Contributions of Expository Writing to Numeric Communication:
Guidelines for Writing Up Word Problems

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ABSTRACT

Writing about numbers is a common task in a variety of fields, from describing relationships among variables in science lab reports, to characterizing election results or population trends in social science essays, to reporting on sports, the weather, or current events in journalism. Although many of the applications come from other disciplines, numeric communication involves several skills from English composition, including techniques for writing essays that incorporate numbers as evidence, use of rich vocabulary to portray the size and shape of numeric patterns, and analogies to convey relationships among variables. In this paper, I demonstrate a set of specific principles for writing about numbers, building upon skills that students have already learned in expository writing courses. This approach shows students how to write the answers to word problems – a fundamental skill that will help them in many types of writing tasks across the college curriculum and beyond.

INTRODUCTION

Writing about numbers is a very common task for college students, from characterizing election results or population trends in political science or history papers, to describing relationships among variables in biology or physics lab reports, to reporting on sports, the weather, or current events in journalism. These applications can be thought of as "word problems" in which numeric facts or calculations are used to answer real-world questions. Despite the fact that many of the examples come from other disciplines, unfortunately word problems *per se* are often relegated to mathematics and statistics courses, where the focus typically remains on the calculations involved, with little if any attention to effective communication of the results.

In books such as *Mathematics and Democracy: The Case for Quantitative Literacy* (2001) and *Achieving Quantitative Literacy: An Urgent Challenge for Higher Education* (2004), Steen and others writing for the National Council on Education and the Disciplines make a compelling argument for the importance of quantitative literacy in arenas ranging from personal finance to citizenship to health. Other books such as *Innumeracy: Mathematical Illiteracy and its Consequences* (Paulos 1996) and *Damned Lies and Statistics: Untangling Numbers from the Media, Politicians, and Activists* (Best 2001) demonstrate that many people emerge from school ill-equipped to apply quantitative literacy skills to the kinds of questions central to functioning in modern society.

Despite repeated documentation of innumeracy in the general population, communication of quantitative ideas is a neglected skill in most writing curricula. In this paper, I demonstrate several ways in which writing about numbers involves applying and adapting approaches learned in English composition courses. Foremost are basic expository writing skills such as introducing a question, writing paragraphs to organize evidence, and summarizing conclusions based on that evidence. Also important are exposure and practice using rich vocabulary, analogies, and metaphors to sketch a mental image of the shape of a numeric pattern.

Writing about numbers also involves learning a new set of principles related specifically to presentation of numeric evidence. Below I work through a series of principles for communicating quantitative information, starting with writing a sentence to report one number and progressing to comparison of two or more numbers. I then explain how to present and tie together several pieces of numeric evidence, which can enhance longer essays or essay questions, including those on the GRE Writing exams.

To illustrate these principles, I use a teaching device called "poor/better/best" which helps make abstract ideas concrete (author citation). After introducing an abstract principle such as "specify direction

and magnitude of an association," I illustrate it with samples of ineffective writing annotated to point out weaknesses, followed by concrete examples and explanations of improved presentation.

REPORTING A SINGLE NUMBER

The most basic skill in writing about numbers is reporting a single number. Context and units are essential elements of a sentence or paragraph about numbers, so the first set of principles defines those components and illustrates how to incorporate that information clearly and concisely into sentences.

Set the context

As in most narratives – fiction or nonfiction – an important part of writing about numbers is to set the context for each fact, conveying "who, what, when, and where." Without "the W's" as they are called in journalism, a number is seen in isolation, rendering it difficult to interpret that number or to compare it with other values. In social science papers, "who" usually specifies a demographic group such as males, children, or Latinos. In science applications, "who" might instead stand in for experimental conditions such as different growth media for plants. Each of the W's typically requires only a few words or a short phrase that often can be included in the topic sentence for a paragraph. "In the past decade," "on mainland China," and "among Democrats" are few examples. In the body of the paragraph, W's for individual facts or comparisons can be easily incorporated into the sentence with the numbers; see additional examples below.

The next two illustrations show poor and better ways to use a topic sentence to set the context and introduce the subject to be discussed later in the work.

Poor: [No introductory sentence.] "George W. Bush received 271 electoral votes while Al Gore received 266."

