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Creating a Critical Thinking Learning Environment: Teaching Statistics to Social Science Undergraduates[1]

Allan B. McBride, *University of Southern Mississippi*

Analytic thinking skills are highly prized in academia, and yet there is speculation and some evidence that such skills are in decline among contemporary students. The putative decline has been attributed to, among other things, too much television viewing and the wider availability of post-secondary education. Whatever the cause, faculty members at secondary and undergraduate institutions of learning are quick to point to an inability of students to perform well on tasks that require such skills. A recent article in *PS* (Hoefler 1994) argues that political scientists have been slow to embrace teaching methods that address these deficiencies and that they should begin to give greater attention to the issue of critical and analytic thinking.

One set of educators (Whimbey and Lochhead 1986) has gone beyond complaints to offer some very specific suggestions to faculty members to help them challenge their students to improve their thinking ability as well as their performance on standardized tests. Whimbey and Lochhead's work on problem solving and comprehension, which comprise integral components of analytic thinking, includes several concrete methods that they report are used by good problem solvers—maintaining a positive attitude toward problem solving, being concerned with accuracy, breaking complex problems down into parts, avoiding guessing, and being active in the problem solving process (26–27).

The first two methods are largely psychological, requiring the problem solver to be convinced that the problem can be solved and to recognize the importance of understanding the facts and relationships in the problem fully and accurately. A key to the second recommendation, according to Whimbey and Lochhead, is fastidious reading and rereading of relevant materials.

Reading is such an important activity that they devote an entire chapter to it and note six myths that are often associated with reading. High on the list of reading myths is the myth that reading aloud, or even moving your lips as you read, is a habit that good readers reject. In fact, Whimbey and Lochhead assert that reading aloud and subvocalizing are important to comprehending challenging material. The remaining myths that the authors attack are a reflection of their aim to encourage reading practices that result in greater comprehension rather than greater speed in reading (137–40). For example, among these they note that the superior problem solver reads carefully and slowly while focussing on challenging words and words that are central to the meaning of the text.

As a faculty member in political science who has borne the primary responsibility for teaching research methods, statistics, and computer-based data analysis for both undergraduate and graduate students in our program, I have been interested in developing some approaches to teaching that would

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help students in this critical area. Therefore I have adopted Whimbey and Lochhead's suggestions in combination with the data analysis approach known as exploratory data analysis (EDA), to help students in undergraduate statistics classes develop better critical thinking skills.

EDA is an approach to data analysis that makes very few assumptions about the nature of the data. In particular, EDA avoids assuming that a data set is normally distributed, and uses a series of graphic presentations (histograms, stem and leaf displays, and box and whiskers) alongside the more customary summary statistics such as the mean, median, standard deviation, and pseudo-standard deviation to determine if a data set is symmetrical and normal (Hamilton 1990a). Hamilton's text is an excellent guide to both this data analysis approach and to teaching introductory and advanced statistics as well.

The Experiment

The course in which I used these two approaches is a required undergraduate elementary statistics course for social science majors at an HBCU (historically black college or university) in north Louisiana. The university is an open admissions college, and, while most of our students are state residents, we also have a relatively large proportion from other states (particularly California, Illinois, and Michigan). The students in the experimental class, held in the spring of 1994, were political science, psychology, geography, and nursing majors. The average GPA for students in the course was 2.84, with a range of 2.17 to 3.92. The average ACT score for students was 16.75, with a range of 12 to 24. The low ACT scores are a reflection of the open admissions status of the university.

At the beginning of the semester, students were introduced to the subject matter of the course, as they would be in any class of this nature. In addition, in both class presentation, and in the syllabus, several recommendations were made to help the students improve their study habits. Among these I emphasized the importance of class attendance, and the virtues of punctuality. I also gave them the following suggestions:

1. Maintain a positive attitude toward your work. People who excel at solving problems, such as those that we will be working on this semester, believe that reasoning problems can be solved through careful persistent analysis.
2. Read slowly and carefully. We will be reading materials that use a vocabulary that will be unfamiliar to most of you. There is evidence that *reading out loud* can be of considerable assistance to comprehension. Write down complex pieces of information in some kind of organized manner to help keep track of it.
3. Be concerned with accuracy. Make sure you understand the basic facts in a problem fully and completely.
4. Break problems down into manageable parts.
5. Avoid guessing. Don't jump to conclusions. Make sure you check any intuitive leaps.

