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Using Writing to Improve Student Learning of Statistics

Robert Hayden

This paper discusses student writing assignments (and my goals for same) in Math 230, Introduction to Statistics, and Math 330, Applied Statistics Using the Computer. What I have done can most readily be extended to other courses in which mathematics is applied to the world around us. It can less readily be extended to courses in pure mathematics or to courses that stress computational techniques or algebraic manipulations.

I want to begin with some discussion of the reasons why I feel a need for writing assignments. This is as much directed at those already convinced of the importance of Writing Across the Curriculum as it is at those who are unconvinced. In talking with the unconvinced, I often find disagreements about the goals and nature of education to be the key differences. Even among the convinced, different sources of conviction lead to different writing assignments with different goals. By making my goals explicit, I hope to stimulate interest among the unconvinced and reflection among the convinced.

Let me tell you about the experience that first showed me the need for student writing in applied statistics. I had written an

examination question that required my students to do a hypothesis test. It ended with a poorly worded question that students interpreted in a variety of ways. Some simply provided the results of their calculations along with a number they had extracted from a statistical table. Others included some jargon about "rejecting the null hypothesis" while others stated a conclusion in more practical terms such as "the tested drug is probably more effective than the standard treatment." Some students provided two or even all three of these responses. In fact, all three constitute restatements of a single fact in different language. Unfortunately, I found little or no correlation between the different answers of students who gave multiple answers. If the numbers clearly indicated that the null hypothesis should be rejected or the treatment declared effective, students were just as likely to say the opposite.

Reflecting on my students' answers, I reached a number of conclusions.

1. Since their final conclusions were no better than what they might have reached via a simple coin toss, all the complex computations I had taught them were of no real value.

2. My students' lack of understanding was mostly no fault of their own. Their textbook spent pages and pages showing them worked examples of how to do the computations, but far less space discussing what the computations meant. Exercises asked them to perform computations but rarely asked them to explain their results. Nor were they ever required to select an appropriate technique. The appropriate technique was alwayswhatever technique was described most recently. This led to some serious thought about what my students needed to learn in a statistics course, and how I might help them to learn those things.

I next asked myself what my students were likely to need to do with statistics after graduation. I tried to order these needs on the basis of how many of my students might have them. I hope you will pardon my listing those needs here, because they are relevant to all kinds of "book learning."

1. Virtually all of my students would need to evaluate quantitative information presented to them in newspapers, at zoning board meetings, by their doctor, or by numerous other sources. These students need to know what a mean or a standard deviation is or means. They need to know the strengths and weaknesses of these numbers as summaries. They need a healthy skepticism toward quantitative claims.

2. A smaller group of my students would need to evaluate the meaning and propriety of more technical statistical tech niques that might be used by researchers in their own field.

3. A still smaller group of my students might need to evaluate statistical work done by subordinates or provided by consultants.

4. A very small group of my students might actually carry out a statistical study themselves. These students would certainly need to know how to pick an appropriate technique. They would almost certainly use a computer to carry out the mechanics of data storage, editing, and analysis.

5. An even smaller number of my students might one day need to carry out a large scale statistical study while stranded on a desert island, or at a remote wilderness loca tion, or in some other situation in which a computer would be unavailable. These students would need to know how to perform the computations by hand.

If we look at most statistics books, and most statistics courses, we find them organized as if my last group of students were the norm. Indeed, the whole pyramid is inverted. Few textbook problems deal with meaning or interpretation rather than computational technique.

So, I resolved to try to spend more time on meaning, evaluation, and interpretation. However, my new found idealism was tempered by a basic fact of schooling: the students won't learn anything that does not appear on the exams. The simple conclusion is that questions involving meaning, evaluation, and interpretation must appear on the exams. Once we reach this conclusion, the need for writing is obvious: the answers to questions of meaning, evaluation, and interpretation are verbal, not numeric. Thus writing becomes not just another subject to teach, nor even a tool for achieving traditional goals, but rather a necessary path to developing higher-level quantitative skills.

These, then, are the values and experiences that have shaped my interest in Writing Across the Curriculum. Let me now deal with some of the practical problems of implementation. The most important piece of advice is: **start slow**. Your students have had an average of 14 years of experience with teachers who preached the importance of higher level skills but tested only on memorization and manipulative skills. Your best sermons will therefore have no effect, and your students will all fail that first exam when you ask them all those questions exercising skills they have never developed. You will become discouraged, curse their stupidity and your own idealism (how silly at your age!), and return to rote drill. Actually your students can do far more than you imagine, but they need your help. There follows some advice on providing that help. Bear in mind that it is based on all of the above. If your reasons for using writing assignments differ from mine, you may prefer a different approach.

