Some Suggestions for Teaching the Sciences

To be blunt, many of us are lousy teachers, and our efforts to improve are feeble. So students frequently view statistics as the worst course taken in college.
Hogg, R.V. (1991), "Statistical Education: Improvements are Badly Needed," *The American Statistician*, 45, 342-343.

According to the Fall 2006 NEA Higher Educational Journal, a survey of professors at the University of Nebraska showed that 94% of them thought that they were better than average teachers. In fact, many teachers at the college and university level have had little preparation for teaching. About the only advice I was given was "don't have sex with your students." Many of us try to teach like a mentor or favorite instructor, and learn on the job. I received very low evaluations from my students the first time I taught.

An analogy could be made with doctors, administrators and politicians. Medicine can be and often has been greatly improved by eliminating the worst practices (bleeding patients, transferring dirty bandages from patients who have died to new arrivals, et cetera), and by using statistics to determine which practices work.

Once established, teachers and doctors (as well as administrators and politicians) receive little feedback from their colleagues on their techniques, and often do not know that their techniques are substandard or unethical. A data base on standard techniques for the most used procedures would be useful. The tenured faculty within science departments need to do a much better job in preparing untenured faculty and graduate students for teaching.

There are several terrible teaching practices that should be avoided. See i) through iii). Some good practices are A) through P).

A) Keep conversations with students fairly professional.

i) Making your students uncomfortable by being unprofessional is bad: in particular, do not flirt with any of your students.

ii) Do not provide almost all of the points for the course after the midsemester drop date.

B) Give assignments, tests, and/or midterms worth at least a total of 30% of the grade before the midsemester drop date as well as after the drop date.

One would hope that the personnel committee would give very low teaching evaluations to instructors who fail to meet this practice.

At SIU, we have received email asking us to give assignments before the drop date and stating that not everyone does so. Near the turn of the century, a webpage for Intro Calculus showed that the instructor was giving "practice exams and homework" that were worth no points, then 4 midterms during the two weeks before the final. This section did terrible on the combined final.

C) Return homework and/or midterms within one week.

Failure to return assignments in a timely manner is epidemic in some departments. I took the two course sequence in Probability and Measure at the University of Illinois where no homework was given because the class was too large. The problem was epidemic among statisticians at NIU where often the homework was never returned. A terrible instructor asked me to remind him when to come to class, and he came to class every time except the one day when I could not find him. He gave no assignments at all except that 2 students had to give a talk. I think that I was the only student to give him a bad evaluation. The instructor gave everyone in the class a B so that he would not be thought an "easy grader" by the personnel committee. One associate professor, who was a good teacher when I got my MS at NIU, had learned from the long term faculty not to give back homework by the time I attended the NIU PhD program. At SIU, I have had the very alarming experience of students thanking me for returning assignments quickly.

D) Do not use a text that is too hard for the class.

This can be a huge problem if done for a core course or a course that prepares students for a qualifying exam.

For example, the Statistical Inference qual at the University of Illinois is a year long sequence from Casella and Berger: *Statistical Inference*, or Bickel and Doksum *Mathematical Statistics*, and Lehmann *Theory of Point Estimation*. These books do not need Probability and Measure as a prerequisite. One year a professor decided that Inference should be taught with Probability and Measure as a prerequisite. The students did poorly and the professor left U of I and so did not write the qual. Two good students failed the qual 2 times and would have lost their positions if they failed a third time. I lent them my solutions to old quals and they passed and now have PhDs. The professor should have taught the course at the appropriate level. Then Inference with Probability and Measure as a prerequisite would have made a great advanced topics course.

Similarly, Royden *Real Analysis* is crucial material for many Math and Statistics departments. Generally Math departments will also have at least one course that has Royden as a prerequisite, say Freedman *Foundations of Modern Analysis*. Replacing Royden by Freedman could be very harmful. Teach Royden, then try to attract students into the course that uses Freedman.

E) Do not cover too much material in a core course.

Core courses are taught by many people and over the years a good syllabus for the course should have been developed. For example, finishing the Intro Calculus syllabus material by midsemester and then covering Intermediate Calculus the 2nd half of the semester is harmful. Teach Intro Calculus during Intro Calculus and Intermediate Calculus during Intermediate Calculus!

F) Be aware of the prerequisites of the course.

At the University of Illinois, I was having problems with Probability and Measure (the instructor was not giving homework!), and I was asked to take the proficiency exam for the prerequisite. Both the Math department and the Stat department offered to give the exam, so I took both. The math departments exam was easy and at the level of the

prerequisite (Ross *Elementary Analysis*). The exam by the Stat department was at a much higher level (Royden), and I would not be surprised if I flunked it. Probability and Measure should have Royden as a prerequisite.

G) Do not give unreasonable qualifying exams.

I once had 2 hours to take a Probability and Measure qualifying exam that had been a take home exam (about 40 hours) the previous time the instructor had taught the course! I actually passed (I had not taken the course from the instructor), but my brain was so worn out that I could not remember the gamma distribution and failed the Inference qual that was given immediately afterwards.

Being able to read and understand a clever solution does not mean that you or the students can come up with the clever solution in a reasonable amount of time. Such problems are memorization problems. One professor was prone to give such problems from Lehmann on the Inference qual. I gave some students old quals and told them to memorize my solutions to the problems from Lehmann, and a record number of MS students passed.

The worst way to write qualifying exams is to have one professor write them. The second worst way in to have two professors write them. The best way is to have everyone who teaches the qual course(s) regularly to contribute problems (this was done by the University of Minnesota Statistics department). Then fewer memorization problems occur and the variability of the difficulty of the exam is lowered. When one or two people write the exam, the level of difficulty can vary greatly.