Periodically throughout the semester I reviewed these suggestions, especially prior to exams, and during administration of exams. I think that it is important to note that I see it as my role as an instructor to make every effort to maintain a positive attitude with the students and to provide as much encouragement as is practical. At the same time, it is one of my enduring goals to challenge my students with difficult material.

At the beginning of the second week I administered a critical thinking test (students were advised that this test was not for credit) developed and validated by Whimbey. The Whimbey Analytical Skills Inventory (WASI) pretest is composed of word problems, progressive geometric shapes, word comparisons, and number progression problems. The math problems require only rudimentary mathematical skills while the rest of the problems can be resolved by careful reading and appraisal. The tests were scored, but students were given no feedback concerning their performance.

After the first week and after the administration of the pretest, class time was divided into two types of periods. The first consisted of relatively straightforward lecture material during which time I would introduce the statistical concepts with which we would work—such as spread, dispersion, center, and shape—as well as the techniques that we would use to measure these concepts. During the second type of class period we devoted our efforts to solving problems (the problems that we solved in the classroom were in addition to those that students were assigned as traditional homework problems). Using a technique suggested by Whimbey, students worked in pairs; the pairs were determined by the students' scores on the pretest with weaker students being paired with stronger students to solve textbook problems. The goal of work pairs is to help students clearly identify and spell out the steps that are necessary to solving specific types of statistical problems.

For example, the computational formula for the standard deviation includes two terms, ΣX^2 and $(\Sigma X)^2$, which, though they appear similar to students, require distinctive steps for their completion. The weaker student of the two was given the task of working through such a problem by telling his or her "pair" exactly what steps to perform to solve the similar yet distinctive elements of the standard deviation formula. The "pair" followed these instructions as closely as possible, making suggestions only as necessary. The task of directing a fellow student engaged the weaker student in the process more directly than merely reading about the material or having the instructor lecture about it. It did this by allowing the student to vocalize the steps necessary to solve the problem while a colleague and the instructor were present to offer suggestions. Students also found it less intimidating and were more willing to take a chance of making a mistake with one of their class-

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mates than they were in situations where the faculty member was watching closely. The more traditional approach of sending students to the blackboard to solve problems, though it is not without virtue, suffers to the extent that it puts the student in the uncomfortable position of working directly in front of the instructor.

The roles can be reversed, allowing the stronger member of the pair to demonstrate how the problem might be solved. The critical elements of pairing the students include the direct engagement of the student in the learning process, which can be done while the instructor is available for guidance, and the opportunity to clearly identify steps and techniques that are beneficial for problem solving. At the outset of the semester I devoted one class per week to this active teaching style, though as we advanced to more complex materials, this approach was used in as many as half of the class periods.

When the time for the first exam arrived, students were advised to prepare for what may be called a performance based exam. In place of the normal "find the solution to this formula" and "define these terms," students were given a small data set (usually no more than 50 cases; aggregated data from the American states or cities works well here) and are instructed to analyze the data according to the techniques that we have used in the most recent portion of the semester. In order to facilitate this process I provided them with a list of techniques and procedures that they may use and the amount of points that each is worth, if correctly performed. I normally included more in the list than could be feasibly completed in an hour exam, so that they may have some choice. I channeled them to certain choices by making the most important procedures worth the most and making it impossible for the students to avoid those options. Students were informed that they could perform only sufficient procedures to reach a maximum potential point level (usually 50 potential points for the procedures they choose).

