are in a better place from that as compared to what I read on Wednesday. They know more than they knew on Wednesday. At least I think the right organizational structure is going through their minds when they're trying to work the problems.

Here J shows that the "organizational structure" of the mathematics comes through in the students' writing and gives her to know that students are doing better than she might have thought from just looking at scores on the sorting or just watching students work in class. As she talked about the students' being in groups, she remarked that she thought that there was "rampant confusion in working the problems." However, as she read the papers, she sensed something entirely

different, for when

> they came down to doing that one problem [in the writing] that really involved everything we did except the rationalizing, they knew.

As opposed to looking at the classroom, says J,

> the writing made me feel better about them than the classroom work. The group work and no writing, just looking at it, I would feel like they were totally confused. With the writing, I think they know more than the classwork would show. So I feel better about where we are because of the writing.

By focusing back on individual performance in the writing, as opposed to what she saw in groups, J can untangle who knows what, who can do what, who doesn't or can't, and what she will then do to plan the next segment of instruction. This is another possible reason the writing seems to "work" for J: she can see individual performance captured in the writing and can use it to her benefit to formulate plans for instruction that will ameliorate the difficulties of those whose knowledge is faulty or absent.

Task Three: L

First Draft. While implementing the third writing task in the classroom, L tells students,

> I now want to go back and give you a problem to do and to write about. This is what we were doing before in this last chapter. This is a multiplication problem, see, and you want to do it. Multiply there. Give your answer in simplest form and explain how you did it. Work it and tell how, in words. And then turn that in when you finish. And be thinking about it because you're going to get another chance to write about it for a grade on

Thursday.

This is the first time that L has shown students the entire cycle of write, read, revise in the writing. It suggests that she feels she should have done this, perhaps earlier. As she did in task two and will do again in the second draft of this task, L leaves the room when students begin to write.

In the interview after the class, L tells me, "A lot of the people who were last [to turn in papers] were the ones that weren't good. The others have been OK." L makes this observation but does not suggest what it may imply about students or task. After talking about various ways to implement the revision, L decides to do the usual: hand back the papers and have students revise on the same day. "My original plan was to do it before break, but I realized that would rush them too much, so I waited until after." This is the first time that L says she has arranged the task to give students more time to work through the task. Of future plans for writing, L says,

> I'm going to start trying to do that more next semester, like at the very beginning have them write. I'm getting more comfortable with grading them. I'm going to try to start.

This suggests that L may use writing tasks again. But her plans seem rather hazy and general. She talks about reading papers and says,

> I still have trouble trying to read into what they are saying, instead of reading just for face value. I try to think, what do they mean by this? And I don't know if I should or shouldn't do that. You sort of have to. I mean, I think I sort of have to. If I didn't, I'd like to see how.

This suggests again that L is not comfortable with what she sees as the ambiguous position of the writing: neither actual test that lists step-wise facts, but nonetheless somehow indicative of student knowledge but difficult for her to interpret and/or evaluate.

Second Draft. Back in the classroom, about thirty minutes into the class period, L says, "I have your papers from the other day on writing. Some of you did real well on this one." L then hands back the papers and says,

> And I told you we were going to do them over. If you have any questions about what I wrote on your paper, I'll come and talk to you about it. I'm going to let you do this problem, which is one like the kind we are working on today. It's the same kind of thing. Do this and tell how you did it.

This is the first time in her talk to students about their writing that she has offered to talk to them individually about their papers.

In the interview, L talks about how she sorted (scored) these papers,

> If they called a square root a square, I tried to drop it down a point. That's an important thing that some of them don't have. They don't know the difference.

Hereby, L offers a criterion of evaluation for the papers, but in a comment on her overall perception of sorting, L says, "I'm not real comfortable. I'm thinking about did I grade them all the same. Did I count off the same?" Thus we see that L is not sure about how consistent or accurate her sorting of papers is; it must be so in evaluative terms since evaluation is an important component of the task in her estimation.

Results: Teacher Perceptions of Writing in General

The results obtained from examining the Narrative of Writing in General for each of the two teachers will be reported under five headings: writing to learn, writing and learning, language and tasks of writing to learn mathematics, writing to learn and student attitudes, using writing-to-learn tasks in the classroom, and results of the tasks.

J's Perceptions of Writing in General

Writing to learn: The tasks per se

When J is asked to formulate a prompt for tasks of writing to learn in mathematics, she formulates one that parallels the procedural writing that has been used in the study. By being able to formulate a prompt that dovetails with those used in the study, she shows her awareness and understanding of the aims and methods of the study.

J is also much aware that writing is not a monolithic unity, that it has various functions that it may take on. Specifically, J shows that she perceives that writing in the mathematics classroom may be used for assessment, for evaluation, and for assisting learning.

J thinks that writing to learn tasks are not required of students in most classes they encounter across the curriculum. This belief is probably an accurate reflection of the status of WAC on her campus, both in her department and campus-wide.

She says that the writing tasks that students have carried out in her classroom are an extra burden on them. She realizes that tasks of writing to learn are not usual tasks students are called upon to carry out in mathematics, that they require serious work on the part of students, and that they are further work for students to accomplish in the mathematics classroom. However, despite the uniqueness of the assignment and the extra burden of the work, these students have been cooperative in our endeavors, and J feels they should be rewarded for such cooperation and work.

Writing and learning

J believes that writing about the mathematics is not the same as doing the mathematics. Being able to write about the mathematics procedures as students have done in this study does not ensure that a student can carry out the procedures. To her, competence in one does not ensure competence in the

other.

Conversely, individual students may know more mathematics procedures than they can express accurately in writing, as seen in the case of Angie, a student about whom she talks several times during the sorting. This indicates that, to J, students' texts may not always be accurate reflections of their knowledge. J says that Angie is an isolated case, however, and not the general rule. There was also an instance when a student seemed to understand as seen in the teacher's response to his writing but was unable to carry out the mathematics procedures on a test. This was the case of Shannon. Again, however, J sees this was an isolated incident, and not the general rule.

Overall, J is not sure whether the writing helped students learn mathematics or not, but she says she knows it certainly didn't detract from their learning.

Language and tasks of writing to learn mathematics

Language comes into play in the mathematics classroom in several guises; it does so or J in the naming of procedures in students' writing. J finds that one student (Gary) knows how to do the mathematics procedure but does not know the name given to the procedure as he showed in one of his writings. J thinks it is then her responsibility to make sure that he does know the name for the procedure, especially in light of the fact that he may have to call up the procedure in a

subsequent course based solely on the name of the procedure.

J also uses metaphors, both simple and extended, extensively in her classroom discussions and does so purposefully because, as she says, she wants students to "hear [her] voice" every time they do mathematics.

Writing to learn and student attitudes

To J, students' pre-existing attitudes may interact with the attitudes she sees necessary to carrying out writing effectively in her class. Those student attitudes she sees as necessary but not sufficient for these tasks to "work" include trust in the efficacy of teacher-requested assignments, trust in the teacher to have students do meaningful "work", and an attitude on the part of students that would allow them to open up to the teacher in the writing, or as J termed it, "emotional writing;" also, students must feel free to tell the teacher not only what they know but also what they don't know without fear of it affecting evaluation in the classroom. For J, student attitudes are extremely important and often affect learning outcomes in her classroom. Thus it is extremely important to her that these appropriate attitudes be in place before teachers use tasks of writing to learn.

Using writing to learn mathematics in the classroom

Writing has become a way to establish dialogue, especially from student to teacher, in J's classroom. This

dialogue is more personal, more intimate, less formal than most classroom talk. Writing has become a dialogue with the teacher in which each individual student responds to teacher questions or prompts about mathematics knowledge and other classroom issues of learning and knowing. For J, this helpful dialogue grows out of the non-evaluative function of the writing assignments, but writing may still function as assessment in the classroom and allow the free, personal, intimate flow of information between student and teacher. Writing has opened up another forum for the dialogue between students and teachers and enhances the dialogue itself. This kind of dialogue is necessary to maintain positive student attitudes about mathematics, about learning mathematics, and about the mathematics classroom. If writing had hindered this dialogue in any way, it probably would have been seen by J as an unsuccessful intervention in her classroom. As it was, J perceives these tasks of writing to learn as fostering this dialogue between her and her students and so add to her classroom.

Writing to learn mathematics: Results of the tasks

For J, the tasks of writing to learn have added information to her store of knowledge about students. Through the writing, J often saw things about her students she would not otherwise have seen. In the writing, she says she saw quicker when students were having difficulties in their

learning, she saw more about those difficulties in their learning, and she had additional and different insights into their learning of mathematics, insights that she would not have had if students had done no writing.

Through the additional dialogue and through these additional and different insights, J saw more about her students than she had previously seen without the writing tasks. In some instances, she saw that students had obvious gaps in knowledge and was aware that students themselves saw the gaps because they wrote that they had these gaps in their knowledge. She learned that some students would not ask questions orally or request assistance when presented with a less intimidating classroom (for example, when most of the class is not present) even when the writing showed them to lack important bits of knowledge and in desperate need of assistance. Knowing this from the writing, the mathematics teacher is presented with additional responsibility: she must choose to act or not act to overcome this reluctance on the part of these particular students. In other instances, she saw in the writing that other students had obvious gaps in their knowledge that they themselves were unaware of. In short, the writing gave J greater and different insight into the learning and difficulties in learning her students were experiencing in her class.

But with this greater awareness on her part also came a greater sense of responsibility for her students.

The greater awareness and responsibility that come with the information available to teachers in the writing the students have done may be a source of greater frustration to the teacher because she realizes the questionable nature or extent of learning for some of her charges (as in the case of Lynette).

For J writing interacts with the role she assumes in taking responsibility for the classroom, learning, and students. In this role, J assumes responsibility to a great degree for the grades (evaluation) that students receive. At some times, J sees herself as taking more responsibility for the evaluation that students receive than they do themselves. The writing that students have done gives her greater insight into both evaluation and assessment. Therefore, she, as opposed to students, being the one with greater insight, is the one to take greater responsibility for both evaluation and assessment now that writing has increased her awareness of students and their learning and knowledge of mathematics. Since writing gives J and mathematics teachers like her both a greater accuracy of assessment and a different assessment, it places on them even greater responsibility if they choose to assume that responsibility. Since the information garnered from assessment has implication for classroom action and thus evaluation, and since the writing isn't part of the regular curriculum for her class or a part of the department-wide syllabus for the course, J feels even more responsible for and

to students than she has without the writing.

