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Integrating Writing To Improve Math Achievement

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Introduction

Can writing be used as a learning tool for students to improve math scores? As teachers of writing, we were aware of the impact that writing has on learning in the language arts field, but wondered whether the same would be true in other curricular areas. With increasing public pressure for accountability, strategies for improving student achievement in the core academic areas of reading, writing, mathematics, and science is critical. Especially in the areas of math and science where American students seem to fall behind the expectations of society, collaboration across curricular areas might be beneficial.

In states like Ohio, where state mandated competency tests are given, many teachers, schools, and districts feel the pressure to improve academic achievement in the assessed academic areas—Writing, Reading, Math, Citizenship, and Science. The Ohio Proficiency Test scores are used to rate the academic achievement of schools on the state mandated "School Report Card" issued to the public reporting the level of school and district success. Each school is rated "Effective," "Needs Continuous Improvement," "Academic Watch," or "Academic Emergency." In one area of the state, Southwest Ohio, only two public schools of the 59 in seven counties met standards for fourth grade math achievement according to the June 1998 "Report Card" issued by the Ohio Department of Education. As a general rule, the strongest single area of the "Report Card" is writing, while one of the weakest areas is math. Based on this, the question emerged: Could the use of writing, a stronger area of achievement, be used to improve math skills, the weakest area of achievement?

Background

In 1982, James Berlin examined some of the oldest teaching and learning theories known, including those of Aristotle and Plato. There are currently multiple theories of using writing as a tool for learning. The basic theories of Piaget and Vygotsky seemed to be the foundation for many of them. One of the most quoted contemporary "gurus" of writing is Janet Emig (1977) who describes writing as uniquely corresponding to powerful learning strategies. Of the four language processes (listening, talking, reading and writing), listening and reading are *receptive* functions, while speaking and writing are *productive* functions. Emig draws from many others, including Vygotsky, (1962) who stated that written speech is a separate linguistic function, differing from spoken language both in its structure and functioning. Bruner (1971) building on Vygotsky suggested three major ways with which "actuality" is represented and dealt: (1) enactive—learning by doing; (2) iconic—learning through images; and (3) representational or symbolic—learning by restatements. That is, "in enactive learning, the hand predominates; in iconic, the eye; and, in symbolic, the brain." Based on these theories, Emig (1977) suggested that since most learning occurs when it is re-enforced, then writing involving hand, eye, and brain marks a uniquely powerful mode for learning. Perhaps her most important argument for writing as a learning strategy/mode, however, was that writing is self-rhythmed—and that "one writes best as one learns best, at one's own pace . . . Writing can sponsor learning because it can match its pace" (12). Emig concluded by stating that writing is epigenetic, that is, it allows you to "see your thinking."

William F. Irmscher's (1979) clarified, supported, and reinforced the previous theorists by supporting the idea of writing producing "articulation of thought" because "it prods us to be explicit" and. "...places on us the ultimate demand for precise and accurate expression" (p.5). By suggesting that getting information is often acquiring unrelated facts, and that we cannot use unrelated facts not anchored to anything else also supports writing as a learning tool.

Archambeault (1991) lamented that many teachers, especially in math classrooms, reject the idea of writing across the curriculum. She states that since contemporary learning theory supports the use of writing as a cognitive tool to enhance retention and assist students to more completely understand abstract concepts it is unfortunate that most mathematics teachers fail to use writing. She focused on two specific aspects of learning theory which support writing as a tool for learning. First, the purposeful construction of mental connections between new and previous information and the active processing of the material. Having students write about content material is supported by these two theories, since writing requires a high level of information processing. Unless they are merely copying verbatim, they are translating information into their own words, making connections with previous information, and forming new contexts. "Writing is also the visualization of content material. The learner is not only making connections, but creating new connections while developing a personal organizational schema" (p. 3).

Detoye (1986) defined metacognition as "thinking about thinking" (p. 39). She recognized two types of metacognitive thoughts during learning and transfer: thoughts about what an individual knows, and thoughts about how one learns. She contended that writing is an easy and effective way to develop these skills. "Transfer of learning means simply that experience of performance on one task influences performance on some subsequent task" (p. 39). She suggested that transfer is not dependent on a simple formula, but rather by creative synthesis; further, language was the medium through which knowledge could be transferred from one situation to another, and are enhanced by the processing of information through an internal language. "Writing to learn is expressive, reflexive writing that occurs when one's mind *is engaged in choosing* words to express meaning. Writing to learn is learning to think on paper" (p.43).

