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A Review of *Writing to Learn Mathematics and Science*, ed. Paul Connolly and Teresa Vilardi (Teachers College, Columbia University, New York and London: Teachers College Press, 1989) 307 pp., $32.95.

The essays collected in *Writing to Learn Mathematics and Science* present new ideas about how teachers are using writing to enable their students' conceptual learning in mathematics and science classes. Their students are not merely writing about topics in these disciplines; instead students are actually writing to learn mathematics and science. A number of features distinguish this book as practical and thought-provoking for writing teachers like me who'd like to affect our students beyond the freshman composition classroom, as well as for those of you who teach mathematics as one of the humanities. In the 23 essays collected here, not composition specialists, but mathematicians and scientists who have used it in their classrooms present the pedagogy of "writing to learn." Thirteen of the essays are by mathematicians who describe how they have used natural written language as an integral part of their teaching from the elementary to the college level. These teachers offer practical advice and examples of assignments that I believe you'll want to experiment with in courses at your institutions. Some assignments may resemble those you already use, and here you'll read the theories behind why they work and how they can be made to work even better. These teachers and their assignments show how the "writing across the curriculum" movement has affected mathematics programs across the country.

ABOUT THE EDITORS AND THE BOOK'S ORGANIZATION

Originating from the Institute for Writing and Thinking at Bard College, and co-edited by the Institute's director, Paul Connolly, and associate director, Teresa Vilardi, each essay in this volume shows how informal writing can transform passive students into active ones, able to understand, not copy, ideas conveyed in lectures and textbooks. Influenced by Bruner, Freire, Polya, and Vygotsky, these teachers offer practical ways to use ordinary language to enable conceptual learning in mathematics classrooms. Leon Botstein's foreword, Paul Connolly's introduction, and mathematics professor Barbara Rose's bibliographic essay provide background for the six parts of the collection:

1) Defining Problems, Seeing Possibilities
2) Writing as Problem Solving
3) Classroom Applications: What Works and How
4) Programmatic Policies and Practices
5) The Context of Learning
6) Responses to the collection as a whole from scholars Vera John-Steiner and Reuben Hersh.

JOHN DEWEY AND THE POLITICAL AGENDA OF "WRITING TO LEARN"

The "Foreword: The Ordinary Experience of Language," by Leon Botstein, President of Bard College, is well worth reading. There Botstein sets the political agenda for mathematics education as we head into the 21st century. He observes that as our passive, customary daily reliance on various technologies increases in the closing decades of the twentieth century, "the more distant and irrelevant the motivation to understand [mathematics and science] seems to have become" (xiv). This collection of essays, according to Botstein, goes a long way toward addressing this dilemma. Botstein notes how this collection is connected to John Dewey's appeal in *Experience and Education* (1938) to the role of "ordinary experience" in education because these essays "take language and writing . . . as elements of 'ordinary experience' that can be used to enhance the teaching of science and mathematics" (xii).

Further, understanding mathematics and science is becoming crucial to the enlightened political participation by all citizens which Dewey espoused. Perhaps the most grandiloquent claim Botstein makes for this volume follows here:

> The use of ordinary language can help break the cultural barriers that have prevented minorities and women from achieving well in proportionate numbers in these fields. By encouraging motivation and understanding through a method that connects the subject matter to the pupil's initial

frames of reference, the pedagogical strategies outlined in this volume can help rectify the distorted selection process within the school system through which a minority, mostly white males, emerges as sufficiently trained to consider careers in science and mathematics (xvi).

According to Botstein, then, this collection of original essays rests squarely in the progressive tradition: the authors combine faith in education with substantive expertise and the willingness to develop new pedagogical strategies.

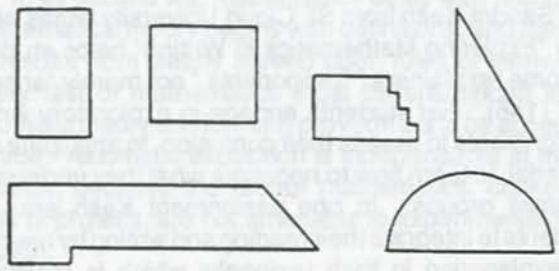
WRITTEN LANGUAGE: A HEURISTIC OF LEARNING

What do we mean by "writing to learn," "natural language," and "informal" writing? In the opening essay, Paul Connolly establishes the theoretical underpinnings of informal writing and "writing to learn" which mathematics teachers provide examples of in subsequent essays. Informal writing is done in and out of class to help students acquire ideas and concepts as their own. "Written language becomes . . . an invaluable heuristic of learning. It develops students' abilities (to read, define, hypothesize), inculcates methods (of problem solving), increases knowledge (particularly, metacognitive awareness), recognizes attitudes, and promotes collaboration" (11). For example, focused freewriting allows a student to begin exploring a term, issue, or problem. Metacognitive process writing helps the student to record her own learning behavior. Creating problems of his own rather than just answering others questions draws the student into the conversation of an expert community.

To give you a glimpse of what is possible in your classrooms, I'll tap the wealth of material from this collection that shows how informal writing meets cognitive and affective goals and enables theoretical mathematical understanding. Some examples I'll discuss apply the cognitive power of writing to conceptual learning. Others use journals to develop metacognitive awareness about the learning process. The contributors to this volume do not mandate these new approaches but they do encourage them, not just for non-technical majors but for the quantitatively adept as well. Still, they realize writing is not the panacea for all the problems that arise in teaching mathematics.

