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The use of writing as a tool for teaching and learning in mathematics classes

Walter C. Block

University of Northern Iowa

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Abstract
Increasingly the belief that there is a close connection between thinking and writing grows. This connection, it is alleged, makes writing a very useful device for learning the subject matter of all disciplines, in addition to being particularly useful in the teaching of thinking skills. If one believes that mathematics should be based on sound thinking, mathematics teachers, such as this author, may well feel prompted to search for ways in which writing may be used as a learning and thinking tool in mathematics classes. This search is the topic of this paper. This paper attempts three major tasks: The first is to present research which establishes the basis for emphasizing writing as a teaching and learning tool across the entire secondary school curriculum. Second, some useful techniques for implementing writing as a tool in any of the disciplines are presented. Finally, the paper discusses some of the advantages and disadvantages that such techniques hold for mathematics classes.
THE USE OF WRITING AS A TOOL FOR TEACHING AND
LEARNING IN MATHEMATICS CLASSES

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James E. Albrecht

11-2-87
Date Approved

Robert H. Decker

11-2-87
Date Approved

Dale R. Jackson

11-2-87
Date Received

Head, Department of Educational Administration and Counseling
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This paper attempts three major tasks: The first is to present research which establishes the basis for emphasizing writing as a teaching and learning tool across the entire secondary school curriculum. Second, some useful techniques for implementing writing as a tool in any of the disciplines are presented. Finally, the paper discusses some of the advantages and disadvantages that such techniques hold for mathematics classes.

Writing Across the Curriculum

"To write is to learn" (Griffin, 1985, p. 403). No less an educational authority than Ernest Boyer (1984) stated uncategorically that "clear writing leads to clear thinking; clear thinking is the basis of clear writing" (p. 21). Just why is writing such a useful learning tool? From all
indications, the reason for the utility of writing as a learning/teaching tool is because it seems to provide a way for students to process information in the content areas. Research suggests the following five major reasons for this:

1. The Relationship Between Learning and Writing

The most supportable reason is that learning demands thinking, and there seems to exist a deeply rooted relationship between the basic processes of thinking (learning) and those of writing. That a special correspondence exists between learning and writing was postulated by Emig (1977). She found, by examining Bruner's (1971) view of learning that humans deal with the world in three major ways: by doing (enactive), by developing an "image" (iconic), or by restating what we experience in words (symbolic). Emig concluded that writing actually forces a student to work in all three modes simultaneously, which is one way in which the appreciable relationship between learning and writing is demonstrated.

Olson (1985) showed what appears to be an almost direct parallel between Bloom's taxonomy of thought processes and the steps in the writing process. Olson believed that thinking and writing are both ways in which we attempt to make meaning of our everyday experiences and that both require sustained practice, two characteristics present in most types of learning.
Adler (1982) considered writing to be one of the fundamental intellectual skills that students must be well grounded in if they are to pursue any kind of knowledge. In his book, *The Paideia Proposal*, he proposed the same curriculum for all students, built on three essential processes: the acquisition of knowledge, the development of the intellectual skills of learning, and enlarged understanding of ideas and values. In the roster he developed of the "intellectual skills of learning," he afforded writing a position high on the list of such skills, which illustrates his belief that writing, thinking, and learning are closely connected.

2. Writing as a System of Symbols

According to Sizer (1984), students need to be able to show their teachers what they are thinking and learning. This allegation implies the second reason for the effectiveness of writing across the curriculum. Writing provides a system of scribed symbols through which students can use language to record what they are thinking and learning in a graphic form.

Emig (1977) analyzed the problem of the student communicating to the instructor using language as essentially a choice between speaking and writing. She also developed a list of eleven ways in which writing is different from, and superior to, speaking as a medium through which to express
what one knows. This list underscores the importance of writing as a system of symbols.

Consider, as an example, concept learning in mathematics. This process involves several stages. Included are (1) generating the idea, (2) recognizing instances of the idea, (3) representing the idea, (4) translating from one form of representation to another, and (5) learning the properties of the specific concept (Rathmell, 1986, pp. 21-22). Writing is a natural choice to serve as a monitor of what the student is thinking (learning) during the recognition, representation, and translation phases, since it provides a graphic record of the student's progress at each step along the way. It also can be used to record, sometimes using the symbols of writing in the English language and sometimes in the symbols of mathematics, the student's perceptions of the properties of the specific concept under consideration, thereby providing an opportunity for both student and teacher to refine the student's perception of that concept.

