

JOURNAL WRITING AND MATHEMATICS INSTRUCTION

ABSTRACT. In this article we discuss the educational value of engaging mathematics students in a specific form of *writing to learn* – the keeping of a *journal* throughout a mathematics course. As the result of an analysis which comprises both conceptual and empirical components, we suggest that journals have the potential to contribute to mathematics instruction in several ways. As the *students write* the journals, they can be encouraged to express and reflect upon their feelings, knowledge, processes and beliefs about mathematics, and consequently grow along each of these dimensions. By *reading* their students' journals, *teachers* may receive a wealth of information about their students and the course, and consequently improve their teaching. Finally, journals can create a new form of *dialogue* between the teacher and each student, thus allowing for more individualized instruction and a supportive classroom atmosphere.

I. INTRODUCTION

One of the biggest challenges for mathematics instruction today is presented by the great number of students showing an inappropriate approach to the subject and its learning. Most mathematics students seem to interpret their role as essentially acquiring (i.e., memorizing) facts and algorithms that can be immediately applied to the solution of given exercises; few students expect mathematics to be meaningful and fewer still see mathematics as a creative undertaking. Consequently, students are too often content with externally manipulating symbols and doing routine problems, without ever reaching a deep and personal understanding of the material. Unfortunately, even though these attitudes and expectations may allow some students partial short-term successes, they are not conducive to the development of conceptual understanding and problem solving skills necessary to succeed in mathematics in the long run.

Changing students' overall approach to school mathematics presents a task for which we cannot hope to find a simple or even unique solution. Nevertheless, we suggest that the use of *writing to learn* can provide a valuable means to facilitate a personalized and making-of-meaning approach to learning mathematics.

Suggesting an intensive use of writing in mathematics courses might seem at first surprising. Few things stand so far apart in students' minds as mathematics and writing, and traditionally the amount of writing required in mathematics courses has been minimal. On the contrary, psychologists and

educators have suggested powerful connections between writing and learning. The assertion that writing, as well as other communication systems, can contribute to learning depends essentially on a Vygotskian view of the relationship between language and thought as a dialectic one, where language and thought are both transformed in the act of representation (Vygotsky, 1962; Bruner, 1986). Furthermore, it has been argued that writing can uniquely contribute to the learning process because of a combination of attributes: writing can engage all students actively in the deliberate structuring of meaning; it allows learners to go at their own pace; and it provides unique feedback, since writers can immediately read the product of their own thinking on paper (Emig, 1977).

In order to appreciate fully the value of writing as a learning tool, however, a reconception of both writing and learning may be necessary. *Writing to learn* rejects a view of knowledge as a collection of facts and ideas, to be delineated through lectures and course readings to students who function as passive learners, receiving and storing information for later retrieval on papers or tests (Knoblauch and Brannon, 1983). Nor does it accept the traditional interpretation of writing as the "simple transcription of the mind's fully formed concept" (Fulwiler *et al.*, 1982). Rather, both learning and writing are conceived as "meaning-making processes that involve the learner in actively building connections between what she's learning and what is already known" (Mayher *et al.*, 1983, p. 78). Not all writing activities, therefore, may qualify as *writing to learn*.

In this paper, we will analyze the educational potential for mathematics instruction of one particular form of *writing to learn* – *journal writing*. The term *journal* here means the keeping of a *log* or *personal notebook*, where students can write down any thought related to their mathematics learning, throughout a whole course. While students should maintain a high degree of freedom about what they write in their journals, they are encouraged to include entries which go beyond the recording of events and personal thoughts – for example, reflections on material learned in class, reactions to readings or lectures, or even responses to open-ended assignments such as "Discuss: *Factoring and finding a product are reverse processes*" (Nahrgang and Peterson, 1986). The teacher is expected to read these entries and occasionally comment and respond to them in a supportive and non-evaluative way – for example, by sharing personal thoughts on the matter, or by suggesting new questions for reflection and exploration. Within these constraints, the structure of a specific journal activity can take on considerable variations in terms of the focus and function given to the journals within the course, students' autonomy in the choice of writing topics, as well as the frequency and expected length of the entries.

Various successful experiences using journals in mathematics classes have already been conducted at various grade levels (Buerk, 1986; Burton, 1985; Goodkin, 1982; Mett, 1987; Mayer *et al.*, 1983; Nahrgang and Petersen, 1986; Powell, 1986; Stempien and Borasi, 1985; Vukovich, 1985; Watson, 1980). However, the evidence produced so far has been mostly anecdotal. Furthermore, in most of the current literature on journal writing, both in mathematics and in other content areas, the focus has been essentially on the cognitive and affective benefits that the *student* may directly derive as a result of *writing* in the journal. In addition, we suggest that it is also important to consider that *teachers* may be affected in their teaching as a result of *reading* their students' journals; furthermore, student-teacher relationships may be affected by the *new dialogue* between students and teacher occurring through the journals.