This greater responsibility which teachers may take and then act on also interacts with J's role as a mathematics teacher and her perception of that role as a teacher in the community college as opposed to the four year institution. At several points, J's awareness and responsibility was played off against her perception of herself as a faculty member at a community college whose mission is to assist those student not sufficiently prepared for the experience or challenges of a four-year institution. J is also aware that she may do more to intervene with students than do other mathematics teachers in her department since she feels she is often more aware of students and their learning than other teachers and since she perceives her role as teacher differently from the roles other community college mathematics teachers may perceive for themselves.

L's Perceptions of Writing in General

Writing to learn: The tasks per se

On one occasion, when L is asked to formulate a prompt for tasks of writing to learn in mathematics, she formulates one that does not exactly parallel the procedural writing that has been used in the study (hers is a task that asks students to summarize in writing their notes of the day's class session), but formulates one which could nevertheless be

helpful to students. Yet, on another occasion, during a classroom discussion of a the results of a test which were being returned to students, L spontaneously composes a general topic for a task of writing about mathematics. This suggests that L understands the general aims and methods of the study.

For L, the writing that students do in the mathematics class needs to be evaluated (rated), but not necessarily assessed. As such, she finds a way to "fit" these tasks into her overall evaluation scheme for students. This suggests also that L feels that students may not have taken the writing seriously if it had not been graded and returned to students in a manner similar to other tests and assignments in the class.

Writing and learning

L sees the ability of students to write as influencing expression in writing about mathematics, especially in the mathematics concepts that students may or may not be able to express in their writing. In addition, she states that her assessment or evaluation of students' knowledge of mathematics as seen in the tasks may be complicated by students' lack of ability to express themselves. This suggests that L takes as important her accurate reading of the texts students produce so as to effectively evaluate student learning as seen in the texts.

Some students may not be helped in learning mathematics

by tasks of writing to learn, she says, as in the case of Linda, one of her students. But most of them, she feels, are helped in their learning by writing.

She does, however, believe that these writing tasks work better for some students than they do for others. L thinks that writing in mathematics class works better for those who enjoy writing more than they enjoy math as in the case of Betty. She believes that this enjoyment of writing can be seen in the ways that students produce their writing: those who take time with the spelling and the writing of complete sentences are probably those who enjoy writing more than they enjoy mathematics, L thinks. In this way, these students' texts reflect their enjoyment of writing. This perception suggests that L sees that writing about mathematics has a strong contribution from writing ability, writing performance, and student attitudes towards writing.

L has expectations of the formal aspects of writing (its structure and its length) that were violated by the writing produced by students in the "bonus" question she used before the project began. She expected longer and more complete answers, almost "an essay" by students in the bonus question. She had similar perceptions about the texts produced in the study. These expectations about the formal aspects of the writing students completed may have been shaped by her own experience with writing in college English classes, an experience she did not enjoy.

Language and tasks of writing to learn mathematics

L thinks that language may be of help to students' learning of mathematics. Specifically, she thinks that students' ability to use talk about mathematics may be an asset to their understanding the "logic" of a mathematics procedure. L also sees the need for language, especially oral language, in the mathematics classroom in the form of student dialogue in the classroom. This dialogue would take place among students as they talk about mathematics topics. L also mentions the Standards as supporting the use of talk among students about mathematics topics.

L uses writing in complete sentences on the board whenever she starts a new topic or wants to get across to students "basic definitions" of term, especially at the start of new mathematics topics.

L sees the need for students to assume more responsibility for their own learning, a responsibility which they could act upon by initiating more questions in the classroom.

Writing to learn and student attitudes

For L, students not "liking" a particular writing task may be a sufficient reason for discontinuing the use of the task. She had used WAC tasks several years ago but discontinued their use since students did not like the

assignments. The dislike L perceived among students for writing may be one source for the fact that L states that, in the present study, she had anticipated more student resistance to writing than she encountered.

Although students seemed to enjoy the writing tasks in the present study more than they did in her own use of WAC, L isn't certain whether or not students think they were helped in learning by the writing done during the present study.

Using writing to learn in the classroom

Writing is still not an integral part of L's classroom, as she sees it, but she would like for it to be. She is willing to change the way she uses tasks of writing to learn: she states that she will change her plans for the instructional support for writing based on her perception of students' reactions to the present writing tasks. However, she reports a general unease with writing in general and with the tasks used in the study. Also, she perceives support for writing in her class as being inconsistent.

Writing to learn in mathematics: Results of the tasks

The writing that students produced often showed that students had less of an understanding of mathematics than L had believed otherwise. For example, students showed less knowledge of the three methods of solving a linear equation than L had anticipated. In general, states L, writing makes

teachers more aware of the lack of understanding on the part of students. According to L, it serves in part to "point out" or highlight students' lack of understanding.

Writing gives L a view of students different from other views of student learning and knowledge she may have had in the past. For example, writing helped L assess or evaluate students' understanding of concepts to a greater degree and in a different way than did usual the mathematics tests. As another example, writing brought to L an awareness of student knowledge or ability different from that brought to her through classroom interaction with students. In short, writing gives a greater depth or detail but a different look at student knowledge of mathematics, according to J.

In reading and responding to student texts, L thought her response to the students' texts involved a great deal of inferencing. L is unsure of what the texts actually indicate about students' knowledge of mathematics. However, as students read the texts on which L had written her comments, she thought that students did not take her written comments on their papers as seriously as they should have, nor did they use them in constructive ways.

Contrasted Perceptions of Writing in General

Thus, J and L perceived writing in general in very different ways but agreed on some key perceptions. They both thought that writing --as opposed to typical tests, problem sets, or class interaction-- gave mathematics teachers more detailed insight into students' knowledge of mathematics. They were both unsure of whether writing per se improved students' learning of mathematics, but were just as sure that it didn't hinder learning. Both felt that the students' writing abilities, attitudes, and preferences interacted with students' expression of their mathematics knowledge in the writing, resulting in some students' greater ability to express their knowledge of mathematics in writing while resulting in other students' less ability to do so. Both saw language in general, especially oral language and naming mathematics procedures specifically, as important aspects of the mathematics classroom. J also saw extended metaphor as an important use of language in mathematics learning. Both remarked on the greater awareness they had of students individually (their abilities, gaps in knowledge, attitudes, idiosyncrasies in learning, etc.) as a result of the writing, but only one (J) saw writing as a dialogue from student to teacher to aid learning in the classroom.

Results: Written Products

Length

In general, the analyses of length showed that, for the most part, students' drafts were longer in the second drafts than they were in the first drafts. This held true for the first and second writing task but not for the third writing task. Table 5.3 displays a summary of the mean number of words per draft for the three writing tasks. Table 5.4 displays the mean differences between draft one and draft two in terms of the number of words per draft. Table 5.5 displays a summary of the mean number of T-units per draft for the three writing tasks. Table 5.6 displays the mean differences between draft one and draft two in terms of the number of T-units per draft.

As stated in Chapter 4, the number of words in draft one was subtracted from the number of words in draft two for each student. (This same procedure was carried out for the number of T-units per draft, also.) The differences in the paired data are displayed in Table 5.7 as an example of this procedure. These differences in paired data were then used to arrive at class means as displayed in the above tables. The differences in the means were tested for significance by constructing a confidence interval for each class mean within each task. The statistically significant differences between

Table 5.3
Length of the Drafts:
Mean Number of Words per Draft

	Draft One	Draft Two
Task One		
J's class	25.50	60.00
L's class	40.75	57.56
Task Two		
J's class	60.33	88.44
L's class	67.94	71.56
Task Three		
J's class	48.86	40.29
L's class	40.17	39.00

Table 5.4
Length of Drafts:
Mean Differences in Number of Words per Draft
Between Draft One and Draft Two

	Task One	Task Two	Task Three
J's class	19.50	28.11*	-9.14
L's class	16.81*	3.62	0.33

Table 5.5
Length of the Drafts:
Mean Number of T-units per Draft

	Draft One	Draft Two
Task One		
J's class	3.50	6.75
L's class	3.88	4.88
Task Two		
J's class	6.44	8.89
L's class	5.81	6.63
Task Three		
J's class	5.29	4.43
L's class	4.33	4.25

Table 5.6
Length of Drafts:
Mean Differences in Number of T-units per Draft
Between Draft One and Draft Two

	Task One	Task Two	Task Three
J's class	3.25*	2.44*	-0.86
L's class	0.97*	0.81	0.08

Table 5.7
Differences in Paired Data
for Length of Drafts
Between First and Second Drafts in Task One, L's Classroom

person	number of words per draft draft one (d1)	number of words per draft draft two (d2)	(d2-d1)
1	29	62	+33
2	61	65	+04
3	51	50	-01
4	21	46	+25
5	52	50	-02
6	43	84	+41
7	62	84	+22
8	32	49	+17
9	24	67	+43
10	27	55	+28
11	48	44	-04
12	74	85	+11
13	29	48	+19
14	20	32	+12
15	35	55	+20
16	44	45	+01

the means which are noted in Tables 5.4 and 5.6 were arrived at in this way.

For the first and second writing tasks, on the average students wrote more in draft two than they did in draft one in terms of the number of words per draft. However, these differences were statistically detectable only for J's classroom in the second writing task and for L's classroom in the first writing task. For the first and second writing tasks, on average students wrote more in draft two than they did in draft one in terms of the number of T-units per draft. And these differences were statistically detectable for J's

classroom for the first and second writing task and for L's classroom for the first writing task. In other words, these two measures of length (number of words per draft and number of T-units per draft) consistently showed increases (some of which were statistically detectable) between draft one and two for the first two writing tasks in both classroom for both the first and second writing task. However, such was not the case in the third writing task. For students in both classes on the third writing task, the average number of words per draft and the average number of T-units per draft were lower in the second draft but not at a level detectable by the statistical procedures used here. This result for the third writing task is consistent across the two classrooms.

These results show that in general students took the opportunity to make longer drafts in the second draft for tasks one and two but not in task three.

Syntactic Maturity

In general, the results of the analyses of syntactic maturity showed no real trends across tasks or classrooms. Table 5.8 shows the results of the analysis of the mean number of words per T-unit; Table 5.9 shows the results of the analysis of the mean number of clauses per T-unit; Table 5.10 shows the results of the analysis of the percentage of words in FFM for the second drafts.

