Teaching Students Objective Skills To Master Science and Science Writings

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A decade of classroom experience and sitting as chair or a member of the advisory committees of numerous graduate students has led me to an alarming conclusion: if an article appears in print in a scientific journal or periodical, most undergraduate and graduate students believe that the information therein, data and conclusions, can be and should be accepted as valid. Even students with some degree of research experience are reluctant or unable to examine critically what is written. "If it appears in print it must be true!" is a common implied attitude of students.

Over the past three years I have addressed this problem in an entomology pest management class comprised about equally of graduate and undergraduate students. The objective of this activity is not directly to make better writers of students (Cobia 1986), although such may occur, but rather to cause students to consider science and science writing in a more objective fashion, and to read from a somewhat skeptical viewpoint, i.e. a null hypothesis attitude. My purpose is to get the students to examine critically the motivation, hypothesis, methods, results, and conclusions drawn by an author(s), knowing full well the article is written to support a specific viewpoint, and that for them the unavailability of the raw data may be a problem. Ironically, students undertake this activity with considerable suspicion and skepticism, questioning my motives and the value of the activity. By the time we've finished the activity, most students have a positive opinion of the activity and my reasons for undertaking it.

The Activity

Because this class in integrated pest management has students from several academic departments, entomology, weed science, agronomy, etc., it is easy to draw on information from all of these areas to support discussion. Most of the students have a working knowledge of statistics, but those who don't, have not been at a great disadvantage. I begin the activity by discussing the history and evolution of scientific thought, methodology, and publication (Mayr 1982, McCain and Segal 1982, Chalmers 1982). This includes examples of science conducted in various countries and periods of history and its support or attack by other scientists, political powers, or religious leaders. Examples of such are numerous and serve to put the pursuit of science in perspective. Suspecting that at that time students will not have time to read it but perhaps will find it of interest later, I recommend they read *The Origin* (Stone 1980) to see the contemporary scientific community's examination, criticism, and vilification of Darwin's research and conclusions. Also I recommend Barnes' (1985) *About Science*, Goran's (1974) *Science and Anti-Science*, and *The Game of Science* (McCain and Segal 1982).

The image of the scientist and the ethics of scientific professionals causes considerable class interchange. We discuss the portrayal of scientists in films and on television. If it does not arise in the discussion, I point out that today there is increased awareness of science (Culliton 1987b), a need to understand science (Miller 1984), and a responsibility of scientists to communicate effectively to the public (Gastel 1983). Classroom interaction usually concurs that there is considerable concern over the ethics of scientists because of a) the changing expectations (demands?) of the public (society) of the accountability of scientists; b) the changing or additional role of the scientist from researcher to policy advisor; c) the emerging role of government into public policy based on scientific (or lack thereof) research, e.g. agrichemical regulation based on "carcinogenic" versus "oncogenic" potential. Students are encouraged to suggest and discuss areas of consumer demands to be informed, consulted, and/or protected concerning the impact of scientific activity in the area of the environment, health, and occupational safety.

The need for professional ethics by the scientist (and other professionals and nonprofessionals) is introduced, and a definition of ethics proposed as

> **"...those principles (rules of conduct) that are intended to define the rights and responsibilities of scientists and engineers (and other professionals) in their relationship with each other and with other parties including employers, research subjects, clients, students, etc.," (Chalk et al 1980).**

Students are assigned to bring to class the ethics statements from their academic disciplines' professional societies, accompanied by the investigative and enforcement mechanisms for alleged violations. Those without professional attachment are assigned groups such as the American Medical Assn., American Bar Assn., and other well-known professional societies. Copies of published articles alleging violations of ethical standards are distributed, and we discuss possible motivations and implications of the violations. Methods of detecting violations and scientific fraud are considered (Wheeler 1987). With the recent publicity of such activity, it has been easy to be timely with such articles (Holden 1987a, 1987b, Crawford 1987).

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Of particular interest to the graduate students is the perceived "publish or perish" syndrome and the role it has played in the demise of scientific integrity (Culliton 1987a). At this point the instructor must be prepared to discuss the written and/or unwritten policy of his or her own university as well as others concerning research and publication and the role it plays in promotion, tenure, and salary decisions.

All this leads into the foundations of scientific research including data collection, deductive, and inductive reasoning (Hill 1985), and the purposes and uses of statistical science. For this I've found of value the introductions to Green (1979) (and particularly his *Ten Principles),* Little and Hills (1978), and Pearce (1983).

I give the students a copy of a published research article dealing with insect control or pest management, often from a less well known periodical, with the author, title, publication identity, statistical significance indicators, and discussion of the results and conclusions omitted. I ask that they write an explanation of what the tabular information says, and draw conclusions from it. They are referred to Day's "How to Write and Publish a Scientific Paper" (1983), particularly chapters one, eight, nine, and sixteen. I tell them that it is sometimes necessary to make histograms or graphs in order to better visualize effects of treatments, and that they should pay particular attention to several items: were controls adequate in number and how they were treated; do data seem to be internally consistent. A particularly good paper by Simon (1980) is used in this regard.