In sum, we are still lacking a convincing argument about how and why *journal writing* can contribute uniquely to the improvement of mathematics instruction. With this paper, we aim to address such a void by providing a comprehensive and articulated analysis of the potential benefits of *journal writing*, based on an investigation combining both conceptual and empirical components.

The article is organized as follows. In section II, the scope and the methodological approach of the study will be further clarified. Also, the context of the teaching experience in which our empirical data were collected will be described in detail. In section III, potential benefits of journals for the student as writer, the teacher as reader, and the classroom interaction, will be identified and discussed employing conceptual arguments supported by empirical data. A brief summary of the major results of the study, in section IV, will conclude the article.

II. FRAMEWORK AND METHODOLOGY

Let us start by clarifying the *scope* of this study, which can be summarized as *contributing to an understanding of the potential benefits of journal writing for mathematics instruction*.

We suggest that it is not only unrealistic, but also inappropriate, to search for conclusive empirical evidence which would allow us to *predict* the outcomes of introducing journal writing in a mathematics class. The extent of the benefits that can be derived from using journals, as is the case with most instructional strategies, will in fact depend essentially upon elements specific to each instructional context – for example, the degree of trust existing between teacher and students in the class, and the extent to which each student actually engages in the activity.

What we can and will strive for, instead, is the elaboration of *working hypotheses*, grounded both in theoretical considerations and empirical data (Glaser and Strauss, 1967), about *what opportunities for learning mathematics journals can offer, and what conditions may affect how students and teachers actually take advantage of any such opportunity*. The role of these hypotheses will be to help individual teachers decide whether, given their instructional goals and teaching style, the strategy is at all interesting for them and therefore worth trying in their classes, and also to provide guidelines for the evaluation of the effects of journal writing when implemented in a specific instructional setting.

To achieve this goal, first an extensive review of major theories about writing and of the existing literature on using journals in various fields was undertaken (see Rose [1988] for a detailed report of this review along with a comprehensive bibliography on the subject of journal writing). This provided a theoretical background against which to interpret and analyze empirical data on the use of journals in specific instructional settings. Several of the major theoretical contributions will be referred to later in this article.

The setting chosen for generating and collecting such data was a regular college mathematics course taught by one of the authors in a small four-year liberal arts college in the U.S.A.. This course, entitled “Algebra for Professional Programs” is a 3-semester hour course taken predominantly by business students in their first or second year of college. It is the first course of a two-course sequence required for the business program in that particular college, and covers topics such as 1st and 2nd degree equations, systems of equations, matrix algebra, linear programming, math of finance, and exponents. The writing experience was structured so as to make journal writing an integral and valued component of the course, yet without modifying the goals and content of the course, nor the teaching approach usually employed by this instructor – consisting mainly of lectures by the teacher, followed by the assignment of homework practice and follow-up discussion. Further details on the *context* of this experience are essential both to describe the approach and methods employed to collect and analyze data, and to allow the reader to interpret appropriately the results which will be reported.

On the first day of the course, the students were given a written hand-out and a brief oral explanation of the rationale for introducing journals – to reflect on and express feelings about mathematical content and the course, to provide input to the teacher, and to engage in a dialogue with the teacher. The students were asked to write three entries per week, with the

journals collected every other Friday and returned on the following Monday, along with comments by the teacher; credit towards the course grade would be assigned for maintaining the frequency and volume of writing, but not on the basis of mechanics or content. Each time journals were collected, the teacher spent approximately two to three hours reading students' recent entries and responding to them.

Although the topics of the journal entries were intentionally left open and flexible, several students expressed difficulty with knowing what to discuss in a math journal. Subsequently, a sheet of 36 suggested ideas was produced by the instructor, containing topics such as: *Respond to a particular class or topic; Reflect on math ideas or feelings about math; Describe your favorite math class; How do I read the text book? How should we use class time to best advantage? How do I go about doing word problems? Where do the rules of math come from? Write possible test questions.*

In addition to the open entries which they were supposed to write at home, students were occasionally requested to write in their journal during class, in response to a topic assigned by the instructor.

As a follow-up to the journal writing activity, the students were asked to write an evaluation at the end of the semester by responding to the following open-ended questions:

1. How has writing in your journal affected your learning of mathematics?
2. How do you feel about journal writing for this course?
3. What are the benefits of journal writing for mathematics classes?
4. How could journal writing be changed to be more effective?

29 students, presenting a great variety of mathematical backgrounds and abilities, enrolled in the course. Amongst this group, 3 withdrew and another failed to keep a journal; 23 of them both kept a regular journal and wrote an evaluation of the journal activity at the end of the course.