Table 5.8
Syntactic Maturity of the Drafts:
Mean Number of Words per T-unit

	Draft One	Draft Two
Task One		
J's class	7.28	8.89
L's class	10.52	11.81
Task Two		
J's class	9.36	9.95
L's class	11.69	10.80
Task Three		
J's class	9.24	9.10
L's class	9.27	9.18

Table 5.9
Syntactic Maturity of the Drafts:
Mean Number of Clauses per T-unit

	Draft One	Draft Two
Task One		
J's class	1.79	1.48
L's class	1.35	1.36
Task Two		
J's class	1.29	1.41
L's class	1.43	1.29
Task Three		
J's class	1.32	1.16
L's class	1.31	1.35

Table 5.10
Syntactic Maturity of the Drafts:
Percentage of Words in Final Free Modifiers,
Second Drafts

	number of words in FFM	percentage of words in FFM
Task One		
J's class	6	1.25
L's class	20	3.06
Task Two		
J's class	0	0
L's class	0	0
Task Three		
J's class	0	0
L's class	2	0.42

For the first writing task, students on the average wrote more syntactically mature (i.e., syntactically complex) drafts in draft two than they did in draft one in terms of the number of words per T-unit, but not in terms of the number of clauses per T-unit or the percentage of words in final free modifiers. However, other than this one pattern in one measure of syntactic maturity for task one, there were no consistent results on the other tasks and analyses of those tasks. For students in both classes, results for the average number of words per T-unit, the average number of clauses per T-unit, and the percentage of words in FFM show a rather random result, sometimes higher in one class than in the other on a particular measure and sometimes lower. Often students were seen to write a more syntactically mature statement in one draft and follow it by putting the same ideas into a less syntactically mature statement in the next as, for example, when Steven wrote "I would use the x and y intercepts since the equation is set up in the form expedient to do so" in a first draft and followed it with a draft in which he wrote, in part, "I'd use the x and y intercept. The equation is set up that way." In short, no pattern emerged on the measures of syntactic maturity across drafts, classrooms, or tasks.

Revision Level

Across the two first two writing tasks, the students most

often employed revisions at the level of the T-unit and the multi-T-unit. These two levels of revision account for more than 50% of all instances of revision across classrooms and tasks. Table 5.11 displays the results of the analysis for revision level.

Revision Strategy

Across the first two writing tasks, the students used the revision strategies of addition, deletion, and substitution. In fact, there were no instances in any draft in which students used embedding as a revision strategy; there was only one instance of the use of the re-ordering strategy noted throughout the drafts. Table 5.12 displays the results of the analysis for revision strategy.

Cognitive Operations

Results of the analysis for cognitive operations are displayed in Tables 5.13 through 5.19. The number of cognitive operations expressed as a ratio of operations per 100 words is displayed in Table 5.13. Recall that this analysis omits operations in the category of physical context since in this study the coding in that category was zero.

The results of the chi-square test for independence of observations are displayed in Table 5.14. This table gives

Table 5.11
Revisions of Drafts:
Level of Revision

Level	Number	Percent	Level	Number	Percent
		Task One			
J's Class			L's Class		
word	0	0.0	word	0	0.0
phrase	12	25.0	phrase	2	6.9
clause	4	14.0	clause	2	6.9
T-unit	28	58.3	T-unit	8	27.9
Multi-T-unit	4	8.3	Multi-T-unit	17	56.6
totals	48		totals	29	
		Task Two			
J's Class			L's Class		
word	10	9.4	word	9	15.0
phrase	28	26.4	phrase	17	28.3
clause	2	1.9	clause	2	3.3
T-unit	38	35.8	T-unit	23	38.3
Multi-T-unit	28	26.4	Multi-T-unit	9	15.0
totals	106		totals	60	

Table 5.12
Revisions of Drafts:
Strategy of Revision

Strategy	Number	Percent	Strategy	Number	Percent
Task One					
J's Class			L's Class		
addition	20	41.6	addition	7	24.1
deletion	15	33.3	deletion	4	13.8
substi-tution	12	25.0	substi-tution	18	62.0
reorder	0	0.0	reorder	0	0.0
embed	0	0.0	embed	0	0.0
totals	48		totals	29	
Task Two					
J's Class			L's Class		
addition	57	53.7	addition	21	35.0
deletion	28	26.4	deletion	18	30.0
substi-tution	20	18.9	substi-tution	21	35.0
reorder	1	0.9	reorder	0	0.0
embed	0	0.0	embed	0	0.0
totals	106		totals	60	

Table 5.13
Cognitive Operations
Evident in the Writing Tasks
Expressed as Occurrences per 100 Words

	Task One	Task Two	Task Three
contrast cues	3.43	2.30	0.19
classification cues	2.07	1.68	1.16
change cues	2.93	2.01	8.82
time sequence cues	0.99	1.06	4.65
logical sequence cues	1.07	2.08	1.36

Table 5.14
Observed and Expected Values
for Cognitive Operations
Chi-square Test for Independence of Observations

	Task One		Task Two		Task Three	
Contrast	48	(30)	61	(58)	2	(22)
Classification	29	(23)	46	(46)	12	(17)
Change	41	(50)	55	(98)	91	(37)
Time Sequence	14	(24)	29	(48)	48	(18)
Logical Sequence	15	(23)	57	(45)	14	(17)
Other	1245	(1248)	2488	(2438)	865	(919)

Note: Expected values are given in parenthesis and are rounded to the nearest whole number. The chi-square value for this test = 202.48* with the critical value = 18.31 (df = 10).

Table 5.15
Observed and Expected Values
of Categories for Cognitive Operations:
The Category of Contrast

	Task One	Task Two	Task Three
Contrast	48 (30)	61 (58)	2 (22)
Other	1352 (1376)	2675 (2688)	1030 (1014)

Note: Expected values are given in parenthesis and are rounded to the nearest whole number. The chi-square value for this test = 29.73* with the critical value = 5.991 (df = 2).

Table 5.16
Observed and Expected Values
of Categories for Cognitive Operations:
The Category of Classification

	Task One	Task Two	Task Three
Classification	29 (23)	46 (46)	12 (17)
Other	1372 (1376)	2690 (2689)	1020 (1014)

Note: Expected values appear in parentheses and are rounded to the nearest whole number. The chi-square value for this test = 2.93 with the critical value = 5.991 (df = 2).

Table 5.17
Observed and Expected Values
of Categories for Cognitive Operations:
The Category of Change

	Task One	Task Two	Task Three
Contrast	418 (50)	55 (98)	91 (37)
Other	1360 (1350)	2681 (2637)	941 (999)

Note: Expected values are given in parenthesis and are rounded to the nearest whole number. The chi-square value for this test = 102.2* with the critical value = 5.991 (df = 2).

Table 5.18
Observed and Expected Values
of Categories for Cognitive Operations:
The Category of Time Sequence

	Task One	Task Two	Task Three
Time Sequence	14 (24)	29 (47)	48 (18)
Other	1337 (1362)	2707 (2687)	984 (1013)

Note: Expected values are given in parenthesis and are rounded to the nearest whole number. The chi-square value for this test = 62.32* with the critical value = 5.991 (df = 2).

Table 5.19
Observed and Expected Values
of Categories for Cognitive Operations:
The Category of Logical Sequence

	Task One	Task Two	Task Three
Logical Sequence	15 (23)	57 (45)	14 (17)
Other	1336 (1377)	2679 (2690)	1018 (1014)

Note: Expected values are given in parenthesis and are rounded to the nearest whole number. The chi-square value for this test = 6.55* with the critical value = 5.991 (df = 2).

observed and expected values of operations in each category for each task. Since this test demonstrated that category was not independent of task, a further test of statistical significance was carried out.

In order to determine which of the categories were or were not independent of the tasks, the test for difference among proportions was carried out; these results are displayed in Table 5.15 through 5.19. Tables 5.15 through 5.19 display the observed and expected values from the tests for differences among proportions for each category; as shown in these tables, the categories of contrast, change, time sequence, and logical sequence showed detectable differences between tasks at the 95 percent confidence level.

Results: Teachers' Sorting of the Written Products

After the scores from the sorting for each draft, each classroom, and each task were analyzed, several results could be seen. These results are summarized in Table 5.20.

Sorting Differences Between Drafts

Across all of the three tasks, the mean of the sorting scores rose from draft one to draft two. In task two that rise from draft one to draft two was 0.5 for J, and 0.5 for L. In task three the rise was 0.16 for J, and 0.15 for L. These consistent improvements in the mean score from draft one to draft two in these two tasks for both teachers suggest that teachers saw the papers in draft two as being more complete and/or more accurate in their representation of the mathematics involved in students' writing. The one area of slight difference between the increase in scores is the lesser increase in scores for task one between draft one and two for L's classroom. J's mean score increased by 0.5 while L's mean score increase by only 0.3. In short, there is about a 0.5 increase in mean scores on the sorting between drafts for the first and second writing tasks. Of course, that these rises were seen should not be surprising given the fact that the difference between the two drafts is the fact of students'

Table 5.20
Teacher Response: Sorting
Mean Scores

	Draft One	Draft Two
Task One		
J's class	3.00	3.50
L's class	2.75	3.06
Task Two		
J's class	3.00	3.55
L's class	2.94	3.53
Task Three		
J's class	2.39	2.55
L's class	3.00	3.15

having done draft one, having worked in class, and possibly having done homework between draft one and two. Having students revise led to improved scores for students across all tasks and teachers.

Sorting Differences Between Tasks and Revision Activity

In looking at the consistent rise of scores from draft one to draft two, it becomes apparent that the rise is

displayed for task one and for task two at about a half point on a 4-point scale for both tasks. In contrast, on task three the rise is again consistent for both teachers but is much smaller (about one-sixth of a point on a 4-point scale). This suggests that the improvement in scores provided by the revision activity (peer revision) was somehow less operative in task three for students in both classrooms. Or this suggests that the improvement in scores provided by a second writing was less operative in task three. For whatever reason, in task three the improvement in scores for the second draft is much smaller than the improvement on the second drafts in the other two tasks.

Sorting Differences Between Teachers

On the first task, J scored her students about the same as compared to L for both drafts. On the second task, J scored her students about the same as compared to L for both drafts. These consistencies between teachers are seen in both first and second drafts. The similarities in the mean scores suggest that something must be going on in how the two teachers operationalized their sorting, perhaps looking for similar features in the students' writing. The only point of difference between teachers is seen in task three where J is .61 points lower in her class's mean score for draft one and .60 points lower in her class's mean score for draft two.

This result suggests that there must be some difference going in the teachers' judgments of the mathematics involved in that task that sets it apart in both drafts from the other tasks.