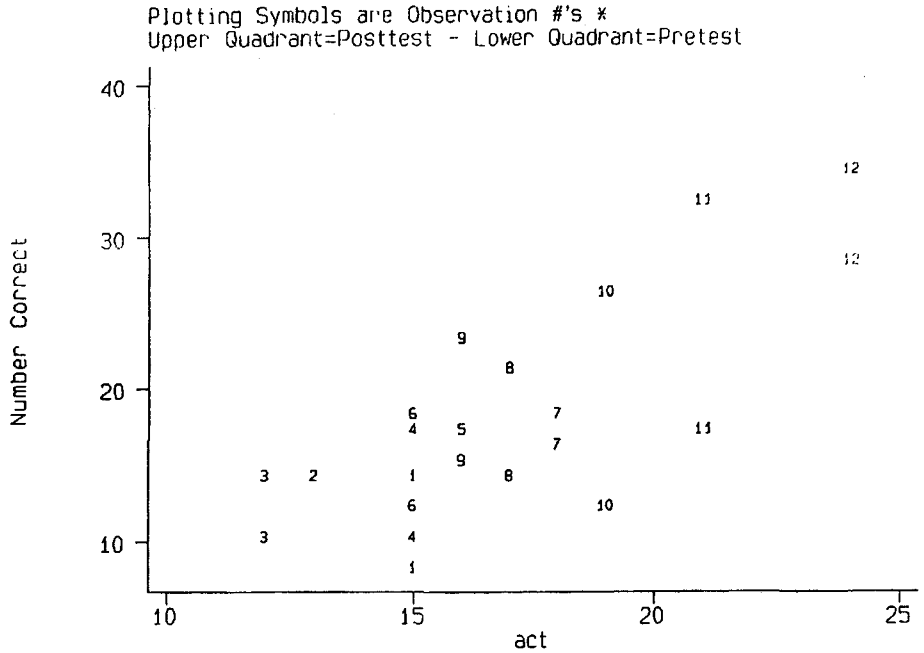
In the second part of the exam they were expected to explain their findings, and justify the use of the procedures that they chose, using criteria such as the shape of the distribution and the level of measurement (which are important elements in applying exploratory data analysis procedures). While this section was worth fewer points (normally about 20–30 points), it was critical for those who wished to score well on the exam. Perfect performance on the data analysis stage, combined with no points in the discussion section, would have resulted in only a minimum "C" for the exam.

. . . I see it as my role as an instructor to make every effort to maintain a positive attitude with the students and to provide as much encouragement as is practicable.

I did allow our students to use their textbooks on the exams, though this is a matter for the individual instructor to decide. My justification for open book (though not open note) exams was that it required students to become familiar with their text as a reference. It is my sense that if I had required a closed book exam most of the students in my classes would try to pass the course with minimal reliance upon the text. This strategy may not be as useful in other settings. However, most data analysis that I perform personally has been supported by such reference materials. In my most recent offering of this course, for the comprehensive final exam two students had used "postits" to identify important pages in the text, indicating to me that they had expended a lot of effort to prepare for the exam and in the process had become more familiar with the text.

Early in the semester I introduced the students to a statistical software package that we used throughout the semester. The package that I use, STATA, is EDA appropriate, user friendly, has an excellent student guide, and makes good use of realistic data sets (Hamilton uses STATA as well; he is the author of the student guide on STATA, and many of the examples can be replicated on STATA since he includes many complete data sets in the text). Once I introduced the software, the students used it to enter small data sets from the textbook which were used in some of the homework assignments. The use of computers is a double-edged sword: it is a strain on students and instructor to learn new material, but students are increasingly expected to be familiar with software and its use upon graduation (Rogers and Manrique 1992). STATA is relatively easy to use and the output includes easily accessible graphs in addition to summary statistics. In EDA, pictures of the data are highly esteemed.

In order to encourage the students to relate the material in this course to other courses in their major, I required them to write a short research paper (3–5 pages of which at least 3 pages must be analytic text) using a data set of their choice. I encouraged them to select a data set that was relevant to a course in which they were currently enrolled and to incorporate the 3–5 page data analysis into papers for this other course. Data sets could be self-collected or students could draw upon sources such as government documents, statistical abstracts, or the popular media (for example, one student developed a data set from the annual publication of information about the Fortune 500). I was fortunate to have attended an NSF sponsored workshop on EDA technique. The instructors for that class provided participants with about 50 small data sets already formatted for STATA, which I made available to students in my statistics class. Data entry will require some individual assistance from the instructor, as data collected from sources such as abstracts and government documents may require some special organization.



Graph 1: Pretest and Posttest Scores by ACT Scores

* *Observations 2 and 5 did not take the pretest.* Stata™

In the research paper students were expected to develop a hypothesis based upon common sense or a theory from their discipline and to either formally test the hypothesis using the chi-square test or to test it more informally by the weight of the evidence. If the data did not conform to their expectations, I encouraged them to try to find alternative explanations of their findings.

It may become obvious that using such a direct and engaging style will result in less material being covered in a single semester, and this is a reasonable criticism. However, my goal as an instructor extends beyond the mere absorption of information; it is my intention to help these students develop an approach to learning and thinking that will benefit them far beyond a particular class.