These 23 complete sets of journals and evaluations, along with the instructor's own reactions to the experience, provided valuable data to understand both *what happened when journal writing was used* in this specific setting, and *what meanings the participants attributed to the experience* – two critical questions in the tradition of ethnographic research (Eisenhart, 1988). A content analysis of these rich sets of data was conducted, searching for *recurring patterns* that, interpreted in the light of existing theories about writing and learning, would allow us to identify and explain complementary ways in which journal writing could contribute to the improvement of mathematics instruction (Glaser and Strauss, 1967). As a result, a number of potential benefits of journal writing were identified and explored, and a taxonomy suggested – as we will report and discuss in the following section.

III. ANALYSIS OF POTENTIAL BENEFITS OF JOURNAL WRITING

In Table I we present an overview and categorization of the complementary ways in which journal writing can contribute to mathematics instruction, as suggested by our study.

In the following sections, each of the claimed potential benefits of journal writing will be elaborated upon and analyzed, with the goal of:

- providing empirical evidence and theoretical support for the claimed benefit;
- understanding more specifically what characteristics of journal writing come into play with respect to this benefit;
- identifying variables which can influence the extent to which the benefit is realized;
- suggesting variations in the way the journal activity can be structured so as to maximize the potential of journal writing in this direction.

TABLE I

A taxonomy of potential benefits of journal writing

Potential benefits as the students write their journal:

- 1.1 A therapeutic effect on the emotional components of learning mathematics can result as students express and reflect on their feelings about the course, mathematics and schooling;
- 1.2 An increased knowledge of mathematical content can be gained as writing about the material covered in the course provides a better and more personal understanding of the same, as well as the stimulus for new inquiry;
- 1.3 An improvement in learning and problem-solving skills can result from the articulation of and reflection on their process of doing mathematics;
- 1.4 Steps towards achieving a more appropriate view of mathematics can be taken as one's beliefs on the nature of the discipline are made explicit and consequently reevaluated.

Potential benefits as the teacher reads the students' journals:

- 2.1 More appropriate evaluation and remediation of individual students can result from the increased individual knowledge of each student gained through the journals;
- 2.2 Immediate changes and improvements in the course itself can be made in response to students' feedback on the course.
- 2.3 Long-term improvements in teaching approach and methodologies may be induced in response to the new insights gained about students, learning and teaching;

Potential benefits as students and teacher dialogue in the journals:

- 3.1 More individualized teaching can be achieved as the teacher directly responds to questions, problems and suggestions expressed by students in their journals;
 - 3.2 A more caring and non-adversarial classroom atmosphere, conducive to students' taking learning risks and supporting the teacher's commitment to continuous improvement, may be created by the mutual trust built through the journal exchange.
-

This will be accomplished by making use of (a) appropriate illustrations from the students' journals; (b) theoretical and conceptual arguments; and (c) contributions from the participants' perceptions of the experience.

1. *Potential Benefits as Students Write Their Journals*

Several authors have posited that the keeping of a journal can foster growth in the writer. The open and exploratory nature of the journal may in fact invite students to record events, thoughts, feelings, and ideas, of which the writer may not initially recognize the relevance or value. The mere fact of reporting them on paper creates a new awareness and may induce further reflection, which can in turn be recorded in the journal itself. Furthermore, the journals will provide a record of the writer's development through time, which can by itself provide new awareness and stimulus for reflection. The process may be further enhanced when teachers provide supporting feedback through their responses to journal entries.

Depending on what students write about in their journal, this cycle of reporting, becoming aware and reflecting can prove beneficial in various ways. Yinger and Clark (1981) have observed that journals put the writers in the position to learn (a) what they feel; (b) what they know; (c) what they do (and how); (d) why they do it. Taking inspiration from these categories and interpreting them in the context of a mathematics course, we have distinguished between potential benefits dealing with affective issues, the learning of mathematical content, the process of doing mathematics, and mathematics beliefs, respectively.

1.1. *Therapeutic Value*

A great majority of our students' entries dealt with *feelings and attitudes* towards mathematics and its learning. Students seemed clearly comfortable expressing their feelings about mathematics and the course, even when they were negative.

As the students wrote such feelings, interesting stages were revealed. The initial and most simplistic level was a statement of the feeling itself, illustrated by the following two students who expressed frustration:

This is math again and I am frustrated again. I hate word problems with a passion. I've never been good at them. I guess I can't think very logical.

I've had it! I'm sick of it! I've spent six hours doing math today! I know what I'm doing (I hope!) but I keep making stupid mathematical errors. It's discouraging to spend so much time on a problem, get to the end, and find out you're wrong. Then I can't find my mistake. I end up having to do the whole problem over. Then I make another mistake. It never ends!