Results: Questionnaire

A portion of the numerical results from the questionnaire that was administered to students is shown in Table 5.21; that table summarizes the results of the first eight of ten items on the questionnaire. The results of the questionnaire are reported here in four ways: by combining numerical results for the first eight items on the questionnaire for the two classrooms, by contrasting the numerical results for the first eight items on the questionnaire for the two classrooms, by examining student responses to the two open-ended questions on the questionnaire, and by examining thematically the class discussion that followed the questionnaire. Students' comments written on the questionnaire are used anecdotally to "flesh out" their responses on the first eight items of the questionnaire.

Combined Results

In general, when the results of the questionnaires are combined for both classes, we find that a majority of students said that writing was not a waste of time (94%). When

Table 5.21
Summary of Student Responses
to the Questionnaire

	Average	J's students	L's students
1. Did writing help you clarify your ideas?			
	Y = 88	Y = 100	Y = 77
	N = 08	N = 0	N = 16
2. Did writing help you know more about your understanding?			
	Y = 94	Y = 100	Y = 88
	N = 02	N = 0	N = 05
3. Did writing help you know more about what you did or did not know?			
	Y = 86	Y = 100	Y = 72
	N = 06	N = 0	N = 16
4. Did teacher comments on your papers help?			
	Y = 88	Y = 100	Y = 77
	N = 11	N = 0	N = 22
5. Did the scoring on your papers help?			
	Y = 75	Y = 66	Y = 83
	N = 11	N = 11	N = 11
6. Did revising and writing a second time help?			
	Y = 83	Y = 88	Y = 77
	N = 18	N = 11	N = 16
7. Was writing a waste of time for you?			
	Y = 05	Y = 0	Y = 11
	N = 94	N = 100	N = 88
8. Did you enjoy the writing?			
	Y = 47	Y = 66	Y = 27
	N = 41	N = 22	N = 61

Note: Item prompts appear here in abbreviated form. Not all column totals equal 100% since some student responses were "uncodeable."

students wrote about writing not being a waste of time, one student commented that writing helped him or her "find my own mistakes," that "it makes me have to really understand the type of problem to be able to write about it" while another wrote that the writing "helped you think about what you were really doing," and "communication is an essential factor to grasp a solid understanding of a concept."

Most students thought that the writing they did helped that "it makes me have to really understand the type of problem to be able to write about it" while another wrote that the writing "helped you think about what you were really doing," and "communication is an essential factor to grasp a solid understanding of a concept."

Most students thought that the writing they did helped their teacher know more about what they did or did not know about how to do the mathematics problems (94%). When they commented, students wrote comments such as "as she graded the papers, she knew what to review the most before our tests," "if a student is unable to express a problem, then that student probably doesn't understand the problem," "she knew everyone that could work the problem," and "it helped to pinpoint why students missed problems."

Most students (88%) thought the writing helped them clarify their ideas about how to do the mathematics problems. They supported their answers by saying, "writing instead of just talking or hearing helps you to better understand the

problem," "it helped me get things straightened in my thoughts," and "it makes me think about the steps you have to do for the problem," and "if you don't know, you can ask and write it down, then it kind of sticks with you."

Most students thought that they were helped in some way by the teachers' written comments on their papers (88%). One student supported this claim by saying, "the comments let you know what you were doing wrong and how to correct them."

Most (86%) thought that the writing helped them know more about what they themselves did or did not know about how to do the mathematics problems. Supporting their claim, students commented, "I realized more about the areas that I needed to work on at home," or "it would make me think about the steps more instead of just doing the problem."

Most students thought revising and then writing a second time on the same topic helped in some way (83%). When asked to tell why they thought that, students wrote, for example, "not all problems are worked the same way and it really makes you think," and "I thought of other questions that I needed to know," and "it gave you a chance to get help after the first time and make it better the second time."

Three-fourths of the students thought that the scoring by teachers on their writing helped them. They said that "just a quick glance let you know how you did," or "it told you how much you knew about the assignment, or "it helped you know <u>how well</u> you truly understood what you were doing and if you

needed help."

Students were about evenly divided about whether they enjoyed the writing or not. Fewer than half of all students said they enjoyed doing the writing; only 47% in the two classes said that they enjoyed the writing. Even when they said that they enjoyed doing the writing, students were only half-hearted in their support, going on to say, "I didn't mind doing them, but I didn't really enjoy them either" or they enjoyed them "as much as one could enjoy algebra."

Results Compared

In comparison, students in both classes thought that writing helped their teacher know about what they did or did not know about how to do the mathematics problems they wrote about (J = 100, L = 88), and students in both classes said that the writing was not a waste of time (J = 100, L = 88). However, as compared to students in L's classroom, many more of the students in J's class thought that writing helped them to clarify their ideas about how to do the mathematics problem (J = 100, L = 77) and that writing a second time on the same topic was helpful (J = 88, L = 77).

All of the students in J's class thought that the writing helped them to know more about what they did or did not know about how to do the mathematics problems as opposed to only 73% who thought so in L's class. In L's class, those students

who answered "no" supported their claim by making comments such as "the writing assignments did not increase my knowledge, but helped to collect my thoughts so I could focus on doing the actual problem."

When asked if they thought that the teachers' comments were helpful in some way, all of J's students said "yes" while only 73% of L's made a similar reply. Of those students in L's class who thought that the comments L wrote on their papers did not help, one supported his claim by commenting, "in all honesty, they sometimes appeared cryptic and needed an oral explanation."

Many fewer of J's students (only 66%) thought that the scoring that their teacher did of their paper helped in some way as opposed to most of L's students (83%). Those of J's students who did not think that the scoring helped said no or gave no response to the question; they wrote no support for their answer or wrote comments such as "sorta" or "I don't know."

But almost no one in L's class enjoyed the writing. In fact, 73% of her students, when asked if they enjoyed the writing, responded "no" or gave no response. They went on to say, "I don't like them because it is so hard for me to write about math things, but I am glad we did it." Another wrote, "what sane person enjoys more work, yet they were helpful." Still another stated, "I didn't enjoy them because I don't enjoy math. However, I feel they were honestly helpful."

Most (66%) of the students in J's class said that they enjoyed the writing.

Open Ended Questions

As part of the questionnaire, students were asked to give their teachers suggestion for making the writing assignments better and were asked to give whatever other comments they wanted to make.

When asked to give suggestions for improving how the writing was used, most students suggested that the assignments were fine as they were. Several, however, suggested that there should be more discussion in class surrounding the papers, especially when they were given back. Students made such suggestions as the teacher should try "to discuss answers instead of just handing them back," that teachers could "give more feedback after the assignment is returned," that "when they grade them, help the students to understand why they missed it," and "touch on different areas and allow students to express their difficulty" in discussions after returning papers.

When they were given the chance to make any other comments about the writing, some students wrote about liking or not liking the assignments, some wrote about how difficult it was to do the writing, and still others wrote that the assignments were difficult but helpful to them. This last

group of students made comments such as "it has helped me to better understand the work and it helped ... [J] to know what to explain to me in greater detail and slower speed than before," "the writing assignments helped me to understand where I needed help and what parts I had down," "I feel that if you were lost, this could clarify where exactly you were lost at. In a way I think a teacher should be responsible for knowing exactly where each student stands individually," "the writing assignments helped me to understand where I needed help and what parts I had down," "you have to know what's behind a math problem to get the points," and "they were useful and helpful and I recommend them highly." Not all students, however, were so supportive of the writing tasks despite not enjoying them; in fact, one student who gave negative responses on almost all the items throughout the questionnaire went on to say succinctly, "Don't use them. They suck."

Classroom Discussion after the Questionnaire

When they discussed the questionnaire, students gave several different responses which clustered around four themes: (1) there needs to be discussion surrounding the writing, especially after handing the papers back, (2) the writing tasks were difficult undertakings, (3) writing makes many mathematics ideas conscious as opposed the usually

"automatic" and unthinking completion of algorithms and procedures, and (4) the writing tasks aided a dialogue between student and teacher about the mathematics, understanding the mathematics, and student and teacher awareness of student performance and knowledge.

When one student in L's class began the discussion, she focused on the need for discussion pertaining to the writing. Excerpts from the transcript of the classroom read as follows:

> Pam: The only thing that I found different for me in here as compared to the other teacher I had [in an earlier developmental mathematics course] is my other teacher went over everything regardless of whether anybody had any questions or not because most people are not going to ask a question. They might think they're holding others back or keeping the class behind. So I thought that I didn't get much out of the assignment because I was used to going over it. I could tell the difference in that.
>
> D: Is that relating to the writing?
>
> Pam: Some. Even though we wrote it and you got your theme back, we really didn't discuss it that much. We were asked if there were any questions. A lot of times, in general, people do not [ask questions].
>
> D: So, let me see if I can see what you are saying.
>
> Pam: I think it should be discussed whether anybody had any questions or not.
>
> D: We needed to talk more about it. Talk more about the writing?
>
> Pam: Yeah.
>
> Patty: I felt it was hard to put into words. I felt it was hard.
>
> Linda: You know, I could work the problem out and know how to do it and still have to think about the words.
>
> Pam: It's not a yes or no answer.

Patty: I thought it was good for me. I just think it was hard. It was hard. It was hard.

Amy and Allison talked about how the writing somehow increases knowledge teachers have of students and talked about the understanding a student has of the mathematics as seen in "solving the problem" as opposed to writing about a problem:

Amy: I think it helped [L] more than it did me. It helped her to see if I was following the proper [?]. What you don't understand, you can't explain what you don't know how to do.

Allison: I would work it, and get it right. And then write it and get it wrong.

D: In math, you get the problem right, in English you get the explanation wrong.

Allison: Right.

Amy: For me to write it out, it helped. I think it helped me remember how to do it. But it seems like for me when I'm doing math I know how to do it at that time. But I have to do it six months later, [and] I don't know how to do it. But then when you take the time to write it down, you really would have to understand what you are doing.

In J's class several students discussed their notion that the writing helped the teacher understand student understanding and so helped the teacher prepare for classroom instruction and for meeting individual needs. All of this leads to a dialogue in which the students feel more power, or at least comfort, in their input:

Tracy: I think people are intimidated by professors. I think if you find a teacher that's trying to help you, you'll achieve more instead of somebody who's not. Like the writing, she's trying to find out where exactly you get lost. Most teachers give you a grade, and that's it.

Sandra: See, this is my [zoology] teacher: Here's your paper. Understand? No. No. I don't understand. But I think, I'll go right on home. I don't care if I understand, I'm leaving.