Comment: This version jumps directly to presenting data without orienting the audience to the topic and objectives, so it will be difficult for them to see what those numbers mean.

Better: "This paper relates to information about the 2000 U.S. Presidential election."

Comment: This version reports the W's (what, when, and where) but does not explain why the topic should be of interest to readers.

Best: "What made the 2000 U.S. Presidential election unusual? What brought about the recounting, Supreme Court involvement, and new voting technology?"

Comment: This introduction uses rhetorical questions to set the context and pique readers' interest in the rest of the essay.

Specify units of measurement

A second fundamental component of a sentence involving numbers is information about units. Students should learn to convey both the *system of measurement* and the *unit of observation*. For example, was height measured in metric (centimeters) or British (inches) units? Was income reported on a weekly, monthly, or annual basis?

Taken together, these two principles provide a mental checklist for planning or evaluating a sentence to report a number: "Who, what, when, where, and units." Consider the following sentences to report numeric evidence for the topic raised in the "Best" introductory sentence above.

Poor: "Bush got 271 while Gore got 266."

Comment: This sentence lacks information on what is being reported or the associated units, so it could be referring to number of campaign dollars collected, turnout at a political rally, or some other concept.

Better: "Bush won that election with 271 electoral votes against 266 for Gore."

Comment: This sentence specifies "who" (Bush and Gore), "what" (electoral votes), and the associated units. The context was already specified in the topic sentence, so the phrase "that

election" can be used to avoid repeating when, where, or the fact that the results pertain to the Presidential election. Additional evidentiary sentences would then report the results of the popular vote that generated the controversy (see below).

COMPARING TWO NUMBERS

Once students have mastered the art of reporting one number, the next step is learning to write sentences that compare two or more numbers. To write effective descriptions of numeric comparisons, they should go beyond merely reporting results of computations, also interpreting a numeric result in the context of the topic at hand, and using vocabulary and analogies to convey the shape of the pattern.

Report and interpret numeric values

As students present evidence to describe a pattern or to answer a question they have posed earlier in the paper, have them both report the raw data and interpret the statistics. *Reporting* the numbers is an important first step toward writing effective numeric descriptions. By including the numbers in the text, table or chart, they provide access to the raw data so readers will be able to see where the calculations came from or to compare the data with values for other times, places, or groups. *Interpreting* the meaning of those numbers or comparisons tells readers how those data answer the original word problem behind the history essay or laboratory report. In quantitative writing that involves many numbers, encourage students to state the question and explain the answer in prose, using an associated table or chart to hold specific detailed numbers to illustrate their assertions. See Miller (2004) for more on complementary use of text, tables, and charts.

Although it is important to interpret numeric comparisons, it is also essential to report the numbers. If students *only* describe a relative difference or percentage change, for example, they will have painted an incomplete picture. Consider a report that states that the ozone level is 40% greater than it was five years ago but does not report ozone values for either year. A 40% difference is consistent with many possible combinations: 0.001 and 0.0014 parts per million volume air concentration (ppm), or 0.500 and 0.700 ppm, or 2.00 and 2.80 ppm for example. The first pair of numbers suggests very low ozone concentrations, the last pair extremely high levels. Unless the ozone levels themselves are mentioned, readers can't determine whether ozone is within the safe range or has reached dangerously high exposure levels (Rasplicka undated). Moreover, they can't compare ozone data from other times or places.

Specify direction and magnitude of an association

A second important principle for interpreting numeric evidence involves conveying the direction and size of the difference between two values rather than merely reporting that they are different. In other words, *which value* is bigger (direction of the difference between values)? *How much* bigger (size of the difference between values)? Consider these sentences that continue a description of the controversial 2000 U.S. presidential election by providing information about the results of the popular vote.

Poor: "In the popular election, George W. Bush received 50,456,002 votes to 50,999,897 for Al Gore."

Comment: This version leaves it to readers to do the calculations themselves to figure out who won and by how much. Although the math (subtraction) is not difficult, making readers pause to do the calculation is an unnecessary tangent that detracts from the main narrative line of the piece. Teach students to write the answer to the word problem behind their calculation, rather than merely providing the raw data.

Better: "In contrast, Gore defeated Bush in the popular vote."

Comment: Now we know direction (who defeated whom) but not magnitude (how close the election was).