Although this kind of entry is likely to provide a therapeutic outlet for the writer, we expect students to benefit even more when their writing reveals an awareness of how their feelings affect their learning of mathematics, as in the following entries:

It is eight o'clock and I am sitting in class dreading math and it hasn't even started yet. As class wore on I began to realize certain aspects about math. Math wasn't afraid of me, I'm afraid of math. I noticed that I have trouble taking tests and that my attitude toward math needed changing. I hope that this is possible. I guess I'm really afraid to think.

By thinking through my past experiences with math, I realized that most of my problems with math stemmed from the fact that I did not believe I had the ability to perform math problems. The math autobiography went from being just busy work to something that was a learning experience for me.

As these students recognized that their fear of mathematics might be associated with a negative attitude or poor test taking, they took the first step in dealing with the problem. By stating their feelings and becoming cognizant of them, they also became more open to change.

The therapeutic value of personal journals has long been recognized by psychologists such as Rogers (1969) and Progoff (1975). Its importance in mathematics instruction should not be undervalued, considering the increasing occurrence of "mathematics anxiety". Expressing their apprehensions about mathematics, reporting past experiences of failure or success, and communicating feelings of incompetence or discomfort about the course could help the journal writers learn about themselves and take steps towards overcoming their perceived difficulties.

Most students (18 out of 23) explicitly recognized the therapeutic value of journal writing in their final evaluation, with comments such as:

It gave me an outlet to express my feelings which was definitely needed with this course.

By writing down how I feel about a certain problem or section, I get the feeling I'm opening my mind up for further understanding.

1.2. Increased Learning of Mathematical Content

Not only can journals constitute an outlet for students' feelings, but they can also provide an opportunity to write about the mathematical topics encountered in the course.

For example, after we had been doing linear programming problems for several days, the students were asked to write in class about this topic, once to define linear programming and another time to write on the most difficult aspects of solving these problems. The following entry is a good example of the power of expressive writing, since the student believed that

she did not know the definition, but in the process of writing she revealed more of the definition than initially thought!

What is a linear programming problem? I still don't know! It has something to do with solving a system of equations to find the maximum or minimum value. It's used for things such as maximizing profits and minimizing costs. The object is to find the highest and lowest solutions. I forgot about the constraints!

Though most of the entries dealing with mathematical content were written in response to specific assignments given by the instructor in class, occasionally students initiated this kind of topic spontaneously – reporting some difficulties or achievements, posing questions, or reporting some exciting discoveries:

I still don't understand whether you know that a system of inequalities fitting an equation will have a maximum or not. How do you know whether its bounded or unbounded? Is it only unbounded if it goes up towards infinity or can it be bounded downward too?

When doing a linear programming problem a graph sets up a visual image. You can only use the graph to tell which two lines are intersecting. Graphing is a good representation but can become very complex. It becomes important how you draw your graphs. They must be done carefully. Graphing has limitations. As you make more restraints the graph becomes complex and cluttered. It would be very difficult to graph an equation of three variables because the graph would be three dimensional.

All the entries reported in this subsection clearly confirm the *potential* of journal writing as a means to learn mathematics content better. Restating concepts and rules in one's own words can in fact facilitate their internalization. Students can no longer be content to manipulate symbols successfully – they have to create their own meaning for symbols in order to express them in words on paper. Writing about a mathematical topic can also help identify learning difficulties and problems, and recognize connections previously unrealized. The expressive nature of writing which occurs in the journal may also stimulate further inquiry and exploration (Mayher *et al.*, 1983).

Students, however, may not always be ready to recognize and to take advantage of this opportunity. Only about a third of our students mentioned this benefit in their evaluation of the journal activity, and several students seemed reluctant to spontaneously choose mathematical topics for their entries. These observations suggest the value of occasionally prompting the students to write about a specific concept or rule, either in class or at home, to allow them to experience, and thus appreciate, this value of journal writing.

1.3. *Improvements in Learning and Problem-Solving Skills*

While writing about their struggle with the course material, students can also become more aware of *how they do mathematics*. Consider, for example, the following report:

Number 29 was a little tricky finding x and y . At first I multiplied the $2x$ and $3y$. That didn't work. I looked at the answer in the back and fooled around with the problem for a couple of minutes before I decided to add the two and it worked out.

The hardest thing in a linear programming problem would be the word problems. I don't know how to set them up or what is relevant or irrelevant to the problem. I also have a bit of trouble changing the rows or finding the pivot element once in a while.

Besides acquiring a better understanding of the type of problem discussed (a benefit of type 1.2), these students benefited from recording the way they did mathematics in yet another dimension. Possibly for the first time, they became aware of their own problem-solving procedures and difficulties; with them reported on paper, the students could then reflect on their merits and shortcomings, and retain or change them accordingly. Thus used, the journals can also become an historical document of what works and fails as students do mathematics.