Tracy: I think it clarifies for you if you are lost. If you are lost, I feel a teacher's responsibility is to know exactly where you are at, where a student stands individually. If you are lost and know some things but you don't know others, it helps in knowing exactly where you are.

Cindy: A lot of teachers won't take the time out. I've had a lot of math teachers and when a teacher doesn't want to help me, I don't want to do it. And you're actually trying to do it. A lot of teachers just come to get paid, and when you miss something [J] will help you. I'm terrible in math. And in the writing you have to think about what you're doing. It's hard, though.

Patty in L's class later explains how difficult the writing is and why she thinks some of the writing should be given more time at home:

Patty: I just think if the first time we did it we could have had it explained a little more. Also, if we could get it and talk about it or maybe take it home with us. It was hard for me. I had a hard time with it. I never heard of this before. Maybe if we could take it home.

In J's class, Sandra is sure that the writing needs to be done in class, not at home. Discussing the option of doing the writing at home, Sandra says,

Sandra: I don't think that would be as good because when I have a problem and [if] I were at home, I'll just ignore it. She says work that problem. If I were at home, I don't have that help. Then she makes a point to go back over it in class. A lot of people have the same problem.

J: She's not going to say, whoa, I don't understand.

Sandra: It helps because a lot of times, I feel stupid; I don't want to feel like I'm holding the class back. I think sometimes everybody else understands and I'm a way back. I think the writing helps me have a better understanding of where I am going. Plus, when you write,

it helps you go back, and then I understand.

Near the end of the discussion in L's classroom, Betty and Melissa talk about how much more aware of parts of the mathematics the writing has made them:

> Betty: I waited a while to talk. I wanted to hear what everybody else had to say. At first I had a hard time trying to think how I did it. But it made me. And what I did I just made myself mentally go through the steps and write that down. And so it made me aware of step by step.
>
> Melissa: Also, I think writing it down helps you memorize. Not really memorize. Know. Makes you know the name of the step. Like if you were going through and doing the distributive property, and you didn't know what that was, after you had written it a couple of times, you would realize it. You know what I'm saying?
>
> D: You connect up that name with the doing.
>
> Melissa: Right.
>
> D: Anything else?
>
> Betty: When I wrote, it forced me to go back over and see how I did the math. Mostly, when you do the math, you do it automatically, without thinking. Writing made me go back over what I did and see what I did before I could write about it.

In short, students seemed to think that doing the writing was difficult, that it slowed down the process of doing the mathematics procedures and by so doing allowed students to identify exact areas in which difficulty occurred for them in the procedure. They seemed to think also that using the writing made explanations and topics more recursive, helped teachers go backwards to explain hazy or misunderstood ideas. The students in L's class, especially, thought that the writing should be followed up by more discussion when papers

were handed back. Writing, they thought, also made them more conscious of many of the mathematics procedures and ideas they had been working with, made the mathematics less automatic and unthinking and more an object for conscious control and contemplation. Students also seemed to think that the writing fostered a dialogue about learning in which teachers were somehow more able to watch the inner workings of the students' performance and so adjust their teaching and better plan for instruction. This dialogue also opened the lines of communication between students and teachers and somehow realigned the power differential between them so that students felt teachers were "on their side," listening to students and trying to help them learn.

Results: Chapter Tests

A summary of the results of the chapter tests are displayed in Table 5.22. The results can be looked at by teacher, by chapter test and writing task, and by classroom. In looking at the results of the chapter tests, however, we must remember that J used one set of tests for both of her classrooms while L used another set for both of her classrooms.

Table 5.22
Mean Scores on Chapter Tests

	Chapter 12	Chapter 13	Chapter 14
		J's Classrooms	
Classroom 1 (non-writing centered)	75.8	81.8	73.5
Classroom 2 (writing centered)	78.0	81.6	75.7
difference (writing centered minus non-writing centered scores)	+2.2	-0.2	+2.2
		L's Classrooms	
Classroom 3 (non-writing centered)	70.5	79.7	74.6
Classroom 4 (writing centered)	77.2	74.7	80.5
difference (writing centered minus non-writing centered scores)	+6.7	-5.0	+5.9

By Teacher

The results show that the students in J's writing-aided classroom scored somewhat better on average than the students in her non-writing aided classroom (by 2.2 points on the tests for both chapters 12 and 14), but scored less by .02 points on the test for chapter 13. This suggests that for J's classroom, on the average, students were only marginally helped on their test scores for chapter 12 and 14 by the writing.

The results show that the students in L's writing-aided classroom scored better on average than the students in her non-writing centered classroom (by 6.7 points and 5.9 points on the tests for chapters 12 and 14 respectively) but were somehow hindered in their scores on the test on chapter 13 (by scoring 5 points less). This suggests for L's classroom that on the average students were helped on their test scores for chapters 12 and 14 by the writing.

By Chapter Test and Writing Task

Across teachers, the results show that students in the writing-aided classrooms scored better on the tests on chapter 12 and 14. This suggests that the writing tasks may have helped to improve scores on these tests as compared to classrooms where students did no writing on topics addressed

on these tests. We can recall that the first writing task ("what are intercepts and why do we prefer to use them") and the second writing task (three linear equations to solve and explain why to use the method you chose) addressed topics covered on the tests over chapter 12. We can also recall that the third writing task (solving a radical expression using multiplication, addition, and simplification) addressed topics covered on the tests over chapter 14. We can also recall that none of the planned writing tasks addressed the topics covered on the test on chapter 13.

By Classroom

Across teachers, the results show that students in the writing centered classrooms scored lower on the tests on chapter 13 (by 0.2 points with J and by 5.0 points with L). This suggests that doing the writing tasks on topics covered in one test and then withholding writing for topics covered in another test somehow results in a lowered score for some students, especially those in J's classroom. As this happened in the writing-aided classrooms of both teachers (in L's to a much greater degree than J's) and since this is a very much unexpected result, the interpretation of these results from the chapter tests remain somewhat problematic.

In sum, the results of chapter tests are consistent across tasks and teachers: students scored higher in the

classrooms where tasks of writing to learn addressed topics covered in typical teacher-made tests of computation and algorithm; students scored lower in the two classrooms where tasks of writing to learn were withheld on topics covered in typical teacher-made tests of computation and algorithm.

However, none of these differences of mean scores were statistically different when the *t*-test for independent observations was applied.

Summary

In their classroom patterns of mathematics instruction, both teachers were seen to plan writing tasks which pertained directly to the mathematics topics they were addressing in the classroom. The writing-experienced teacher seemed to respond to varying student demands for time in drafting as opposed to revision and seemed to embed the writing tasks in a greater variety of placements in teacher-centered activity than did the writing-inexperienced teacher. The writing-inexperienced teacher gave relatively equal amounts of time for both drafting and revision and placed writing tasks in less of a variety of positions in classroom activities than did the writing-experienced teacher.

In reference to other methodological and procedural issues, the writing-inexperienced teacher seemed to find the procedural issues she had to deal with in planning the writing

tasks to be somewhat taxing, and they occupied her attention in planning and in interviews. Both teachers placed writing later rather than earlier in their units of instruction, suggesting that both saw the writing tasks as ways to develop or culminate ideas in the instructional units rather than as ways to introduce ideas. Both teachers devoted about the same total classroom time to the writing but allotted time in different ways.

Their perceptions about the three writing tasks and their perceptions about writing in general varied greatly. J thought that the students' writing "improved" from first to second drafts, especially in regards to students' responses to her comments on first drafts, while L was less impressed by any improvements through revising and often perceived students as ignoring her written comments on drafts. Both thought that students who didn't do well on the writing didn't do well on the chapter tests. J reported that she thought that teachers might be more inclined to use "procedural" writing, as exemplified by the three tasks in the study, as opposed to other kinds of writing tasks in mathematics classrooms but thought that other mathematics teachers would resist the use of writing in general if the writing brought them the kinds of information about students' knowledge that they did not want to face, especially when that knowledge was faulty or missing.

Students thought that writing was a difficult task, that writing a second draft helped them in some way, that writing

made them more aware of what they did or did not know about the procedures written about, and that the writing aided teachers in their role of helping students learn. Some students in L's class also claimed that there needed to be more talk surrounding the writing, especially when drafts were returned to students. Students in both classrooms were divided about whether they enjoyed the writing or not.

The length of students' writings was, in general, greater in second drafts than in first drafts. The syntactic maturity of the writing was rather low for college freshmen. Students used relatively "high" linguistic levels of revision in tasks one and two; they used addition, deletion, and substitution as strategies of revision almost exclusively in these two tasks. In the third task, they essentially started their drafts over rather than revising them. Cognitive operations varied with task for the operations of change, contrast, time sequence, and logical sequence.

Students in the writing-aided classroom tended to score higher than their classmates in non-writing aided classrooms, but not to a degree which was statistically significant.

CHAPTER 6

SUMMARY OF RESEARCH

Summary of the Study

This study was designed to examine the use of tasks of writing to learn mathematics in college developmental mathematics classes when students revise their writing about mathematics topics and are aided in their writing by their mathematics instructors.

Two college mathematics teachers who taught developmental mathematics classes as a major part of their teaching assignment were selected on the basis of previously-established criteria. Two classrooms of each instructor were chosen for the study, with one classroom from each instructor designated as a writing-aided classroom. In these two writing-aided classrooms, tasks of writing to learn in mathematics were used after they were collaboratively planned by the teachers and the researcher. In addition, two case study students were nominated by teachers for interviews about the writing used in the study.

The researcher and the teachers planned three tasks of writing designed to aid students in learning the mathematics

topics being addressed by the teachers at the time of the study. Each of the three tasks was implemented in the two writing-aided classrooms. Tasks were planned in accordance with previously established criteria for constructing writing to learn tasks in mathematics and in accordance with previously established criteria for revision. No writing was used in the non-writing classrooms.

Teachers were interviewed and fieldnotes and tape recordings made. Teachers were interviewed before the tasks of writing to learn were used, during the time the teachers and researcher cooperatively planned the tasks, during the time each teacher read and responded to the students' writing, and after classes in which the writing was implemented. From time to time, other interviews also took place. Later, transcripts of tape recordings were made of those sections of interest (teachers' perceptions of the particular tasks and of writing in general).

The researcher also became a participant-observer in the four classrooms of the study. Classrooms were visited and fieldnotes and tape recordings were made. Later, transcripts of the tape recordings were made of those sections pertinent to the study, including teachers' references to mathematics topics or thinking addressed in the writing, and the incorporation of writing into the on-going instruction in the classroom.