Clark (1984), noting the need to improve writing in schools suggested that if teachers assign writing to reinforce the content, writing then becomes a natural part of the learning process. As students us writing to solve real learning problems, they will naturally improve writing skills as well. For reasons such as these, NCTE (National Council of Teachers of English, 1983) affirmed the position that students should write frequently in every course as a way of learning the subject matter and of sharpening their writing skills. Clark (1984) defined expressive writing as writing to figure things out, and an efficient tool for learning and thinking about content.

Applications of Writing to Improve Math Learning

A study conducted by Monroe and Pendergrass (1997), compared the effects of two models of vocabulary instruction: a definition only method (copy the definition from the dictionary and memorize it), and an integrated method combining a Concept Definition (CD) graphic organizer (which resembles a pre-writing web) with the Frayer model discussion model that builds on schema (Reutzel and Cooter, 1996). The combination of the CD and the Frayer model allowed for both oral and written discussion to take place during math instruction. The results showed that the CD-Frayer model was effective in increasing student use of math vocabulary.

Ehrich (1991) believed that students must have tools to promote the cognitive process, and that these tools should allow for communication of ideas from teacher to student, student to teacher, and student to self. Writing, she found, was one such tool. During her four-year research, she implemented five types of journal writing in her math classes. The first was process writing where students wrote in response to mathematical situations. The second was writing and cognitive dissonance, allowing students to begin to know what they know and believe by writing justifications for their answers. Third was writing for affirmation, for which students wrote about problems that they had already answered correctly. The fourth was writing and exploration that gave students the opportunity to solve unfamiliar problems by wandering freely to explore what they think and why. The fifth, Erich calls "aha" writing that allows ideas and concepts to appear spontaneously. Erich found writing promoted and supported cognitive processing by providing opportunities for diverse thinking.

In a study by Bell and Bell (1985) it was demonstrated that writing positively impacted student progress in problem solving. Using pretests and post-tests, two comparable Year 9 math classes were instructed in the same material. One class was taught using the traditional teacher-centered chalk-talk method. The other combined that method with structured expository writing. Students who found a specific problem easy would include in the process writing why they found it easy. For students who found it difficult, it became an opportunity to pinpoint the point of confusion. Four weeks after the study began, post-tests showed that the students using expository writing had better problem-solving skills. Miller (1992) documented how similar student writing also benefitted teachers by revealing how "first-year algebra students comprehended or misconstrued specific concepts and algorithms" (p. 3).

In response to resistance to writing across the curriculum, Kurfiss (1985) offered two alternative foundational propositions: (1) writing can help students learn and think about content in any discipline, and (2) writing used for learning does not require explicit *teaching* of writing, only *use* of writing. She also cited a study reported by Newell (1984) that college students who wrote short thought-question essays about content material demonstrated a more integrated concept of material and more complex and varied thought processes, including hypothesizing and evaluating.

Perhaps one of the more impressive studies was one conducted by Evans (1984) in which she examined the effect of writing in math class with 5th graders. In this quasi-experimental study, Evans used two fifth grade classes: one was instructed in math employing three types of writing and the other instructed using no additional writing. The initial class profiles, based on CTBS scores were the Test group (22 students) scored 55% in Computation and 54.2% in Total Math, while the Control group (23 students) scored 71.1% in Computation and 75.4% in Total Math.

The first type of writing done by the test group were explanations of how to do something (process writing) (Evans, 1984). The second type was definitions (creating their own) and the third type was "troubleshooting" where student had to explain specific errors on homework or quizzes which Evans found most enlightening because it informed her (teacher) who needed what help. The results indicated a significant difference in the performance for both multiplication and geometry tasks between the test and control groups. For both, the test group outperformed the control group and in observing individual scores, Evans found that students with the lowest pretest scores in the test group made the most gains.

Methodology

This study was designed to determine if writing, an identified stronger area of achievement on state-wide assessments, could be used to improve math, the weakest area of achievement on state-wide assessments. The purpose of this study was to determine whether summary, process, and analytical writing helped students better comprehend the concepts and procedures of high school geometry. The hypothesis that guided this study was that, even without assessment or instruction of writing skills, a systematic and regular use of writing during the math instruction of high school geometry, would result in increased math achievement as compared to the math achievement of students enrolled in the same course that receive the same instruction without the integration of such writing.