Students often used their journals to report how they were doing their homework or studying for a test. Some students not only recorded their study habits, but proposed changes and reported subsequent assessment of those changes:

I went about studying for the test by going through my notes, looking over the homework I had done, going through the book, and I did the chapter review exercises and the practice tests at the end of the chapter. I feel that doing those two exercises helped me on the test because I discovered my weaknesses by doing the problems and then looking at the answers.

The problem was, I would always wait and do my math assignments the day before it is due. In that short span of time I could go over my notes and reread the text, and still not understand about $1/2$ of the material. Well this week, I have changed that habit. Now the various operations are sticking in my head, and if I need help, I'm not pressed for time anymore.

An increased awareness of the process of doing mathematics seems especially important for the students' success in mathematics. By asking the students to report in their journals how they solved a problem or approached the study of a topic, they can be encouraged to become introspective of how they do and learn mathematics, and consequently be brought to identify more general heuristics to solve mathematics problems as well as to realize the possibility of alternative approaches to the same learning task. Fulwiler (1982) has advocated the journal as a regular tool in any subject area to assist students with problem solving, as the act of writing helps clarify both the process and content of problems.

Most students seemed aware of this benefit of journal writing, as they often spontaneously used their entries for this purpose; about half of them pointed it out explicitly in their evaluation, with comments such as:

I have been able to realize what I am doing wrong in my thinking process. Once I know what I am doing wrong, I have been able to change and thus do better.

I am able to see on paper my thought processes towards problems instead of some abstract thought in my mind which are hard to keep.

1.4. *Reconceiving One's Conception of Mathematics*

The following entries, written in response to one of the suggestions on the topic sheet – *Discuss whether mathematics is invented or discovered* – show the potential of journal writing to bring mathematics students to reflect on the nature of mathematics and consequently on their approach to learning this discipline:

I think that we as humans create mathematical truth as we need it. Therefore if a difficult problem comes along which can't be solved by our intuition or other skills, a math identity will be created so that a solution can be found. If math just existed independently, we wouldn't know how or why it was put there in the first place so it would be looked on with more disregard. But if we as people create new mathematical truth as it is needed, then we place more importance on it since it proves to be helpful.

I think that mathematics is discovered. If it was invented, then there would be many errors as people use different numbers in equations. I am pretty sure that my high school math teachers said that men such as Galileo worked on problems until they discovered the correct formulas that made the equation turn out a feasible answer Also, if it was invented then mathematicians would constantly be improving their "inventions". It seems also that formulas would be patented because many people have set ideas of what is theirs so they would probably claim formulas.

These two entries reveal quite different conceptions of mathematics. While the second student discloses a commonly shared belief about the nature of mathematics, one that conceives of math as progressing linearly and without error, the first student represents a view probably held by most mathematics teachers but few students. It is unlikely that these students had ever thought about or articulated their position until they wrote this journal entry, yet doing so marks the beginning of *writing to think* about mathematics.

It was disappointing and initially surprising when we realized that our students rarely wrote explicitly about their views on mathematics in their journals, and only two of them explicitly mentioned in their final evaluation that journal writing had somehow affected their view of mathematics. The lack of entries addressing the nature of mathematics per-se, however, is revealing since it may reflect students' prior experiences of mathematics as something you *do* but you never *talk about* (Oaks, 1987).

Encouraging students to state and reflect upon their beliefs about mathematics in their journals could thus be very valuable as a starting point for a growth cycle to be established. Our experience suggests that if we want students to take advantage of journal writing in this direction we need to devise better stimuli and exercises to encourage them to write *about* mathematics. The positive results obtained by the question “Was mathematics discovered or invented?”, for example, indicate the value of suggesting concrete topics and dilemmas which may invite students to question the nature of mathematics.

2. Potential Benefits as the Teacher Reads the Journals

Journals can provide the teacher with a wealth of information about students and the course which could be lost otherwise. Most assignments and classroom interaction can reveal only little of the students' individual problems, reactions and personalities. Though informal conversations with students could provide even more valuable information than journals, a teacher rarely has the opportunity to spend time with individual students outside of class.

As illustrated by the quotes reported in the previous subsection, in journals students can reveal their views of schooling and learning, their feelings about mathematics, their way of learning mathematics, and their difficulties with specific topics. As teachers become readers of their students' stories, they can in turn become better teachers in more than one way.

2.1. Better Evaluation and Remediation of Individual Students

In the experience we have been discussing, the journals certainly allowed the teacher as a reader to get to know students individually, and to realize their specific problems and difficulties – whether they were of a cognitive or affective nature. As a consequence, the teacher became more aware of the individual needs of each student, and could respond better to them – both individually and corporately. In addition, journals provided a unique record of student development, which in turn helped the teacher evaluate the growth which occurred as a result of the course.