3. Writing is a Participatory Method of Learning

A portion of the effectiveness of writing as a teaching/learning tool might be attributed to the fact that writing is one of the four "participatory methods" of instruction identified by Krumm and Hanson (1984). It is, according to Krumm and Hanson, one of those unique areas
that combine both direct and open methods of instruction. It allows teachers to model a level of direct involvement with content area subject matter for students that has the effect of motivating the students to engage the material at a new and higher level. Also, as a participatory method, writing can be used in ways that supplement direct and open methods of instruction without increasing the planning obligations of the teaching staff. Other benefits of writing as a participatory method is that it permits more teacher interaction with the student and fosters an increased level of self-discipline on the part of the student.

Active participation by the student is also supported by Adler (1982) who believes that it is essential to enlarge one's understanding. He asserted that writing is one of the intellectual skills which requires the student to participate actively in his/her own learning.

4. Writing is a Multi-Level Approach to Learning

A fourth reason that writing is so useful as a learning tool is that it allows students to approach more than one facet of a task while using just the skill of writing. Herrington (1985) found this to be the case in her study of the effects of using writing as a learning/thinking tool in two Chemical Engineering classes taught at Rensselaer Polytechnic Institute in 1983. She concluded that students
could not only write in order to address content, but also to engage the social conventions of a professional forum as well. This showed that writing allowed students to become involved with the subject of Chemical Engineering on two distinctly different levels.

Another example of writing enabling students to approach tasks on more than one level was provided in the analysis of Austin and Howson (1977) of language and mathematics. Language and mathematics, and therefore writing and mathematics, are for Austin and Howson connected in two ways. First of all, writing is connected by special mathematical symbols to the operational system of mathematics. The writing of symbols helps students to tell themselves what to do. Secondly, the writing of language can assist the student in recording the steps in the logical (conceptual) system of mathematics. For example, writing can be used by students as a means of recording why conclusions must follow from certain premises. When used as an assist in these two ways, writing allows students to approach the task of learning mathematics on both operational and conceptual levels at one time.

Emig (1977) argued that this simultaneous activity forced by writing also engages both the left and right hemispheres of the brain at the same time, thus providing maximum engagement of students with subject matter in the learning
arena. This is another example of writing allowing the learner to engage an activity on more than one level. In this instance, the learner can engage a task on both a sequential level and a holistic level through one skill.

5. Implementation of Learning Research

Writing, as a highly individualized process, allows the teacher and learner to make use of some significant findings on learning that have been uncovered by recent research.

For example, writing allows the learner to engage subject matter at a proper pace for that individual since, with writing, the pace is produced by the learner him/herself. It is, as Emig (1977) pointed out, "... self-rythmed. One writes best as one learns best, at one's own pace" (p. 126). Research indicates that pace, defined by John Carroll (1963) as the time needed in learning, is an important aspect in the task of learning.

One can see that writing activities do provide opportunities for implementing recent research in the area of reinforcement through teacher feedback to the student. This seems especially effective if proper feedback is achieved through responding intelligently to student writing (Sullivan, 1986).

There are doubtless other excellent reasons why the use of writing as a teaching, learning, and thinking tool across
the entire secondary school curriculum works as well as it does and is as desirable as it is. In any event its effectiveness is well documented.

Writing Activities That Facilitate Learning

While there are many proposed activities used to implement the use of writing across the general curriculum of the secondary school, the following four forms seem particularly useful:

1. Free Writing

Free writing is aptly described by its name. The writer begins by writing whatever comes to mind about a specified topic. Punctuation, sentence construction, grammar, spelling, and the like are ignored. The idea is to get the student to write out his/her thoughts on paper for a few moments. It is the writer's equivalent of what is called brainstorming.

Even though its form is quite primitive, free writing does have several attributes that make it a desirable writing alternative for the non-English classroom: it can be used to focus the attention of the students on a specific topic to be discussed later. It can be used as a vehicle for students to record their immediate ideas and impressions of an experience they have just observed. Writing can also be used by the student and the teacher to pinpoint and diagnose
problems that surface in the student's understanding of concepts discussed in class (Burton, 1985).

For teachers who worry about the obvious lack of respect for the technical aspects of writing, Arnold (1983) suggested that "... teachers should not put too much emphasis in the beginning on spelling..." (p. 33). Free writing is meant to be a private record read mainly by only the student and teacher and used primarily by them as a tool for further revision and study of ideas and concepts. This should be a viable alternative for mathematics classes, as it is for many other classes.