The two case study students were selected according to

previously established criteria and interviewed. Tape recordings and fieldnotes of the interviews were made. However, the two case study students dropped out of the interviews and, eventually, the mathematics classrooms under study. In their place was put a questionnaire derived from the schedule of questions for case study students and from teacher input. Later, after all the writing tasks were implemented, the questionnaire was administered to students, and a general classroom discussion about the writing ensued in the two writing-aided classrooms.

In the writing tasks, writings were completed by the students in response to planned prompts. First drafts of the writings were read, responded to, and sorted by teachers and then photocopied for analysis. Teachers returned drafts to students and one of three revision conditions followed: (1) teacher-led calls for revision, (2) teacher-modeled revision, or (3)peer-group revision. Second drafts of the writings were read, responded to, and sorted by teachers and then photocopied for later analysis. Teachers then returned the second drafts to students.

Test scores were collected from "chapter" tests that were currently in use by teachers in the four classrooms during the time of the study.

Research Questions

The study was designed to answer six questions about writing to learn in the mathematics classroom when students revise their writing and are aided in their writing by teachers' support for writing:

(1) What are the lengths of drafts students produce in completing these tasks, both before and after revision?

(2) What are the levels of syntactic maturity of the final drafts of these tasks?

(3) What are the levels of revision students use when they revise their drafts?

(4) What are the revision strategies students use when they revise their drafts?

(5) What are the cognitive operations students appear to use when they write such drafts?

(6) What are teacher and student perceptions of drafting and revising for these writing-to-learn tasks in the classroom?

Findings

From the present analyses, several findings can be stated.

First, the lengths of drafts varied in terms of the number of words per draft from the shortest class means for

drafts (25 words per draft) to the longest class means for drafts (88 words per draft). Class means in terms of the number of T-units per draft also varied, from the shortest class means for drafts (3.5 T-units per draft) to the longest class means for drafts (8.9 T- units per draft). For the most part, students' drafts were longer in the second drafts than in the first drafts, with statistically significant longer drafts for tasks one and two in terms of number of words per draft and number of T-units per draft.

Second, the syntactic maturity of the drafts varied in terms of the number of words per T-unit for second drafts from the lowest class means for drafts (9.1 words per T-unit) to the highest class means for drafts (11.81 words per T-unit). Class means in terms of the number of clauses per T-unit for second drafts ranged from a low of 1.16 clauses per T-unit to a high of 1.48 clauses per T-unit. Class means for the percentage of words in FFM in second drafts ranged from a low of 0.0 percent of words in FFM to a high of 3.06 percent of words in FFM.

Third, in the first and second writing tasks students used revision at the level of T-unit and multi-T-unit for more than half of their revisions, using these two levels more than they used revisions at the level of the word, phrase, or clause.

Fourth, students used the revision strategies of addition, deletion, and substitution almost exclusively. In

the third task, students changed their drafts in ways that were not codeable using the present revision analysis scheme.

Fifth, students used the cognitive operations of contrast, change, time sequence, and logical sequence at statistically significant levels. Students used different numbers of cues of cognitive operations for the different tasks; cognitive operations were found to be dependent upon task, with different tasks yielding different amounts of cognitive operations. Specifically, task one called forth more cues of contrast than the other two tasks; task two called forth more cues of logical sequence than the other two tasks; and task three called forth more cues of change and time sequence than the other two tasks.

Sixth, a number of perceptions about the writing were reported by teachers and students.

Teachers perceived these tasks as being unusual tasks for students in the mathematics classroom: they thought that the students were not familiar with the tasks and that such tasks were not ordinarily used by their professional peers in college mathematics departments. The teachers were not sure if the tasks per se helped students to learn, but neither did they think the tasks inhibited student learning. The teachers perceived the information they received about students through the writing as being different from the information they received about students in problem sets, tests, or classroom interaction: the information was, they reported, more detailed

and somehow also different in quality. The teachers perceived a difference between most students, whom they thought fully capable of expressing in writing what they knew about a mathematics topic (i.e., "how to solve it"), and a few students who, they thought, knew the mathematics topic but could not express that in writing. One teacher, J, thought that the writing fostered a dialogue that aided student-teacher relationships in the classroom and was pleased with the revising/rewriting that students did to produce the second drafts. The other teacher was not pleased with the revising/rewriting that her students did to produce the second drafts, claiming that students did not incorporate teacher comments sufficiently into their second drafts.

Students reported that they thought the tasks helped them clarify their ideas about how to do the mathematics problems, that the tasks were not a waste of time, that the writing helped teachers know more about what students did or did not know about how to do the mathematics problems, that they were helped in some way by the teachers' comments on their writing, that the writing helped them know more about what they themselves did or did not know about how to do the mathematics problems, and that writing a second draft on the same topic helped in some way. Many did not enjoy doing the writing. In their comments during class discussion after the questionnaire, many students said that the tasks were difficult; several students said that there needed to be more

discussion of papers as papers were handed back, and a few stated that the writing made conscious the mathematics procedures that were otherwise often done in an "automatic" manner.

Finally, students in both writing-aided classrooms scored somewhat higher on chapter tests covering material which they wrote about than did their counterparts in non-writing aided classes taught by the same teachers. However, the scores were not significantly different.

Conclusions

Conclusions Addressing the Research Questions

The original questions that motivated the study centered around the texts that students produced when they undertook tasks of writing to learn in mathematics (the length, syntactic maturity, revision levels and strategies between drafts, and cognitive operations) and perceptions by teachers and students about the tasks.

First, students produced relatively short drafts when they wrote in these tasks, both when they wrote a first draft and when they wrote a second draft. On the whole, second drafts tended to be longer than first drafts with the greatest increase in the mean number of words per draft being an increase that approximately doubled the mean number of words

per draft in one classroom. Still, these drafts are rather brief for school-sponsored writing tasks, given the fact that most college freshmen are asked to write drafts of several hundred words in their English classes.

Second, the levels of syntactic maturity tended to be rather low. Words per T-unit were low. Clauses per T-unit were also rather low. The percentage of words in FFM in second drafts was also low. These descriptions of the syntax contrast with those provided elsewhere (Hunt, 1965; Wolk, 1970; Faigley, 1976; Loban, 1976) and show these students scoring comparable to the lower ranges for high school students in terms of number of words per T-unit and clauses per T-unit (Hunt, 1965) and comparable to low-performing high school students in terms of Loban's (1976) study of C-units and below college freshmen in percentages of words in final free modifiers (Wolk, 1970). In sum, these drafts show rather low syntactic maturity for college freshmen.

Third, students typically revised at the T- and multi-T-unit level rather than revising at the level of the word, phrase, or clause. In fact, in the third writing task, very few points of verbatim reference could be found in order to code revision in accordance with the procedures used elsewhere (Bridwell, 1980; Monahan, 1984), and students' second drafts were found to be "uncodeable" in that task. This contrasts rather sharply with the predominance of the lower levels of revision used by students in high school English

classes (Bridwell, 1980) and by high school seniors labeled "basic writers" (Monahan, 1984), as most of these students would similarly be labeled in their college basic writing courses. However, this is not a surprising finding, since, in most cases of revision, students are overtly cued by teachers as to the revisions which they should undertake; most of these cues given by teachers for revision center on rather "low" linguistic levels of revision, consisting of the usual number or symbol systems of composition textbooks.

Fourth, in their writing students used a variety of cognitive operations (operations of contrast, change, time sequence, and logical sequence), except that they did not use the operation of physical context, probably because of task demands rather than their inability to do so. Cues of cognitive operations were seen to interact with task, suggesting that different tasks called forth different cognitive operations from students.

These are rather low scores on measures of length and syntactic maturity. The revisions at "high" linguistic levels and contrasts rather sharply with the typical action reported in the literature for students making second drafts of school-sponsored writing at high school and college developmental levels. And the results from the analysis of cognitive operations show students utilizing a variety of operations that seem to interact with task demands. However, taken with the positive outcomes on the chapter tests where

students in classrooms using writing scored somewhat higher than students in classrooms not using writing (although not statistically detectable), it seems that these characteristics of students' writings do not preclude benefits for students in terms of their learning mathematics by support for tasks of writing to learn in the mathematics classroom.

Fifth, teachers perceive these tasks as being unusual tasks for students in the mathematics classroom: they think that the students are not familiar with the tasks and that such tasks are not ordinarily used by their professional peers in college mathematics departments. The teachers are not sure if the tasks per se helped students to learn, but neither do they think the tasks inhibit student learning. The teachers perceive the information they receive about students through the writing as being different from the information they receive about students in problem sets, tests, or classroom interaction: the information is, they think, more detailed and somehow also different in quality. Perhaps this more detailed information comes from the linkages between ideas that students make as they write since writing forces explicit linkages or statements of relationship between ideas, as seen in the results of the analysis of cognitive operations. The teachers perceive a difference between most students, whom they judge fully capable of expressing in writing what they know about a mathematics topic (i.e., "how to solve it"), and a few students who they thought knew the mathematics topic but

could not express that in writing. In addition, one of the teachers thinks that writing fosters a dialogue that aids student-teacher relationships in the classroom.

Students think the tasks help them clarify their ideas about how to do the mathematics problems, that the tasks are not a waste of time, that the writing helps their mathematics teachers know more about what students do or do not know about how to do the mathematics problems, that students are helped in some way by the teachers' comments on their writing, that the writing helps them know more about what they themselves do or do not know about how to do the mathematics problems, and that writing a second draft on the same topic helps in some way. Many do not enjoy doing the writing. In their comments during class discussion after the questionnaire, many students said that the tasks were difficult; several students said that there needed to be more discussion of papers as they were handed back, and that the writing made conscious the mathematics procedures that were often "automatic."

Conclusions about Other Issues Raised During the Study

In the study, these two teachers used what they saw as "procedural" writing: writing about how to do a particular mathematics problem. In procedural writing, the task may focus on what students can do in terms of how to solve a particular problem (as in the third writing task) or on other

ideas students have about the procedure such as which is the preferable procedure of any two given procedures (task one) or which procedure may be applicable to a particular problem and why that is the case (task two). In addition, teachers are capable of constructing prompts for procedural writing similar to the ones used in the study and which focus on procedural issues.

When the teachers incorporated revision activities in their classrooms, the students often responded by using relatively high levels of revision rather than the lower levels typically seen in studies of revision in English classes.

When the second draft comes in a later class session, (as was sometimes the case with L) the mathematics subject matter for instruction had moved on to a related but different topic. In such cases the second draft returns to an earlier topic and focuses students on that earlier topic with the result either that instruction becomes recursive or that students may perceive that the writing may seem slightly unrelated to current topics of instruction.