Best: "However, Gore won the national popular election by approximately half a million votes, with roughly 50.99 million votes compared to 50.46 million for Bush."

Comment: This sentence conveys both the direction and magnitude of the popular vote results, reports approximate vote counts for each candidate. If detailed tallies are needed, they could be shown in a small table accompanying the prose.

Calculations to express direction and magnitude

Not surprisingly, mathematical computations such as subtraction, division, or percentage change can be used to quantify the size of a difference between two numeric values. Although these calculations are usually mastered in the elementary grades, many writers of all ages have difficulty writing about the numeric results. See (author citation) for more suggestions about ways to write about the results of different types of numeric comparisons.

Vocabulary to express direction and magnitude

Another valuable tool kit for characterizing the shape of a numeric relationship includes rich, varied language, analogies, and metaphors. These approaches are less familiar to many people who write about numbers, but can substantially enhance the description of numeric patterns. Here are a couple of examples:

"In the 2000 Presidential election in Florida, Bush eked out a narrow victory over Gore."

Comment: The verb "eked" and the adjective "narrow" each communicate the closeness of the election.

"Patients given the placebo worsened rapidly over the course of the clinical trial, whereas those given Medication Q deteriorated more modestly."

Comment: The adverbs "rapidly" and "modestly" convey that health conditions of patients in the treatment and control groups progressed at different rates. In other words, the magnitude of change differs even though the direction of change is the same for both groups (both worsened).

Vocabulary can also be used to convey substantive aspects of the topic under study. For example, the word "sparse" communicates both the topic (density) and the level (low). Words such as "expensive," "majority," and "obese" also convey both the topic and approximate numeric value. Students should be encouraged to use topic-specific vocabulary to express numeric level rather than generic wording related to "high value" or "small number". This approach also provides an opportunity for students to integrate "GRE words" (e.g., sophisticated verbs, adverbs, and adjectives) into routine usage rather than simply memorizing them from flash cards.

Of course, science and mathematics have specialized vocabulary to describe associations between two variables. A *positive* or *direct* association means that as the value of one variable increases, the value of the other variable also increases, as in the relationship between temperature and pressure of a confined gas. A *negative* or *inverse* association means that as one variable increases, the other decreases, as in the relationship between educational attainment and unemployment. Parabolic, normal curve, sinusoid (or sine wave), and other well-known families of curve shapes from mathematics provide standard, familiar ways to describe patterns to readers familiar with that vocabulary.

Similes, analogies and metaphors to describe patterns and relationships

Similes, analogies and metaphors can also be used to paint a verbal picture of a pattern or a relationship between variables. For example, phrases such as "the J-shaped age pattern of mortality," or "the bell-curve IQ distribution" evoke images of the shape of a pattern that can then be fleshed out with illustrative numeric values. Descriptors such as "smile-shaped" or "rainbow shaped" provide a way to describe parabolic relationships to readers who aren't conversant with that mathematical moniker.

To explain a positive association to an unfamiliar audience, students can be taught to draw an analogy with a more familiar relationship such as how children's height and age move up together. To

remind readers of the shape of an inverse association, they could relate it to the relationship between higher prices and lower demand. Analogies and metaphors also can be used to explain more complicated patterns or relationships. Consider the following explanation of seasonal adjustment of employment rates, published in the business section of the *New York Times:*

> "Most of us routinely engage in a little seasonal adjustment of our own. Say, for example, you always put on five pounds between Dec. 1 and New Year's Day, and then work it off at the gym over the next six months. When you step on the scale on Jan. 1, you don't say 'Yikes! I'm turning into a blob.' You say 'Here we go again." But what if, one year, there were a sugar-plum shortage, and you gained only two pounds? You'd probably be relieved. But you'd be even happier if you used economics-style seasonal adjustments, because then you could claim that you actually *lost* three pounds. And so you would have, compared with what you usually weigh at that time of year." (Eaton 2002)

The fact that this illustration was published shortly after the winter holidays probably only increased its effectiveness.

By using such similes and analogies, students can learn to describe the overall shape of a pattern, rather than reporting a long series of individual numeric values or writing about several pairwise numeric comparisons. By observing and describing the big picture – the forest rather than every tree – students often have an easier time relating that pattern to the underlying relationship among the specific variables they are studying, reinforcing the substantive content of their subject matter.