2. Academic Journals

Journals can best be described as collections of free writing assignments that have been made on a regular basis by an instructor for the benefit of the students. An academic journal is one in which the writing that has been done has had the express purpose of helping a student grapple with the academic subject matter and gain insight into that material. "Journals give students a permanent record of the course ... in ways that ordinary class notes cannot" (Burton, 1985, p. 41).

It is recommended that journals also be done without restriction as to writing form, grammar, and the like, just as free writing is done, and that students not be held
accountable for mechanical correctness (Burton, 1985). There are, however, schemes that have been suggested for helping evaluate journal work should the instructor decide this is desirable (Burton, 1985; Fulwiler, 1980). The primary rationale for these approaches does not seem to center on direct benefits to students, but rather on ensuring that students remain motivated to write in their journals. Burton recommends that, if journals are to be evaluated with respect to style, students be given the opportunity to rewrite them before final submission.

These authors, with Jensen (1987) recommended that class time be given daily for writing in the journals, perhaps the last five to seven minutes of class time. The key seems to be not so much when the students are allowed to write, but that they be allowed an opportunity to do so regularly.

The instructor always has the option of whether to read the journals. Some instructors have felt that journals were private and that they had no right to look in them. One of the foremost authorities on the keeping of journals, Fulwiler (1980), believed, however, that there were three good reasons why teachers should read students' journals. First, when students begin to keep journals, the teacher should read them in order to help the student expand the breadth and depth of the journal. Second, students will always be much
more convinced of the "worth" of journals if the teacher collects them and looks at them. Third, most students believe that since they are writing journals they should "count for something" (p. 18). Fulwiler recommended that teachers grade journals on the basis of number of pages completed, using this as the sole criterion upon which to base evaluation. Burton presented an entire grading scheme complete with five areas in which the journal could be evaluated, but Burton also recommended giving students a chance to rewrite their work.

Hahrgang and Petersen (1986), in their mathematics classes at Michigan Technological University, incorporated academic journal writing into their classes in such a way that they were used to account for twenty percent of the student's grade. They were used in place of ten unannounced quizzes and given proportionate weighting in their grading scheme.

3. Personal Journals

While academic journals are used to help students process information from subject area material, personal journals are to help them gain insight into what is happening to themselves, to their own thoughts and feelings.

Personal journals serve a self-discovery purpose, getting writers to examine their own belief system, taking stock of the changes in their thinking, and forcing them to take a
critical look at their individual attitudes. This is done by having students reexamine their journals as written records kept from, perhaps, the beginning of the class until the time of examination. Personal journals can thus become a useful affective assist to students of mathematics, just as they have been for students in other content areas.

According to Fulwiler (1980), "Tasks such as these provide the students with the means to witness their own progress . . ." (p. 19). Fulwiler also recommended that teachers keep personal journals as records of what worked in class, what did not work, what could be done next week, what could be done with this class next year, and so on. If this were done at the time students wrote in their journals, it could be classified as a "participatory method," according to Krumm and Hanson (1984). The modeling provided by the teacher in keeping his/her personal journal in this fashion would certainly send a clear message to the student about the importance of writing as a learning tool.

4. Writing for Problem-Solving

Charles and Lester (1982), first defined a "problem" then illustrated six different types: drill exercise problems, simple translation problems, complex translation problems, process problems, applied problems, and puzzle problems. Mathematics provides a unique area in which to find
problem-solving situations that may be used to improve the thinking skills of students; problems of all six of these types may be found in quantity in the study of mathematics.

The topic of problem-solving and the activities associated with it have been much discussed in academic circles in the past few years, and deservedly so. Problem-solving has been identified both as a "complex thinking process" (Presseisen, 1985, p. 45) and as a "strategy of thinking" (Costa, 1985, p. 68). Many schools across the nation have become quite active in emphasizing problem-solving within and across their curriculums. For example, Cedar Falls High School in Cedar Falls, Iowa, has been awarded a special grant for its work in implementing a problem-solving component into its curriculum through its science and mathematics departments (Dotseth, 1985).

In addition to using mathematics for a problem-solving component of the curriculum, it is also possible to emphasize the use of writing as a problem-solving tool by using writing for problem-solving in mathematics classes. The reason this is valuable is that "They [students] use language patterns as organizers to draw together various aspects of their experiences" (Wirtz, 1985, p. 98). Students can, then, use writing to organize various aspects of the task at hand to their advantage. Writing as a means of recording language
patterns is invaluable, and writing, as noted earlier in this paper, also serves to help students record not only what they remember, but what they are thinking as well. As Dittmer (1986) said, "... writing is a means of knowing what we think, a means of shaping, clarifying, discovering and illuminating our thoughts" (p. 63).