When teachers read students' writings, they approach that reading in a number of ways. They may attempt to read merely what is on the page, that is, read in a very literal fashion without adding their own interpretation, or more likely, they may read and interpret as when J or L said, "what he or she means is" this or that. More often than not, the teachers

seemed to be using this second kind of "reading" as they read and sorted student papers. Teachers also tapped other sources of information while they read students' papers, combining that knowledge of students with what they saw on the page. Often one or the other teacher reported that she gave a particular "score" to an individual student during sorting because she knew that the student did or did not know a particular bit of information, or because she knew that the student acted in certain ways in relation to the subject matter of the classroom, or because of other knowledge from sources outside the writing. As teachers responded to the papers by writing on them, they employed a rather wide repertoire of responses to the papers: they wrote question marks, posed questions, wrote marginal and end notes, highlighted and underlined sections, used check marks, gave directions for a new draft, or wrote "hints" on where students might look for more information. Both left much about their responding unsaid to students: teachers often voiced rationales and explanations to me in the interviews and went on to say that they did not plan to share these rationales and explanations with students.

The actual texts of students's writings were short and informal. The content of the writings were "dense" with mathematics ideas, however, as shown by the number and variety of cognitive operations evident in their drafts. Within the space of fifty to seventy-five words, students discussed the

procedures in ways that lead the teachers to remark that they could tell whether students understood the procedures or not.

Discussion

Procedural Writing

In the study, these two teachers used what they saw as "procedural" writing: writing about how to do a particular mathematics problem, either in the general procedure (applied to all such problem types) or in the specific (applied to one particular problem). In procedural writing, the task may focus on what students can do in terms of how to solve the problem (as in the third writing task) or on other ideas students have about the procedure. With the experience of using writing to learn tasks, mathematics teachers are capable of constructing prompts similar to the ones used here that focus on procedural issues in mathematics. Not surprisingly, the teacher in this study with more experience of using writing tasks seemed to be more confident in discussing how these tasks might be formulated, in incorporating them into the classroom, in responding to the time students needed for drafting and revising, in noting how they contrasted with other tasks of writing (especially non-procedural writing tasks), and in talking about how the tasks interact with student attitudes. In addition, the more writing-experienced

teacher seemed to maintain students' positive attitudes to writing although exactly how this was accomplished or whether it related more to general classroom procedures and other issues than it did to these particular tasks could not be ascertained by this study.

Revision and Pace of Instruction

When the second draft comes in a later class session, the mathematics subject matter in instruction had sometimes moved on to a related but somewhat different topic. One of the results of using revising as part of the instructional support for writing may be to slow the overall pace of instruction in that it forces teachers and students to return in the second draft to topics previously covered and thus gives students the opportunity to achieve greater depth of learning of those topics as suggested by somewhat high scores on chapter tests for students in the writing-aided classrooms. This fast pace of instruction and its interaction with writing, especially in a return to the same topic in a later draft, may call for students to incorporate an enlarged or changed understanding of mathematics that the writing seems like completely new drafts.

Students' Writings in Mathematics as Texts

The actual texts of students's writings were short and informal, and they evinced comparatively low syntactic maturity, as defined here. However, to the teachers, the content of the writings give an impression of being "dense" with mathematics ideas. As texts, these students' writings had little in common with some of the characteristics of texts examined and reported in the literature of most research in writing carried out in traditional English classrooms. Despite this fact, the texts were read and interpreted by the teachers and seemed comprehensible to them. And they were read and viewed by the two teachers here as new and different sources of information about students' understanding of the mathematics content.

Reading and Responding to Students' Writing in Mathematics

When teachers read students' writings, they may approach that reading in a number of ways, including using a great deal of interpreting and inferencing. Teachers also tapped other sources of information while they read students' papers and combined that information with information from the page. As teachers responded to the papers by writing on them, they employed a rather wide repertoire of responses. The teachers left much about their written and oral responses to students'

writing unsaid to students. However, the seeming comfort with which the teachers read and interpreted the papers differed and may be productively described by use of the writing-experienced/inexperienced dichotomy. Indeed, the inexperienced teacher in this study felt quite a bit of discomfort in the ambiguity she found in reading and interpreting the papers but reported that she felt more "comfortable" with the reading in later portions of the study. In short, reading, responding to, and sorting the papers invoked a highly complex series of tasks that teachers undertook which called forth a variety of actions and knowledge on the part of the teachers and which interacted with teachers' experience with using writing in the mathematics classroom.

Mathematics Teachers' Use of the Content of Students' Writings

Teachers may use the information contained in students' writing to assess student understanding of mathematics topics for individual students, to assess student understanding of mathematics topics for whole class purposes of their own, to guide their planning for instruction for individual students, to guide their planning of instruction for whole class instruction, to help report back students' understandings to students, or to evaluate and grade students. The teachers' use of the content varied greatly between the teachers.

Instructional Support for Writing to Learn in Mathematics

As these teachers used the writing tasks, a number of teacher actions and characteristics of the task and task environment seemed to constitute what I have called instructional support for writing. These actions for instructional support are noted below. Both teachers did not use all the actions reported, nor did any one teacher use them consistently across all drafts and tasks. However, these actions were seen at one time or another and seem to lend support to students for the demands of writing in the mathematics classroom.

Support While Implementing a First Draft

Teachers supported first drafts in their instruction in a number of ways. They focused the writing task on a mathematics topic which is currently under study, and they explicitly linked that writing task to the mathematics topic currently under study. They announced a general outline of the draft or task and gave general directions for the entire draft or task. They set immediate goals for students to accomplish in order to fulfill the general outline of the draft or the general directions for the task. They answered student questions about the task parameters. They announced an allotted time for drafting and responded to changes in students' needs and/or demands for time to draft. They

announced length guidelines for the draft in terms the number of sentences or paragraphs they expected in the drafts. They linked the mathematics topic written about to subsequent instruction.

Support While Reading and Responding to the Drafts

Teachers supported the writing during their reading and responding to the drafts in a number of ways. They read all student papers. They made written comments on all student papers, comments that took a variety of forms. Written comments focussed on mathematics content rather than on issues of "English" such as form, surface features, or style.

Support While Implementing a Second Draft

Teachers supported second drafts on the same or similar mathematics topic in a number of ways. They returned papers to students and called for revision. They explained or established the meaning of their written comments. They announced a general outline for the revision and/or set immediate goals for students to accomplish in order to revise. They adapted directions, goals, or purposes for students who did not complete a first draft. They announced an allotted time for the drafting. They announced a length guideline for the draft. They responded to changes in students' needs and/or demands for time for drafting. And they read, responded to, and returned the drafts to students.

Support After Second Drafts

Teachers supported writing in instruction after the second drafts in several ways. They returned the second drafts with written comments, and they discussed with students the learning or difficulties in learning they noted in the drafts across students and, in some cases, with individual students. They linked the mathematics topic written about to subsequent instruction.

Overview of Instructional Support for Tasks of Writing to Learn in Mathematics

The supports mentioned above are actions that were observed at one time or another in the two classrooms and which seemed to offer potential support for students' use of writing in the classroom. The one part of instructional support that seemed lacking, at least in as much as several students reported in the questionnaire, was the paucity of talk or discussion in one class surrounding the return of the papers to students.

Recommendations for Further Research

1. Because the entire area of writing to learn in mathematics is relatively new, it is somewhat uncharted. One of the needs in the area is for a scheme of kinds of writing tasks that may be useful inside the area of writing to learn

in mathematics. The dichotomy in WAC between writing to communicate and writing to learn is a useful one, but other--more detailed--schemes of classification need to be developed inside the research area of writing to learn in mathematics so that future studies may more fully center on the differences between, for example, procedural writing in the general and procedural writing in the particular as discussed above. In sum, the learning and other outcomes of such tasks need to be conceptualized inside a framework that delineates kinds of writing to learn tasks. Rose (1989) has begun such a scheme based on Britton's function categories, and Davison and Pearce (1988a, 1988b) developed one based on the degree of manipulation by students of the language presented by teachers or textbooks. However, additional schemes with well-developed criteria probably need to be formulated in reference to task demands, to problem types, and to audience. To be useful, such a scheme should be capable of spanning tasks of writing to learn in mathematics, at least in the areas of arithmetic, algebra, and geometry.

2. The teachers in this study reported that the use of writing to learn tasks changed the relationship between students and teacher. Exactly what this change might involve, what its source may be, and the factors effecting it need careful consideration. A productive avenue for study of these relationships and their changes might come from the use of the ethnography of communication such as seen in the examination

of teachers' "roles" in supporting and responding to writing (Dunn, Florio-Ruane, & Clark, 1985).

3. In the present study, a useful contrast was made between a teacher experienced in the use of writing tasks and a teacher who was not experienced with writing tasks. Future studies could profitably examine contrasts between several teachers who are already experienced in the use of writing. Also, studies need to explore exactly what the knowledge base of writing-experienced teachers might consist of so as to assist in the development of teacher training and inservice programs for teachers interested in beginning and sustaining the use of writing-to-learn tasks in mathematics.

4. The reading and responding to students' writing that teachers carried out in this study tapped a rich range of actions, beliefs, and perceptions on the part of the teachers involved. Much of what the teachers had to say about their reading and responding seemed to have much in common with what writing teachers have to say about reading and responding to students' texts in writing-centered classrooms, such as those in English and the language arts (cf. Freedman, 1985). Certainly, the reading and responding to students' papers that mathematics teachers do needs a much more in-depth analysis and characterization.

5. The teachers of the study reported that the writing that their students did about the mathematics was comprehensible as a text. They also reported that the writing

displayed students' knowledge in such a way that they were able to make fairly clear and seemingly-cogent analyses of the knowledge displayed there at an intuitive level. We need to know exactly how knowledge might be displayed in these texts and how it relates to teacher judgments of the texts. Kinds of knowledge need to be clarified as well as how the knowledge is displayed in the texts. Other facets of examining knowledge displayed in the writing which need to be explored include prior knowledge (that is, the knowledge base that students have before acquiring new knowledge), the source of students' knowledge (that is, where it was acquired), time the knowledge was acquired, and the task that surrounded the acquired knowledge (that is, the particular task that allowed, engendered, or supported the acquisition of the knowledge acquired). All of these factors may play into the acquisition and/or display of mathematics knowledge in writing tasks.