The first thing you need to change is your teaching. De-emphasize mechanics. Assign only enough computational problems to get the ideas across. Keep the numbers **very** simple. Encourage the use of calculators or computers for any computations beyond the bare minimum needed to grasp the concepts. Spend lots of class time on interpretation and meaning.

Next, **provide sample test questions**! This communicates the nature of your expectations and the fact that you are not kidding. Once you have taught the course this way a few times, you will have a bank of old exams. Share them freely. Let students see for themselves that you really do ask embarrassing questions on exams. Distribute these old exams well in advance. Students cannot change their study habits the night before an exam. Indeed, you will find that they will initially, but very strongly, resist changing their study habits at all. There really is not much you can do about that except to fail those who do not perform at the level you desire. Things will improve as word gets around and students enter your class with expectations already tempered by your reputation.

Then there is the matter of writing exam questions. Start small. Problem 1 on Exam 1 should not be

> Compare and contrast the methods, assumptions, uses, and histories of parametric and nonparametric statistical techniques, giving special attention to their impact on the methodology of the social sciences.

A more reasonable start might be

> For the data 3,1,4,1,21, find the mean, mode and median. Which of these would best summarize this data? Why?

Since I am hoping that many of my readers **do not** teach statistics,

I do not want to give a large number of statistical examples. The principles should be clear.

Keep in mind that the main goal is to force the students to think. Forcing them to write is just a tool, a way to hold them accountable for thought. You do not have to make them write a lot of words as long as you get them to think a lot of thoughts. One-sentence answers may meet your goals. Also keep in mind that reading and writing may often be interchanged. Instead of asking students

Find the slope in y=2x+3.

Or even

Interpret the slope in y=2x+3.

You might ask

How much does y change for a unit increase in x when y=2x+3?

Now the answer is a single number—much easier to grade than a student written sentence or a paragraph on the subject.

Sometimes teachers are discouraged by the quality of writing they get or discouraged from asking for writing by fears of what they might get. In my experience, lack of mastery of subject matter will far outweigh any writing flaws. Indeed, you may discover that your students know far less than you thought about the meaning of those numbers you taught them to calculate. This can be taken as a sign of either the futility or the importance of your work, depending on your outlook on life. You should work on teaching your discipline until the content of the answers is better than the expression. In the process, you will find that the expression improves by itself. No one communicates well when they have not

the faintest idea what they are talking about.

Yet another issue is grading student writing. Here my solution is as simple as it is radical: don't. I grade them only on such knowledge of statistics as they are able to communicate to me. As long as their mastery of the mechanics is good enough so I can understand what they are saying, they can get full credit. The only grammatical advice I ever give is, "Never start your first sentence with a pronoun." Many of my students are as anxious about grammar and punctuation as they are about statistics. For better or worse, I try to handle things so they never notice they are in a "W" course. My exams are meant to reflect what statistics is all about, not to reflect what writing is all about.

However, there are some things on the border line between statistics and rhetoric that I do take into account. I prefer short, direct answers. (Often students are amazed at how short an answer I will accept.) Ambiguity or vagueness is taken as a sign of uncertainty and costs points. So do irrelevancies. I insist that students read the question carefully and stick to it. Indeed, the biggest problem I find (other than lack of knowledge of statistics) is failure to answer the question asked. This, of course, is a problem of thought rather than syntax.

I have been writing as if all the writing I require is on exams. That is very nearly true. Remember that I am trying to find ways to get students to think and ways to hold them accountable for thinking, and exams are the ultimate accountant. I have experimented with projects where students analyze a set of data and write up a report, but I have not had a great deal of success with this. Just worrying about what the numbers mean is a wrenching change for many students. Asking them to consider the meaning of dozens of numbers and integrate them into a report is really too much to ask. Perhaps this will change as other instructors, especially those

in the high schools and grade schools, start to emphasize meaning and interpretation.

Perhaps I should close with some sort of "evaluation" of the success of what I have been doing. This is impossible. I have no idea of what students thought a standard deviation meant before I started asking them. Based on their answers during the brief transition period, before they expected such questions on exams, my suspicion is that it never dawned on them that a standard deviation **had** a meaning. It was just a cue-word used to Pavlovically stimulate a certain computation. On the other hand, I have often noticed that mathematicians and statisticians are among those **least** compelled to quantify everything, perhaps precisely because they **do** know the meanings of numbers—which entails knowing which numbers are meaningless. For me it is enough that today much of my students' attention is directed toward the parts of statistics that I consider most worth knowing. A decade ago almost all their attention was devoted to the parts least worth knowing. I cannot quantify that change, but I can tell you it is a very important change, and a change that could only have been brought about by making students write.