Population and sample

The population was high school (grades 9-12) students enrolled in mathematics courses. For this study, a convenience sample was drawn from a suburban Midwest high school, the only high school serving the district. The district serves one municipality and parts of another small city and a township. The ethnic composition of the school is 92% white, 5% black, 2% Asian and less than 1% American Indian, Hispanic, and multi-racial combined. The attainment of Bachelors Degrees or higher among all residents of the three municipalities is less than 25%. The median income of all households in the three municipalities is $31,114.

Two heterogeneous geometry classes of 21 and 22 students were selected for use in this study. Students enrolled in each section were randomly assigned. The classes were then randomly assigned to treatment groups. Course of study and material covered were the same in each section. Each had both genders, multiple grade and ability levels, and were taught by the same 14-year veteran teacher. Prior to the study, each class had completed approximately 75 per cent of the course curriculum. The classes met for 90 minutes per day, five days a week. The time period of the study was four weeks.

Design

This quasi-experimental study involved random selection of one class as the experimental group in which the only independent variable introduced was the use of the writing process by students. Students in the experimental group were given identical notebooks to use as journals. In these spiral-bound journals, the experimental group responded to the math instruction in three types of writing. During the four week study, students were asked to record three types of writing in their journals: 1) to summarize in their own words any instructional lecture given by the teacher; 2) to write a step-by-step process how to solve each of two example problems before attempting to actually solve them; and 3) to write an explanation/analysis of why they missed problems on homework, quizzes and tests. Using written summary of the instructional lecture was selected so that students would have to immediately recall, process, interpret, and paraphrase the new information received. The use of process writing to describe the step-by-step solution of sample problems was chosen to allow for the transfer and application of that new information. The written analysis of missed problems was implemented to point out areas (to both student and teacher) needing further clarification. This study did not address the variable of students' writing skills. There was no assessment of existing skills or instruction in summary, process, or analytical writing per se. The students were told simply to "Write a paragraph which summarizes today's lecture/ . . . describes step by step the process you will use to solve the sample problems/or . . . tells why you missed each problem." The control group proceeded with the previously established classroom and instructional procedures and routines typical of a math class.

Instrumentation

In preparation for the study, the classroom math teacher was given these instructions: "Following each lecture for the introduction of new material, have students write a paragraph summarizing, in their own words, the main points of the lecture. Prior to beginning homework assignments, have students write a paragraph describing the step-by-step process used to solve a sample problem. For problems missed on assignments, quizzes or tests, have students select representative problems and write an explanation/analysis of why they missed that problem." For this study, the teacher was asked to check that students were writing in their journals, for math/concept accuracy, but not for writing conventions. Students received no extra credit for keeping the journals.

The same teacher-created pretests and post-tests were used with both classes for each chapter. Chapter 11 covered the concept of area and Chapter 12 covered the concept of volume. The teacher had used these tests in previous years with similar students to assess knowledge, comprehension and application of the concepts. The teacher allowed students in the experimental group three to five minutes following instruction to write the entries in the journals. The type of writing was dependent on the day's activities; that is, they did summary writing if the teacher lectured, process writing if they were attempting to solve practice problems, and analysis writing after correcting homework or a quiz. During that time, she would check only to see that students were writing in their journals, answering questions and clarifying as needed. She did not read each journal entry, but at times would randomly check and read entries as she walked about the room as students were writing. Students in the control group were given this time (an additional 3-5 minutes) to work on practice problems related to the concepts taught.

Results

Because pretests and post-tests were used in existing, randomly chosen groups, analysis of covariance (ANCOVA) was used for data analysis to adjust for initial differences and compare adjusted scores. The probability level of .05 was selected for use in the study. Separate ANCOVAs were utilized for each chapter taught during the study.

Table 1

Group		Post-test Chapter 11	Pretest Chapter 11
A	Mean	18.1875	3.4375
	N	16	16
	Std. Deviation	7.5031	4.1788
	Minimum	3.00	.00
	Maximum	28.00	17.00
B	Mean	17.7778	4.2778
	N	18	18
	Std. Deviation	6.1219	5.3005
	Minimum	6.00	.00
	Maximum	28.00	23.00
Total	Mean	17.9706	3.8824
	N	34	34
	Std. Deviation	6.7036	4.7531
	Minimum	6.00	.00
	Maximum	28.00	23.00

Initial descriptive statistics indicated that scores for Chapter 11 pretests were lower for the experimental group (A) than those of the control group (B). Table 1 shows the mean for the chapter 11 pretest for the experimental group was 3.4375 and the standard deviation was 4.1788. The minimum score was 0.00 and the maximum 17.00. The control group on the same test scored a mean of 4.2778 and standard deviation of 5.3005, with minimum and maximum scores of 0.00 and 23.00, respectively.