Combining tools for describing patterns and associations

The most effective descriptions of numeric patterns combine vocabulary with numeric evidence. Those approaches reinforce one another and tap into different ways of explaining and visualizing patterns that will appeal to students (and readers) with varied strengths. Have students begin by painting a verbal picture of the shape of a relationship before they present any specific numeric values:

> "Last week was uniformly sweltering in New York City."

In subsequent sentences, they should then report numeric evidence to demonstrate that pattern and quantify the size of the difference or trend:

> "Daily high temperatures for the week were within three degrees of one another and averaged 95° F – more than ten degrees above normal."
>
> *<u>Comment</u>: The phrase "within three degrees of one another" illustrates the narrow range implied by the term "uniformly." The phrase "averaged 95° F – more than ten degrees above normal" documents that it was "sweltering."*

EXPOSITORY WRITING TECHNIQUES FOR ORGANIZING IDEAS

Writing about numbers is much like building a legal case or conducting a scientific investigation. The numbers are simply evidence for or against a particular point, and are integrated together to test a hypothesis or write a compelling description of a pattern (Miller 2006). Although students have been introduced to the idea of using quotations as evidence in essays for English composition, rarely have they been taught to think about using numeric data as evidence for history or science inquiries. They have been told to include data in their essays for political science essays or lab reports for science courses, but typically have not been given much guidance about how to do so in ways that answer the question underlying the assignment. For instance, they often include a trend graph in a history essay without describing the shape of the pattern or how it answers the question addressed in their essay. Or, when asked to report data in a lab report, students sometimes include a table of numbers but do not interpret them or show how they relate to the hypothesis for the associated experiment. If they include numbers in their prose description, students frequently type a "naked number" into a sentence without explaining why it is there or what it means. By doing so, they leave it for readers to figure out for themselves how the numbers answer the word problem that the assignment is intended to address.

Overcoming these problems involves applying a familiar approach from expository writing: Using paragraphs to organize ideas, with clear topic sentences to introduce the purpose of each paragraph – the question to be answered using the evidence presented in that paragraph. In English composition courses, students learn to write essays with thesis statements followed by textual evidence in the form of specific quotations from *Huckleberry Finn* or other literary works. Likewise, they should be taught to write topic sentences followed by numeric evidence for analytic essays about historical population trends or relationships between two or more variables in a science laboratory report.

To encourage application of these skills to writing about numbers, students should be shown how to adapt the standard essay structure taught in English composition courses to a research paper or laboratory report that includes numeric evidence. Although the exact structure varies somewhat across formats and disciplines, most formats include an introductory paragraph that presents the topic or question under study, several evidentiary paragraphs that report and interpret facts and patterns related to that question, and a concluding paragraph or section that explains how the body of evidence answers the question raised in the introduction. In the evidentiary paragraphs, students should be taught to refer to an accompanying table or chart that presents the full set of detailed numbers, using prose to describe the pattern and explain how it answers the question at hand. By organizing information into paragraphs, each of which addresses one aspect of the question, students can learn to maintain a clear, logical narrative about their topic.

For instance, a thorough discussion of gasoline prices in the United States might start with a paragraph on national trends in prices over the past few decades. A second paragraph might discuss the variation in gasoline prices by region and whether those geographic patterns have been consistent across time. Additional paragraphs could compare gasoline prices in the United States with those in Europe and other countries, and how those prices are affecting costs of other goods, consumer behavior, and gasoline supply. As they move from one topic to another, students should use topic sentences to introduce the subject matter in each paragraph before reporting and interpreting the associated numeric evidence. Transition sentences can then be used to guide readers from one major point (and paragraph) to another rather than stringing all of the information into one undifferentiated block of text.