Students are allowed to work together in whatever group size they wish, but are asked not to solicit opinions from faculty for fear of getting misimpressions because of faculty bias. Care must be taken in the selection of the article that the tabular information gives sufficient information from which to draw conclusions, but is not so obvious as to be non thought provoking. A short one or two page paper is best.

During the next class meeting opinions are sought as to results and conclusions to be drawn, problems with the methodology, or presentation of the data. They are asked to suggest an appropriate title for the article. I then give them a copy of the original paper and the author(s) conclusions are then presented along with statistical significance indicators. We discuss problems such as worst-case situations, unjustified extrapolation of data, loss summation, and selective data use (Turpin and York 1981), as well the impact of sample size and number, and apparent differences versus statistical differences.

The procedure is then repeated with a longer or more difficult paper. With the third paper they are asked to individually and without initial consultation to write a "Conclusions" section as well as an "Abstract" for the paper (Cremmins 1982). I do suggest, however, that it is appropriate and advisable to have a fellow student review the paper before it is turned in, and incorporate the reviewer's suggestions if appropriate. In the future I plan to give additional credit for peer reviewed papers. After collecting the assignment, I distribute copies of the original article and discuss it. Suggesting students make a copy of their paper before turning it in facilitates discussion as each can see what he or she wrote as we discuss the paper.

One piece has been missing that I plan to include: the "moderately" bad unpublished piece, or the "really" bad unpublished paper. Pride prevents me from using one of my own rejected articles as one always believes it can be massaged to a publishable state. I have therefore written under a pseudonymn an article "submitted for publication" which will be given to the students for their critical review. Hopefully, they will be able to detect errors of methodology, inference, and fact.

This has been a successful and worthwhile activity. I conduct it very early in the semester and the enthusiastic discussion helps to set the climate for the rest of the semester. I have found the time this activity takes to be most productive in creating an atmosphere of inquiry and discussion. It causes students to examine values and motivation of theirs and of scientists in "the real world." It does not give them many answers, but it does give them food for thought and perhaps guidelines for professionalism.

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Testing and Student Aggression

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Test scores are important to students because these scores are often the major determinant of course grades. There is an implied and generally accepted contract between teachers and students that the tests will be representative of materials reflecting the purposes of the course and that the tests will be developed, administered, and graded fairly. In those cases in which there is an actual or perceived material departure from this implied contract, students may take issue with it (Poppen and Thompson). Since this contract itself is often implied, the procedures to deal with perceived breaches are not well understood; hence, students may react to perceived breaches in an aggressive, even hostile manner.

Student aggression is a frequently observed, but an undesired and unintended outcome of classroom testing. Few, if any, faculty members have ever completed a teaching career, having escaped with no battle scars resulting from attacks by students frustrated with testing procedures and test scores. Young as well as older teachers are potential targets for these frustrated students; none are exempt. While the potential for student aggression exists for all teachers, many experienced teachers have learned through trial and error how to avoid many situations that might result in student frustration and aggression (Bernstein).

The basic premise of this paper is that student aggression related to classroom testing can be reduced if not avoided altogether by properly constructing, administering, and grading tests (Saigh, Shiram). The overall objective of this paper is to address improved testing techniques to avoid student aggression. More specifically, the paper will (a) identify student characteristics that are related to aggression, (b) identify testing situations that are related to aggression, and (c) present basic concepts and operational procedures to improve teaching and testing methods and thereby avoid student aggression.

Conceptual Framework for Improved Testing

The teaching-learning-evaluation process is an interrelated process involving numerous components. In its simplest form, this process involves (1) setting instructional objectives, (2) assessing student needs, (3) offering relevant instruction, (4) testing and evaluating intended outcomes, and (5) using evaluation results to improve instruction and learning (Gronlund). Having identified these basic components, it is clear that difficulties could arise in any of these areas. Several of these components are discussed briefly before turning to testing and evaluation.

Instructional objectives identify the expected learning outcomes, i.e. the intended student performance at the end of the instructional period. The more information contained in the objectives the greater the students' chances of achieving these objectives. The objectives are to be used to direct student learning and testing and evaluation of learning process. Stated objectives should include all important objectives for the course and should be realistically attainable in terms of the students' backgrounds, abilities and overall workloads and the time available for the course.

Validity

The major reason to test students is to evaluate their progress in learning. Learning progress is measured through evaluation techniques by the extent to which students individually achieve instructional objectives. Hence test instruments should be closely related to instructional objectives. A test would be considered valid only if it matched course objectives. Validity can be defined as the accuracy with which the test measures what it is **intended** to measure (Ebel, p. 444). A test's validity can be evaluated by determining whether the items on a test are related to the topics that should be included, whether they adequately cover the relevant topics, and whether the balance among topics is appropriate (Hills, p. 11).

Validity of the test is influenced by the test itself as well as how the test is administered and scored. The following factors can prevent the test from functioning as intended and reduce its validity: unclear directions, inappropriate level of difficulty of test items, ambiguity, and poorly constructed test items (Gronlund, pp. 79-80). Factors in administration and scoring of a test that would reduce its validity would include providing insufficient time to complete the test, providing unfair help to some students, and inconsistent scoring.

Reliability

Measurement of educational achievement is subject to inevitable errors, related to the sample of questions used, anxiety, fatigue, etc. (Ebel, p. 407).

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