6. Teachers' judgments of sorting functioned in some ways like the tacit knowledge which is tapped in holistic assessments of quality of writing. A productive line of inquiry would be to investigate the relationship of these judgments one to another, the concept validity, rater reliability, as well as inter-rater reliability of the judgments.

7. Some students were judged by the teachers as preferring not to write about the mathematics. A few students were judged by the teachers to be less able to write about

their knowledge than were other students; that is, teachers reported that some students knew more than they said--or perhaps could say--in their writing. These students, however, were only a few of all the students doing the writing, and most students seemed not to be limited in the writing tasks by their preferences or abilities in writing. However, the preference to write or not to write about mathematics needs to be more fully examined, especially in relationship to tasks of writing to learn, as does writing ability.

Much that was productive in this study came from examining not just a single line of inquiry but from examining in many different ways what took place as teachers used writing, revising, and supported writing in instruction. Much remains yet to be clarified. However, the most productive line of inquiry may be the claims of the teachers themselves that writing offered them changed and somehow increased insight into what their students knew and how they knew it. They claimed that writing changed their classrooms; in fact, one teacher claimed that writing changed her classroom by changing the relationships between teacher and students. Teachers claimed that the use of writing brought about or fostered these changes. If their claims are to be believed and if the aim of instruction is to change relationships between teachers, students, and mathematics knowledge for the better, then tasks of writing to learn in mathematics offer us

a productive way to begin such changes.

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Appendices

Appendix 1
Case Study Student Interviews:
An Informal Schedule of Questions

Pre-intervention Questions

1. Can you describe a typical class in this course? What goes on? Lead me through a typical class session.
   Follow up probe: You say that the instructor does ____ about the topic you are studying. About how much time is spent on that? What are you doing while the instructor is doing that?

2. Tell me about what you are studying in math class now. What is difficult for you? What is easy?
   Follow up probe: You say that _____ is (easy/difficult) to understand about the topic. What has Mr. X been saying about it? Can you show me some work on paper you are doing on that topic?

3. Tell me about the work that was going on in class today.
   Follow up probe: What did you understand? What did you not understand? Can you show me any work on paper from today?

After the Drafting Session of Each of the Three Writing Tasks

1. Here is your writing from today. Would you read it aloud to me and tell me what you were doing.
   Follow up probe: At this point, you say "_____". What does that mean? Where did you pick up that piece of information?
   Further probe: You say that _____. Can you tell me more about that?

2. What do you think about this assignment to write? Was it easy? Difficult?

3. While you were doing the writing, what mathematics were you thinking about? What was the writing making you think about?
   Follow up probe: You say that you were thinking about ____ at this point. Could you tell me more about that?

4. Today you were doing writing that an English teacher might call _____ [mode or pattern of development]. Have you ever do ne any writing like this before?

5. Is there anything else to say about doing this kind of writing? About doing this kind of writing in mathematics?
   Follow up probe: Can you explain that to me in a

different way?

After the Revision Session of Each Writing Task

1. Here is your writing from today. Would you read it aloud to me and tell me what you were doing.
Follow up probe: At this point, you say " _____". What does that mean? Where did you pick up that piece of information?
Further probe: You say that _____. Can you tell me more about that?

2. What did you think about doing this writing assignment? Was it easy? Difficult?
Follow up probe: You say that writing this part was (easy/difficult). Could you talk more about that?

3. While you were doing the revising, what mathematics were you thinking about?
Follow up probe: You say that you were thinking about _____. Can you tell me more about that?

4. Tell me about the revision session today. Mr. X asked you to do _____ to get the revising started. What did you do?
Follow up probe: Did what Mr. X do help you revise? How so?

5. Today you revised by doing _____[description of revision condition]. Have you ever done anything like that else where?

6. Let's compare your first draft from the last class session to the draft after today's work. As you read aloud today's draft, I'll read your first draft silently. [At each revision]: You said _____ in today's draft, but here in yesterday's draft you say _____. What changes do you see between them?
Follow up probe: What was the reason for your changes? What made you think of making the change? Where or when did you pick up that piece of information?

Post-Intervention Questions

1. Tell me what you are studying in math class now. What has been difficult for you? What has been easy?
Follow up probe: You say that _____ is (easy/difficult) to understand. What has Mr. X been saying about it? Can you show me some work on paper you are doing on that?

2. Earlier in the semester you described a typical class

session in your math class like this. [Read same to student.] How would you describe a typical class session now?

Follow up probe: You say that the instructor now does _____. About how much time is spent on that? What are you doing while the instructor is talking about that? Why do you think he is having you do that?

3. Tell me about the work in writing that has been done in class this semester. Would you recommend that Mr. X continue doing that next semester?

Follow up probe: You say you (would/would not) recommend doing _____. Why is that?

4. Tell me about the three kinds of revising you did (alone, with Mr. X leading, and in groups). How were they different? Which worked the best for you? Why?

Follow up probe: You say that in _____ revising you felt that _____. Can you tell me more about that?

5. Is there anything else that you think I need to know about writing in mathematics class?

Appendix 2
Questions About the Writing Assignments
(Student Questionnaire)

1. Do you think that doing the writing assignments in this class helped you to clarify your ideas about how to do the mathematics problems you wrote about?

___Yes.
___No.
Why do you think that? Comments:

2. Do you think that doing the writing assignments in this class helped Ms._____ know more about what you did or did not know about how to do the mathematics problems you wrote about?

___Yes.
___No.
Why do you think that? Comments:

3. Do you think that doing the writing assignments in this class helped you to know more about what you did or did not know about how to do the mathematics problems you wrote about?

___Yes.
___No.
Why do you think that? Comments:

4. Do you think the written comments that Ms. _____ wrote on your writing assignments helped you in any way?

___Yes.
___No.
Why do you think that? Comments:

5. Do you think that the 1 or 2 or 3 or 4 that Ms. _____ wrote on your writing assignments helped you in any way?

___Yes.
___No.
Why do you think that? Comments:

6. Do you think that writing a second time on the same topic (rewriting your assignments) helped you in any way?

___Yes.
___No.
Why do you think that? Comments:

7. Do you think that doing the writing assignments in this class were a waste of time?

___Yes.
___No.
Why do you think that? Comments:

8. Did you enjoy doing the writing assignments in this class?

___Yes.
___No.
Why do you think that? Comments:

9. If Ms. _____ or any other mathematics teacher were going to use writing assignments in MATH 0830 again next year, what suggestions would you make?

10. What else do I need to know about your thoughts on the writing assignments we did in class?

Appendix 3
Odell Coding Scheme

Adapted from Odell (1977) pages 107-132

(1)Linguistic cues to CONTRAST:

1. Connectors
   or, nor, else, lest, otherwise, alternatively, but, however, nevertheless, on the contrary, on the other hand, instead, though, although, in spite, despite

2. Comparative or superlative forms
   more/most, less/least, -er/-est

3. Negative
   no, not, without, nothing, none

4. Negative prefixes
   anti-, im-, in-, ir-, il-, dis-, -less, un-, non-, a-

5. Lexicon
   noun, verb, adjective and adverb forms of such words as contrast, paradox, distinction, difference, and their synonyms

(2) Linguistic cues of CLASSIFICATION

1. Syntax
   Sentences in which a linking verb joins a subject with a predicate nominative (The assumption here is that one of the noun phrases, either the subject of the predicate nominative, labels the other; that is, one of the noun phrases suggests a more general class, of which the other noun phrase is an instance or example.)

2. Use of Phrases
   for example, for instance, an example, an instance

3. Lexicon
   Noun, verb, adjective, and adverb forms of such words as similar, resemble, class, and their synonyms.

(3)Linguistic cues to CHANGE

1. Verb, noun, adjective, or adverb forms of the word change or a synonym for change.

2. Verb phrases which can be plausibly rewritten so as to include become (e.g., realize = become aware)

3. Verb phrases which include began (or a synonym) or stop (or a synonym) plus a verbal (e.g., "I began to cease from noticing...").

(4)Linguistic cues to PHYSICAL CONTEXT

Nouns that refer to a geographical location (e.g., the name of a city, a geographic region, a point on a map), an object in a physical setting (e.g., a house or a tree), a sensory property or a physical setting (e.g., the sound of wind in the tree).

(5)Linguistic cues to TIME SEQUENCE

Adverbial elements indicating that something existed before, during or after a moment in time.
For example: then, when, next, later, meanwhile, subsequently, previously, earlier, at that moment

(6)Linguistic cues to LOGICAL SEQUENCE

1. Words implying a cause-effect relationship. For example:because, therefore, since, consequently

2. The phrase if ... then

Appendix 4
Questions for Teachers

1. About the Development of Writing Tasks

   a. Do you think the Development of Writing Assignments accurately portrays what happened (what you said, what you did, what I said and did, what students said and did)? If they are accurate, to what extent?

   b. If there are parts that are <u>not</u> accurate, which parts are they and what would be a more accurate description?

2. About the Conclusions and Inferences

   a. Do you think the Conclusions and Inferences are reasonable conclusions and inferences to draw? If they are reasonable, to what extent?

   b. If there are conclusions or inferences that are <u>not</u> reasonable, which parts are they and what would be more reasonable ones to draw?

   c. If I have omitted some other conclusions and inferences that you would draw, what are they and why would you draw them?

3. About the project in general

   a. Do you think the writing helped students learn?

   b. If you yourself drew some conclusions about what you observed or learned during the course of the project, what would they be and why? Would you briefly tell about them.

   c. What else do I need to know about your thoughts on the writing assignments we did in class?

      1. about collaborating with another faculty member

      2. about using writing with students in general

      3. about constructing assignments for writing

         -selecting mathematics ideas to write about

         -the kind of writing to have students complete

         -phrasing or setting up the actual prompt for

students to write about

4. about presenting the assignment to students in the classroom

5. about commenting on student writing

6. about using the 1-2-3-4 system

7. about having students rewrite/revise

8. about the ideas, in general, behind the project

4. What else do I need to know about your thoughts on the use of writing in a developmental mathematics course?

Vita

David L. White attended the public schools of East Tennessee. He graduated from the University of Tennessee, Knoxville, in 1974 with a B.S. degree in education, majoring in English. In 1976, he began teaching English and reading in the Knox County (Tennessee) school system, where he taught for seven years at the high school level. During that time, he also worked toward an M.S. degree, majoring in English education at the University of Tennessee, Knoxville, which he received in 1978.

He took additional course work at the Bread Loaf School of English of Middleberry College, Middleberry, Vermont with the generous support of their fund for rural teachers of English. He also took additional course work at Stanford University, working in the language, literacy, and culture program of the school of education there.

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