> Poor*:* "In 2008, the price of gasoline topped $4.00 per gallon in the United States. Only ten years earlier, it cost just over $1.00 per gallon (Figure 1). Gas cost $0.20 more on the West Coast than in any other region of the U.S. (Table 1). In Europe gasoline is far more costly than in the United States. These costs affect costs of other goods because fuel is used in the production, storage, and shipping of many products.
>
> > *Comment: This description simply lists statistics from several different tables and charts without explaining how they relate to one another or how the statistics fit together to yield a comprehensive picture of why gasoline prices are an important issue in the U.S. today. By lumping all of these points into one paragraph, it does not provide enough time to shed enough light on the distinct points to be made about time trends, regional differences within the U.S., international comparison, and so forth.*
>
> Better: [Transition sentence from a paragraph describing national price trends to a paragraph describing regional patterns.] "As shown in Figure 1, gasoline prices roughly quadrupled in the United States between 1998 and 2008. Table 1 examines whether this time trend occurred in every region, and provides information to compare prices by region."
>
> > *Comment: By starting a new paragraph and section to present evidence on gasoline prices by geographic region, this version signals a second step in the investigation. The first sentence summarizes the conclusions of the preceding section (on average gasoline prices in the U.S.). The second sentence introduces a dimension –region – to be considered in a further dissection of the national pattern. Subheadings such as "Trends in gasoline prices," and "Variation in gasoline prices by region" could be used to provide further guidance through the different parts of the analysis.*

SUMMARY

This paper has shown the many ways that expository writing techniques can contribute to improving communication of quantitative information across the wide range of fields that involve numeric evidence. To convey numeric facts and patterns clearly and precisely, students should be taught to build upon what they already know about structuring effective essays to present evidence. They should also be encouraged to use vocabulary and analogies to provide a thorough description of a numeric pattern. With the addition of a few basic principles that pertain specifically to reporting and interpreting numbers, students can learn to write more compelling, precise descriptions of numeric patterns, whether in a science laboratory report, a social science essay, or a journalism assignment.

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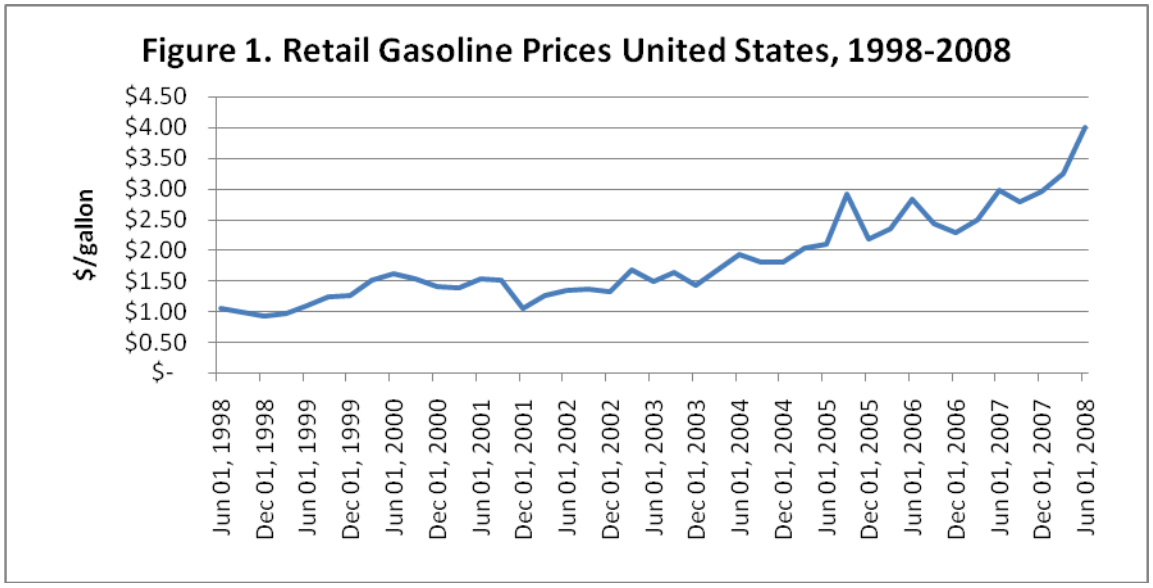

Table 1. Gasoline prices ($ per gallon) in the U.S. by region, 1998, 2003, and 2008			
	June 1998	June 2003	June 2008
United States	$1.05	$1.48	$4.01
East Coast	$1.01	$1.44	$4.03
Midwest	$1.06	$1.51	$3.98
Gulf Coast	$1.00	$1.40	$3.94
Rocky Mountain	$1.16	$1.51	$3.99
West Coast	$1.16	$1.66	$4.24