CLASSROOM APPLICATIONS: INFORMAL WRITING ENABLES PROBLEM SOLVING

In "Using Writing to Assist Learning in College Mathematics Classes," Marcia Birken describes the kinds of informal and formal writing her students do at Rochester Institute of Technology. She claims that by " . . . having my students learn mathematics through writing . . . I've learned a great deal about students' mathematical misconceptions, and I can usually pinpoint exactly where their thinking went wrong and help to redirect it" (41–42). Her in-class writing and homework assignments require students to interpret and analyze answers and to reflect on concepts. She responds to this writing and gives credit for it, but she does not grade it. Here's an informal writing assignment she calls the "Logical Order Question":



Instructions for Sheet 1. On this sheet of paper construct a geometric design using the six shapes given above. You must use all of the shapes, without repeating any shape, and keep their relative scale. You may turn, translate, rotate, reflect, or otherwise move the given shapes in any manner you feel satisfies your artistic desires.

Instructions for Sheet 2. On this sheet of paper write down, in English, the steps that are necessary to create your design. No drawing should take place on this sheet of paper — only instructions given in English sentences. Be explicit enough that someone else can follow your instructions and recreate your artistic masterpiece. (43)

Birken does grade essay questions on exams like this one that she asks in Calculus II: "We have just finished studying the Fundamental Theorem of Calculus. Write one to two paragraphs explaining why this theorem is so named and how it links the indefinite integral (antiderivative) and the definite integral" (44).

At Southern Connecticut State University and Colby College, William P. Berlinghoff helped non-technical majors to do "Locally Original Mathematics Through Writing." He has transformed such writing assignments as "Write about a famous mathematician or mathematical event" or "Report on an article" to emphasize the

". . . process of solving a particular problem or examining a particular mathematical object, a problem or object assigned to that student alone" (89). For example, to develop a mathematical way of thinking among non-science students, Berlinghoff assigned a mathematical research paper on numbers that involved original research and collaboration with the teacher. His students searched for patterns of numbers from a table they had made while they were learning prime factorization. The papers they wrote were descriptions of their investigations.

Sandra Keith from St. Cloud University writes about how "Exploring Mathematics in Writing" helps students become "explainers," "proponents," not merely "answerers" (146). Her students engage in exploratory writing assignments to assess their confusion, to anticipate new material, to learn how to negotiate what they understand in small groups. In one assignment Keith asks her students to integrate their reading and writing by rewriting an explanation in their textbooks which is difficult to understand. Unlike journal or process writing, her assignments introduce the idea of context and audience for writing. For example, students produce a "crib sheet" for a friend who is behind in the course or write the author of their book a critique of a section in a chapter.

One of the most persuasive cases for writing to learn is made in this volume by Arthur B. Powell and his student Jose A. Lopez. They report a case study for "Writing as a Vehicle to Learn Mathematics . . . " in Developmental Mathematics I at Rutgers University's Newark College of Arts and Sciences. Like many students in college today, the students in this course thought of mathematics as an "abstruse symbol system" and a "fixed body of knowledge whose secrets will not be revealed" (161). To promote critical reflection on mathematical experiences, Powell asked students to write daily in journals about any topic or questions related to their learning the math in the course and to the way they felt about it — a learning log. As you'll see from the excerpts of Jose Lopez's journal that Powell includes in this essay, the entries moved from summaries of class to personal reflection on learning math. They also revealed to Powell misconceptions and gaps in Lopez's understanding.

THE CONTEXT OF LEARNING

In Part V of *Writing to Learn Mathematics and Science*, Anneli Lax and the late Hassler Whitney are among those who claim that if mathematics education is to support risk, invite experiment, and allow error, students must be encouraged to use their own language to form their own understanding of mathematical concepts. This section of the volume is concerned less with techniques and assignments than with a philosophy of learning that recognizes the need to change what continues to happen in most math programs today.

In "On Preserving the Union of Numbers and Words: The Story of an Experiment," writing teacher Erika Duncan describes the benefits of combining math and writing which she and mathematics professor Anneli Lax discovered. On their way toward designing a math course for New York University freshmen who were not expected to be very good at math, Duncan and Lax held to their

> . . . shared belief that, as different as our disciplines might appear on the surface, in both, one must not think of fixed methods for finding the solutions to a given problem, but rather one must learn to conceptualize a wide variety of converging and diverging possibilities, forever being refined as each student let her or his own beginnings shape and set up logical boundaries for each new forward-reaching step (232).

Duncan and Lax encouraged oral discussion and collaboration which allowed students to hear the process of solving problems from "the first spoken conception to the present stage" (242). Students' mathematical autobiographies revealed their individual problem-solving methods. A composition about the virtues and drawbacks of open-endedness and imaging in math and writing led one of their students to the following reflection — a reflection which captures the shared message of all the essays in the volume:

> Open-endedness has the connotation of something being incomplete and therefore not finished. But open-endedness can also mean that there is space left for further questioning and stimulation of thought. . . . Images can be placed in people's minds, but will they incite a person to search for or create other images? (246)

I'm convinced by the testimony of these mathematics teachers and their students that had "writing to learn" been used in the mathematics classrooms of the '60's, I still might not be in a technical field today, but I would certainly be a mathematically literate citizen. As a writing specialist, I am encouraged that the math and science teachers who contributed to *Writing to Learn Mathematics and Science* believe all students can learn mathematical ways of thinking.