These four, then, are some beginning activities that allow the use of writing as a learning and thinking tool across the curriculum. Once an instructor has experimented with them, they are potentially limitless in their capacity for expansion. The only restraints are those of good taste, common sense, and the instructor's imagination.

The Use of Writing in Mathematics Classes

For a mathematics teacher, like the author of this paper, the most intriguing aspect of using writing as a teaching, learning, and thinking tool is in its application to the mathematics classroom. There appear to be both potential advantages and disadvantages of incorporating this little-used method of learning in mathematics.

Advantages for Teacher and Learner

The advantages of using writing in the mathematics classes may be studied from two perspectives: First, what advantages does the use of writing in mathematics classes hold for the student? The first is that the use of writing gives students
a tool with which they can attempt to process the conceptual information that is being presented. They can use writing to put into their own words what each piece of material means to them, and they can refer to that record from time to time.

Another advantage of having used writing, in whatever form, is that students will be able to revise and rewrite their interpretations of concepts as their understanding of them matures and becomes more solidified. They may be able to pick out mistakes they have made and refine their knowledge of mathematical concepts as the classes they are taking reach each new plateau of understanding.

Closely related to these benefits is the opportunity the students have to conduct a "self-examination" of their mathematical knowledge by re-reading their own writings. Since they can see what their own weak points are, they will be able to approach the instructor with more specific questions that will allow both persons to be more efficient in identifying and prescribing remedial measures.

Yet another advantage of the use of writing in the mathematics classroom is that students will be able to examine their attitude about mathematics and perhaps discern whether it is helping or hindering them in their pursuit of learning. There may not be much one can do about a poor
attitude toward any subject, but often just knowing that one's attitude could be a problem can help that person.

There are also two major advantages that using writing as a teaching tool in mathematics classes hold for the instructor. One advantage is being able to use writing as a diagnostic tool. Through examining writing as a record of a student's thinking, it may be possible to determine what mistaken ideas about which specific concepts cloud a student's understanding of the overall picture in mathematics. Once that diagnosis has been made, valuable time in prescribing remedial activities to help that student get back on the right track can be saved.

Another advantage of using writing as a learning tool for the mathematics teacher is that he/she can keep his/her finger on the affective pulse of the student by examining samples of student writing after a particular class or at a particular time of the year. It is important to know when a particular topic or approach is becoming counter-productive so that one can make a change in the tactics of presentation and thus re-engage the student and perhaps the class.

Disadvantages for the Teacher and Learner

The adaptation of writing as a teaching and learning tool in mathematics classes holds disadvantages for both student and instructor as well. The biggest disadvantage
for students is that they will undoubtedly be forced to work harder and spend more time thinking than was formerly required. This will be true because in order to write, one must go through the stages of grasping the subject material: the enactive stage, the iconic stage, and (finally) the representative stage where the actual writing will take place.

This means that students will view writing as a great challenge, especially since most of them are not used to using writing in mathematics classes. (Even though this may be perceived as a disadvantage by students, it will in fact be an advantage of the greatest possible value.)

A disadvantage for teachers will be getting used to spending time deciding what the actual mechanics of the writing program will be. Questions like: Which types of activities will be used and when? Do I want to evaluate these activities? How will this evaluation be conducted? will need attention. There will also be an initial minimal increase in planning time (if a journal is not used) to phrase topics and questions and to anticipate possible answers.

The biggest disadvantage for the instructor will probably be the lack of understanding expressed by the student, and perhaps by the parents of the student. Both will probably wonder why writing is alleged to be so valuable in mathematics classes. This will, perhaps, be especially true in rural
regions where opinions about correct learning methods are
often viewed from a traditional perspective and are very
slowly and painfully changed. The teacher who incorporates
writing activities into his/her mathematics curriculum will
find it helpful if the entire group of "stockholders" in the
school is informed as to why writing is so valuable a learning
activity.

In spite of the disadvantages, incorporating writing
into the mathematics curriculum as a process tool appears to
be a very desirable goal for mathematics teachers.

As with any idea, the specifics of the operation and
philosophy must be thoroughly discussed with those
administrators, board members, and others whose unqualified
support one would need to get the process off the ground.
There seems to be a good possibility that many thinking
individuals, concerned about the quality of mathematics
education and the general education students receive, will
not be able to resist whole-heartedly endorsing the idea.

It may well be a difficult component of the curriculum
to design and implement, and substantial periods of
experimentation and adjustment will undoubtedly be needed,
but it seems apparent that the tremendous potential which
writing as a teaching tool holds for students and teachers
in mathematics classes far outweigh those difficulties.
References


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