Post-test scores for Chapter 11 show the experimental group (A) had a mean of 18.1875, standard deviation of 7.5031, minimum score of 3.00 and maximum score of 28.00, while the control group had a mean of 17.7778, a standard deviation of 7.5031, minimum score of 6.00 and maximum score of 28.00. Overall, the post-test scores for the experimental group (A) were higher than the control group (B).

Using the post-test for Chapter 11 as the dependent variable, the results of the ANCOVA are shown in Table 2.

Table 2

Source	df	Mean Square	F
Model	3	3800.722	111.066
PRETEST	1	420.715	12.294
GROUP	2	2295.945	67.093
Error	31	34.220	
Total	34		

R^2 = .915 (Adjusted R^2 = .907)

The F statistic of 67.093 exceeds the predetermined probability level of .05 ($p<.001$). Also, the adjusted R^2 = .907 shows that 91% of the difference in post-test scores are explained by the treatment (grouping). The null hypothesis using Chapter 11 pre-post-tests is rejected; therefore, students who receive math instruction which includes writing as a part of the regular instruction show greater achievement in the given area than students who receive the same instruction without the integration of writing.

Initial descriptive statistics indicate that scores for Chapter 12 pretests are lower for the experimental group than those of the control group. Table 3 shows the mean for the Chapter 12 pretest for the experimental group was 17.6111 and the standard deviation was 13.0165. The minimum score was 0.00 and the maximum 48.00. The control group on the same test scored a mean of 17.8947 and standard deviation of 19.3876, with minimum and maximum scores of 0.00 and 67.00, respectively.

Table 3

Group		Post-test Chapter 12	Pretest Chapter 12
A	Mean	56.2222	17.6111
	N	18	18
	Std. Deviation	31.9263	13.0165
	Minimum	7.00	.00
	Maximum	96.00	48.00
B	Mean	55.4000	17.8947
	N	20	19
	Std. Deviation	25.6380	19.3876
	Minimum	7.00	.00
	Maximum	98.00	67.00
Total	Mean	55.7895	17.7568
	N	38	37
	Std. Deviation	28.4217	16.3697
	Minimum	7.00	.00
	Maximum	98.00	67.00

Post-test scores for Chapter 12 show the experimental group (A) had a mean of 56.2222, standard deviation of 31.9863, minimum score of 7.00 and maximum score of 96.00, while the control group had a mean of 55.40000, a standard deviation of 25.6380, minimum score of 7.00 and maximum score of 98.00. Overall, the post-test scores for the experimental group (A) were higher than the control group (B).

Using the post-test for Chapter 12 as the dependent variable, the results of the ANCOVA are shown in Table 4. The F statistic of 68.784 exceeds the predetermined probability level of .05 ($p<.001$). Also, the adjusted R^2 = .846 shows that 85% of the difference in post-test scores are explained by the treatment (grouping). The null hypothesis using Chapter 12 pre-post-tests is rejected; therefore, students who receive math instruction which includes writing as a part of the regular instruction show greater achievement in the given area than students who receive the same instruction without the integration of writing.

Table 4

Source	df	Mean Square	F
Model	3	42143.453	68.784
PRETEST	1	8371.155	13.663
GROUP	2	13360.213	21.806
Error	34	612.695	
Total	37		

R^2 = .859 (Adjusted R^2 = .846)

Based on the results of this study, it can be concluded that the null hypothesis, the systematic and regular use of writing during the math instruction of high school geometry students will have no effect on their math achievement, is rejected. Students who receive math instruction that includes writing as a part of the regular instruction show greater achievement in the given area than students who receive the same instruction without the integration of writing.

Discussion

"A chain is only as strong as its weakest link" is an old adage. If American education were analogous with a chain, then, in fact, that weakest link would be math. State mandated assessments such as the Ohio Proficiency Tests reflect this notion. But it goes beyond one state. The Third International Math and Science Study (TIMSS) indicates the same. ("Pursuing Excellence," 1997). TIMSS is a 1995 assessment of the math and science performance of over 500,000 students in 41 countries at three different grade levels. This study showed that fourth grade students in the United States perform only slightly above the international average in math and science. More discouragingly, the TIMSS indicated that there is a drop from slightly above average at fourth grade to below average in both subjects in eighth grade and, at twelfth grade, U.S. students scored at or near the bottom in both subjects. (Jones, 1998). The study viewed the findings with regards to four topics: (1) curriculum and learning expectations; (2) teaching; (3) teachers' lives; and (4) students' lives. The U.S. Department of Education (1997) stated, "In the global economy of the Information Age, students will need to master the basic and advanced mathematics" (p. 5). It further states that students taking algebra, geometry, and other advanced courses in high school are more likely to go to college regardless of the income levels of the families. In the same publication, other findings indicated that 90% of new jobs created will require more than high school level math, while also showing that one of three job applicants currently lack math skills required for a job.