This result became especially evident during the semester following the empirical study, when some of these students took another course with the same teacher, where journals were not kept. Although there was still a special friendship between teacher and students, there were no more

glimpses into the students' feelings about and knowledge of the course, and no dialogue to individualize instruction.

It is interesting that about one third of the students explicitly identified this benefit in their questionnaire response. Students are not often given the opportunity to provide this kind of information about themselves to teachers, and they apparently see its importance to the teaching-learning process.

2.2. Responses to Feedback on the Course

Another pedagogical benefit of reading journals is the unique feedback about the course they can provide to the teacher. If students are sufficiently comfortable in sharing specific responses to the structure, procedures, and teaching of the course, the teacher can use this information to improve the teaching of the course itself.

Our students were eager to provide feedback on various aspects of the course. A notable example was the students' spontaneous comments on new testing procedures that the teacher had tried to introduce in the course. Below we have reported some significant excerpts:

I found it very helpful to be able to go back and correct my mistakes with the incentive of extra credit. In math you can't move on to something new before you master the old.

I am glad [you] gave us the take home math word problems. I think this will help a lot because I will not be so pushed for time. Also, I will be able to work the problems out at my own pace.

The students' positive responses strengthened the teacher's belief about the value of these experimental procedures, and convinced her to make them a permanent feature of the course.

Not always, of course, did the students respond unanimously to the same event in the course. For example, the teacher received contrasting feedback from different students about the use of class time and the pacing of the course. This was helpful, too, since it reminded the teacher of the variability across students in the course and of the need for individualizing instruction.

Both through their eagerness in providing comments on the course, and in their responses to the evaluation questionnaires (where half of the students explicitly identified this benefit), the students in our course showed their appreciation for having the opportunity of providing feedback on the course through their journals. As one student expressed in her evaluation of the journal activity:

I don't know if you have changed any of your teaching methods because of what you have read in someone's journal, but if you have then I'm sure it's affected not only my learning of math, but that of everyone else as well.

2.3. *Long-Term Instructional Improvements*

Besides immediate feedback on the teacher's effectiveness in the specific course, journals can provide teachers with information which can induce long-term instructional improvement.

In our experience, for example, when students repeatedly mentioned the benefit of having the teacher care about them individually, it impressed upon the teacher the worthwhile effort to personalize education in each class. It was also helpful to know how students studied and approached problems, so that common weaknesses in study skills could be identified and explicitly addressed in future classes. Reading journals made the teacher more aware of common misconceptions and difficulties regarding the course material, and of the fact that most of her students' mathematical beliefs were at odds with her own.

The new realizations about students, learning and teaching gained by reading the journals may cause the reconsideration of some basic assumptions in the teacher's approach to the teaching of mathematics, which may in turn lead to fundamental changes in curriculum decisions and teaching style.

3. *Potential Benefits as Students and Teacher Dialogue in the Journals*

When students write entries and the teacher reads and responds to them, a new mode of communication is created in the classroom – a private dialogue between the teacher and each student. Not only can teachers and students learn more about each other and interact more personally in this way, but a different rapport between them can be established, with positive benefits for both parties.

3.1. *Development of More Individualized Teaching*

In our experience, the journals certainly allowed the unfolding of an unprecedented dialogue between teacher and individual students, witnessed by the exchange of questions, responses, comments and remarks in the journals throughout the semester.

As students expressed their feelings and frustrations in their journal, the teacher was able to provide some immediate support through her empathic and constructive response, as illustrated in the following exchange:

Student's entry: . . . that test blew my mind. I thought it would be hard but not that hard . . . I thought I'd get at least a low C, not an F. I'm really ashamed of myself. I started off the semester with good intentions and this is how I act on them.

Teacher's response: *Can you respond in more specific ways to what you missed in the test? What did you know and didn't know? What kind of mistakes did you make? What do you think you need to do differently for the next one?*

Constructive and concrete suggestions in terms of study habits and approaches to learning mathematics could be provided to individual students by responding to their specific problems as revealed in their entries. Specific misconceptions and difficulties could also be resolved without delay or loss of class time by directly responding to the questions raised in a student's entry, or by pointing out mistakes in the procedure reported.

Student's entry: I understand inequalities but I don't understand how the text graphs them. To me, if I have $-3 < x \leq 3$ and it is graphed like



Why is the x where it is if x is less than or equal to 3? I also have difficulty in solving word problems. The word problems in section 1–4 gave me trouble.