Findings

How did the students fare as a result of the instructional procedures discussed above? I could provide the grade distribution for the course, but that would provide you with little more than information about my grading strategy. In order to evaluate their performance on a more reliable and valid measure, I concluded the course with the Whimbey Analytical Skills Inventory posttest. This test is valuable since it does not directly measure the statistical techniques that are learned in the class; rather it focuses on more general analytic skills and, according to Whimbey and Lochhead, is also a rough gauge of IQ. The WASI pretest and posttest use very similar, though not identical questions. I tested the difference between the student's mean scores on the pretest and the posttest (see Table 1).

As a class, there was an average improvement of 7.5 points between the pretest and posttest. This outcome was not the result of just a few students improving their scores dramatically while the rest only held their position; all of the students improved their scores on the posttest, including those who had scored well on the pretest (i.e. no "regression to the mean" effect). This is particularly relevant since the students had received no feedback on the first exam; the tests were separated by approximately 12 weeks minimizing the potential for a pretest effect. Furthermore, there was evidence that the students were willing to tackle more of the problems at the end of the semester than they had at the beginning of the semester (the mean number of problems attempted on the pretest was 25.6 out of 38; on the posttest the mean was 35.4 out of 38. The differences were statistically significant P(t) = .0007.). The greatest gains were made by students with higher ACT scores but all students benefitted (see Graph 1).

Conclusion

Several factors may contribute to the observed outcomes of the experiment, among these should be included the small class size, as well as potential effects resulting from the instructor's personal style, to the extent that my personal style may influence my students' learning patterns. While the informal nature of the experiment does not allow me to exclude these potential explanations, my own experience as a statistics instructor suggests that the method that I have described above was at least partially responsible for the outcomes.

Students who are given the opportunity to participate actively in the learning process made substantial gains, a finding that should not be surprising. Friere (1970) has advocated a more active role for the learner as did Maria Montessori.

TABLE 1

Variable	Observations	Mean	Standard Deviation
Pretest	10	14.2	5.63
Posttest	10	21.7	7.04
Difference	10	−7.5	4.06

H_0: Pretest − Posttest = 0 (paired data)
t = −5.84 with 9 d.f.
Pr > |t| = .0002

The Montessori teaching method, used most often in elementary and secondary education, is also based upon an action-oriented (not to mention sensorially based) curriculum, and it is an approach that is gaining popularity in public schools. If it is true that many contemporary college students have not achieved the highest level cognitive skills, it may be incumbent upon faculty to adjust their teaching to reflect that reality.

Note

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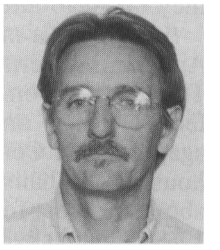
About the Author



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Where Does Policy Analysis Belong in the Undergraduate Public Administration Major?

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The practice of public policy analysis draws upon multiple disciplines and perspectives: analyses may rest on the methods and tools of economics, political science, operations research, history, sociology, and/or psychology, dealing with substantive issues across a wide realm. This type of multidisciplinary analysis and reporting requires a certain level of skill and experience. Perhaps this is why courses in policy analysis tend to appear in the curricula of graduate public administration programs more often than they do in undergraduate curricula.

In another vein, throughout the undergraduate curriculum, departments have been introducing senior capstone courses in recent years. For undergraduate programs in public administration, the idea of a senior-year capstone course is appropriate, but schools need not create new courses solely for this purpose. Undergraduate PA programs would do well to require a rigorous course in public policy analysis. Such a course has an appropriate place in the core of a PA program and is also well suited to serve as an integrating experience for students nearing completion of the PA program.

Swain (1993) has made the case that policy analysis should be the vehicle for integrating public policy into the graduate public administration curriculum. I submit that policy analysis can integrate the component parts of the undergraduate major and be considered as a candidate for a capstone course.

Policy Analysis and Public Administration

The origins of policy analysis and of public policy as a field of study may evoke some unpleasant memories for public administration scholars.

Indeed, a conspicuous element of the public policy movement was its explicit rejection of public administration. The founders of the new programs gave intellectual reasons for this decision: public administration was descriptive rather than prescriptive, it was preoccupied by institutions rather than choice and action, it wore the blinders of a single discipline (political science) and was lacking in interdisciplinary vision. But the reasons were in fact political as well as intellectual (Stokes 1986).

Ironically, as public policy curricula have evolved, they increasingly have included institutional analysis. Similarly, policy evaluation and policy analysis have become increasingly important in the practice of public administration. In part, this may reflect the prominence of the administrative rationality paradigm of organization. The attempts to rationalize policy making using techniques drawn from various disciplines, and to study

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