The TIMSS no doubt tugs at the pride of America. It should be regarded as a national embarrassment. Even more alarming, it is an indicator that we as a nation are looking at a generation who are deficient in the skill (math) that could effect our economy (production and work force), technology (development and implementation), and society (education and life-style).

Whether out of pride or practicality, schools are attempting to address the problem. In Ohio, like other states, schools are adjusting curricula to meet higher academic expectations in math as well as the other core areas. At least one district in Ohio proclaimed a district-wide "Year of Math Emphasis" in which each discipline was expected to increase achievement in its area as well as support math achievement with interdisciplinary references (Campbell, personal communication, August 24, 1998).

The TIMSS evaluation would suggest that we need to look at why our students are being outperformed by like students in other countries. As schools, we have control over the factors the TIMSS addresses. One factor—teaching—is addressed through this study. The cognitive processes used in writing to support concept learning facilitates students' use of critical thinking. The current study examined how writing effected students' ability to construct their own meaning from the math studied.

The results of this study indicated that the mere integration of journal writing to the instruction of geometry produced highly significant increases in the level of achievement of target concepts. It required no expensive materials, books, equipment, programs, or teacher training. It required no special student instruction. It simply took an existing skill (writing), at whatever level, and applied it as a tool for learning geometry. Many would agree that writing, whether notes from a lecture or a shopping list, aids in recall and memorization. But, the writing implemented for this study differed from standard note-taking. Words can be copied (from a visual aid or from a lecture verbatim) without comprehension or processing. The summary writing, process writing, and analysis writing implemented for this study used Bruner's (1971) three major ways to represent and deal with actuality: (1) enactive—learn by doing; (2) iconic - learn by depiction in an image; and (3) representational or symbolic - learn by restatement. Also Bruner's view that "if the most efficacious learning occurs when learning is re-enforced, then writing through its inherent re-enforcing cycle involving hand, eye, and brain marks a uniquely powerful multi-representational mode for learning" is supported by this study.

In this study, students had to intake information, process it, and restate it in their own words. They had to employ writing as Irmscher (1979) noted as "articulation of thought" because "it prods us to be explicit" and "...places on us the ultimate demand for precise and accurate expression" (p.5). They couldn't sleep, daydream, or ignore what they didn't understand, or assume they understood what they didn't. They couldn't allow the information to remain a vague, formless concept. The summary and restatement of the lecture forced them to form a sharp, focused concept or, made them (and/or the teacher) aware that the concept was not understood and that help was needed. This was an early indicator that allowed for almost immediate intervention. The process writing used for application of sample problems allowed students to apply the new information in an organized, logical, step-by-step manner. This helped them to think about *process* rather than hurrying through to reach p*roduct*. Again, this was an indicator that allowed for early intervention. And the written analysis of missed problems allowed students to identify problem areas on their own. Was the problem a *calculation* error or a *process* error? The analysis was yet another means for students to clarify and verify the material/concepts before moving on.

The results of this study supports initiation of other studies to replicate these findings not only in high school geometry, but in other areas of math, as well as other content disciplines and with other age levels. If writing supported student learning in geometry class, it is reasonable that the same would apply in most areas of learning. In fact, the idea for this particular study followed an assignment given by this researcher to students in a high school developmental writing course. The students were asked to write a *process paper* about using the *writing process*. They had to actually implement what they were writing about (pre-writing, drafting, revising, editing, and publishing), which served to reinforce, to make connections, and to clarify (to student and teacher) strengths and weaknesses regarding what was understood and mastered as well as what was not.

Future investigations may look at the effect of writing process instruction for both teachers and students on the achievement in the specific course/subject areas to which it was applied. It would also be interesting to determine if the increased writing in other content disciplines (as instructed) would increase the quality of the writing generally.

In states where high stakes assessment in areas like math are required and where the school districts and teachers are increasingly accountable for results, the conclusions from this study should stand out. Clearly, this strategy is one that teacher preparation should address with its prospective teachers and it is one that all districts and classroom teachers can readily apply.

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