Teacher's response: *On the graph of $-3 < x \leq 3$, the x over there to the right of the arrow is just the label for the real number line. They just are calling the line " x ". It doesn't mean that x is over there. Good question, though. I really appreciate it when students can cite specific questions they have about the text. Did you ever get no. 4!? If not, see me after class and I'll help you with it. Keep up the good work.*

Teaching may become more individualized as teachers provide feedback to students' ideas and concerns through their responses to the journals. Our students were certainly very appreciative of this element of journal writing, as expressed in the following excerpt from a student's evaluation questionnaire:

... If I had a question concerning one of the topics we were studying in lecture, it would be answered by you in my journal. It's a way of pinpointing what we don't understand in math and having our questions answered so that we can learn to understand a difficult topic.

3.2. The Creation of a Supportive Class Atmosphere

An increased mutual respect and positive rapport between teacher and students were observed by the instructor in our course, who felt this was one of the most beneficial effects of the whole experience. A similar impression was shared by about a third of the students and is well expressed in the following excerpt from one of the evaluation questionnaires:

I feel writing in my journal has helped in learning just because it shows that you care enough about teaching and your students to listen to their comments and give suggestions and

encouragement. I think many times students won't talk or speak up and say how they feel because of the "classroom atmosphere". But writing helps me say what I want without feeling intimidated.

When teachers care enough to solicit student opinion and respond individually to each student, students may start looking at teachers and schooling in a new light. While teachers partially lose their evaluative role for a more supportive one, students may feel encouraged to be more daring in their attempts to learn. If their respect and trust for the teacher increases, they will be more willing to put effort in the course and to engage in learning activities, even if they may not initially see their worth. As Connell's (1987) research purports, students' motivation is positively correlated with the degree to which they perceive the teacher to *care* for them.

We should not forget that the new rapport which journals can establish in a classroom can likewise have an important effect on the teacher's own motivation. The increased respect and trust which students may develop can, in turn, allow teachers to get new energy for the task which first brought them into the profession – to help students grow.

IV. CONCLUSIONS

If major problems with learning in mathematics appear to stem from preoccupation with product and answers, anxiety, external manipulation of symbols, and passive and disengaged learning, then our analysis suggests that journal writing may provide a valuable addition to current modes of mathematics instruction.

Journal writing in fact introduces new important dimensions in the mathematics classroom: by writing in the journals, students make use of *writing* as a learning tool in the context of mathematics; by reading students' journals, teachers access a wealth of information usually unavailable to them; and by commenting on students' entries, responding to specific questions and posing new ones, teachers engage in a unique and continuous dialogue with each individual student throughout the course. In turn, each of these elements has the potential to provide a variety of benefits for mathematics instruction.

When students write journals, they can be encouraged to express and reflect upon their feelings, knowledge, processes, and beliefs about mathematics, and consequently be helped to cope with negative emotions, learn new content and skills, and be encouraged to reconceive their views of school mathematics. As teachers read the journals, the student stories can help expose individual needs and common difficulties as well as provide immediate feedback on the course; through this awareness, teachers may

immediately become more responsive and effective in the teaching of their course, and eventually be brought to reconceive their educational beliefs with even more radical long-term effects. The journals can also positively influence the student-teacher interaction and classroom atmosphere; when students and teachers freely communicate and see each other as caring human beings, the classroom can turn into a more pleasant environment where all members become partners in learning.

Our analysis implicitly revealed a close relationship between *what the students write about* in their journals and the *potential benefits* of journal writing identified. In Table II, we make such a relationship more explicit and present it in a schematic form.

TABLE II
Relationship between writing topics and potential benefits of journals

	POTENTIAL BENEFITS AS . . .		
	students write their journals	the teacher reads the journals	students and teacher dialogue through the journals
Entry Topic: Feelings and attitudes	therapeutic effect	better evaluation and remediation of individual students	creation of a supportive class atmosphere individualized teaching
Math topics and concepts	increased learning of mathematical content	better evaluation and remediation of individual students long-term instructional effects	creation of a supportive class atmosphere individualized teaching
The process of doing mathematics	improvements in learning and problem-solving skills	better evaluation and remediation of individual students long-term instructional effects	creation of a supportive class atmosphere individualized teaching
The nature of mathematics	reevaluation of one's view of mathematics	better evaluation and remediation of individual students long-term instructional effects	creation of a supportive class atmosphere individualized teaching
Structure teaching of the course	therapeutic effect	improvements in the teaching of the course	creation of a supportive class atmosphere

Since not all students may spontaneously realize the possibility of this variety of content for their entries, it may be important that teachers occasionally intervene by suggesting or even assigning specific writing topics that can open up new ways of using journals.

It is important, however, to remark that not only *what* the students choose to write about, but also *how* they do so, may affect the extent to which the potential benefits of journal writing we suggested can become a reality. The more the students use their journals to write *expressively*, i.e. as a place where they can *think on paper* and not just *report* already formed ideas, the more they will exploit the potential of writing as a tool for learning and growth. The more the students are open and sincere in revealing their feelings, problems, misunderstandings, and beliefs, the more their teachers will be able to learn from the journals and consequently improve their own teaching. The more timely, empathic, and stimulating the teacher's response to students' entries is, the stronger will be the effects on student-teacher interaction and classroom atmosphere.

Our experiences with this strategy have also revealed considerable *individual differences* in the extent to which students and teachers take advantage of the opportunities offered by the journal activity. Further study on how individual variables – such as personality, learning and teaching styles, mathematical background, or gender – may influence students' and teachers' decisions and behavior with respect to journal writing would thus be valuable and may further help individual teachers decide whether and how to employ this strategy in their classes.

REFERENCES

- Bruner, J. S.: 1986, *Actual Minds, Possible Worlds*, Harvard University Press, Cambridge, MA.
- Buerk, D.: 1986, *Carolyn Weber's Journal: Voicing the Struggle to Make Meaning of Mathematics*, Paper accepted for the Working Paper Series, Wellesley College, Center for Research on Women, Wellesley, MA.
- Burton, C. M.: 1985, 'Writing as a way of knowing in a mathematics education class', *Arithmetic Teacher* 33, 40–45.
- Connell, J. P.: 1987, *A Motivational Analysis of Student Engagement and Disaffection*, Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans, LA.
- Emig, J.: 1977, 'Writing as a Mode of Learning', *College Composition and Communication* 28, 122–7.
- Eisenhart, M. A.: 1988, 'The ethnographic research tradition and mathematics education research', *Journal for Research in Mathematics Education* 19, 99–114.
- Fulwiler, T.: 1982, 'Writing: An act of cognition', in C. W. Griffin (ed.), *New Directions for Teaching and Learning: Teaching Writing in All Disciplines*, pp. 15–26, Jossey-Bass, San Francisco.

- Fuwiler, T.: 1982, 'The personal connection: Journal writing across the curriculum', in T. Fulwiler and A. Young (eds.), *Language Connections: Writing and Reading Across the Curriculum*, pp. 15–31, National Council of Teachers of English, Urbana, ILL.
- Glaser, B. G. and Strauss, A. L.: 1967, *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Aldine Publishing Co., Hawthorne, NY.
- Goodkin, V.: 1982, 'The intellectual consequences of writing: Writing as a tool for learning', Ph.D. dissertation, Rutgers University.
- Knoblauch, C. D. and Brannon, L.: 1983, 'Writing as learning through the curriculum', *College English* 45, 465–74.
- Lincoln, Y. S. and Guba, E. G.: 1985, *Naturalistic Inquiry*, Sage, Beverly Hills, CA.
- Mayher, J. S., Lester, N. B. and Pradl, G. M.: 1983, *Learning to Write/Writing to Learn*, Boynton/Cook Publishers, Inc., Upper Montclair, NJ.
- Mett, C. L.: 1987, 'Writing as a learning device in calculus', *Mathematics Teacher* 79, 461–65.
- Nahrgang, C. and Petersen, B. T.: 1986, 'Using writing to learn', *Mathematics Teacher* 79, 461–65.
- Oaks, A.: 1987, 'The effects of the interaction of conception of mathematics and affective constructs on college students in remedial mathematics', Ph.D. dissertation, University of Rochester.
- Powell, A. B.: 1986, 'Working with "underprepared" mathematics students', in M. Driscoll and J. Confrey (eds.), *Teaching Mathematics: Strategies that Work*, Heinemann, Portsmouth, NH.
- Progoff, I.: 1975, *At a Journal Workshop*, Dialogue House Library, NY.
- Rogers, C.: 1969, *Freedom to Learn*, Merrill, Columbus, OH.
- Rose, B.: 1988, 'Using expressive writing to support the learning of mathematics', Ph.D. dissertation, University of Rochester.
- Stempien, M. and Borasi, R.: 1985, 'Students' writing in mathematics: Some ideas and experiences', *For the Learning of Mathematics* 5, 14–17.
- Vygotsky, L. S.: 1962, *Thought and Language*, MIT Press, Cambridge, MA.
- Vukovich, D.: 1985, 'Ideas in practice: Integrating math and writing through the math journal', *Journal of Developmental Education* 9, 19–20.
- Watson, M.: 1980, 'Writing has a place in a mathematics class', *Mathematics Teacher* 73, 518–20.
- Yinger, R. J. and Clark, C.: 1981, *Reflective Journal Writing; Theory and Practice* (ERIC Document Reproduction Service ED 208 411).

Graduate School of Education and Human Development
Lattimore Hall 424
University of Rochester
Rochester, New York 14627, U.S.A.

Roberts Wesleyan College
2301 Westside Drive
Rochester, New York 14624, U.S.A.