H) If you announce that you are giving in class exams, do not make the in class exam into a take home exam at the end of the exam.

I was once taking a massive work load, but if the instructor has graded the exams at the end of the exam, my scores would have had by far the highest scores. He kept making the exams take home at the end of the exam, and one student was able to get higher scores than me.

A simple model for student learning is that students learn from 1) the text, 2) the lecture and 3) the feedback received from assignments such as homework and exams.

Often the instructor can choose the text. Look at what instructors of similar courses have used. For example, Statlib (http://lib.stat.cmu.edu/) has a link to *Other places* that has links to webpages for Statistics departments throughout the US. Also, (www.amazon.com) has a link to *books* and then *Advanced search*. If you enter a title or subject, the search will return the best sellers at Amazon, as well as reviews. Often the two top sellers will be rather expensive, but sometimes cost effective alternative (e.g. from Dover) can be found. Cost effective texts may be reasonable if their quality is not much lower than that of the expensive "standard" best sellers.

If you use your own text or course notes, it should be reasonably priced and of good quality.

iii) Using a text that nearly no one uses (e.g. it was written by a mentor), is a bad idea if the text is poorly written.

A good text can go a long way to make up for a bad lecture.

The lecture needs to be organized, an instructor who is unorganized and puts part of his or her lecture in one corner of the board, another part in the middle and another part in another corner ("writes all over the board"), will likely be ineffective. If there is a left and right board, start from the top of the left board and work to the bottom. Then go to the top of the right board and work to the bottom. Then erase the left board and start at the top.

Using an outline can be effective. I number points from each chapter, say 1) to 30), and start with 1) when I go to the next chapter. I also use notation 1), 1)*, 1) know for exam or 1) know for final. The notation "1)" means that the point is not very important, "1)*" more important, "1) know for exam" means that it will be on the exam as well as quizzes and homework, while "1) know for final" means it will be on quizzes, homework exams and the final.

Also write a page number corresponding to the text for each point. Both you and the student will make transcription errors, and the student can more easily find the errors if they can find the material in the text. Also, as a student, I often could not follow what the instructor was doing while writing down notes. Afterwards I could usually figure out what was done. If you do a problem or example from the text, write down the problem or example number and the corresponding page.

As I write down the material, I also say what I am writing down out loud, since the students do not have x–ray vision and can't see what I write until I move out of the way.

I) If a student catches an error, correct the error and thank the student. Being horribly offended or denying that you made the error is ineffective.

I face the class and ask questions for the more important material.

J) If one student is doing all of the answering, say "someone else" or "I want the answer from the front two rows" of "from this side of the class."

Once in Intro Calc, a very weak student asked so many questions that I had to tell him that I could not answer all of his questions in class and still cover the material needed for the final. He would have to ask some of the questions outside of class.

Science professors do the worst on feedback. Often the only feedback from the instructor comes from 2 or 3 midterms, and often the majority of the feedback is obtained from the grader who sometimes is not an expert.

Teaching should be about students learning. I allow a sheet of notes for the quizzes. In my low level courses, I have had sections where many of the students do not study and fail to bring a sheet of notes. If I notice that many of the students are staring at the quiz with no idea how to do the problem, then I will put a similar problem on the board. If the section is very weak, I show a solved problem on the top of the quiz, and then give a similar problem on the lower half of the page. Based on the student performance on the combined final, this technique seems to "trick students into learning," but I do not like using the trick unless I am desperate.

If I have a grader, I have the grader grade the homework, but I grade 10 to 25 quizzes

per course as well as 3 or 4 midterms. (Lower level courses such as calculus and finite math get about 25 quizzes and 25 homeworks while higher level courses get about 11 of each. I rarely have a grader for higher level courses.)

K) When the student makes an error on the assignment that you grade, write in the answer. Rather rarely, if many students make the same error, I write the solution on the board or photocopy my solution and give it as a handout.

I can write in the answers for students of a 3 hour class if the class size is 30 or fewer. I can handle a 4 hour class of size 30 if I have a grader. Without a grader the work load becomes severe with more than 20 students.

When I taught a lecture of 120 students for noncalculus based statistics, my quizzes and exams were multiple choice. If the student got the wrong answer, then I would look at and correct the wrong work. I did not look at correctly answered questions.

Courses with common finals should include questions from old common finals on the exams. Courses for a qual should include questions from old quals. If the qual or common final does not allow notes, then I do not allow notes on the exams.

This feedback allows the student to learn what types of questions will be on the exam and can show the student that he or she has not yet learned the topic. The quizzes allow the instructor to find out when the majority of the students have not learned an important topic. If the majority of the students miss a quiz problem, then the instructor can work out the problem in class and do more examples. The feedback also makes it easier to write an exam that most of the students can finish.

When teaching is 50% of the researcher's workload, about 20 hours a week should be devoted to teaching, including the time lecturing, office hours, preparation and grading. Do not shirk on feedback to greatly reduce your teaching hours. Teaching 10 hours when you are paid for 20 is pathetic.

L) Learn your students names. Return assignments in alphabetical order.

I write each student's name on a sheet of paper (often right after they turn in a quiz or exam) along with something, (perhaps in code such as 'L' for long hair, or "like Azar" if the student reminds me of another student named Azar, or where or who by the student sits) to help remember the names.

M) When more than one student is present during office hours, rotate questions among the present students. Often more than one student will have the same question so this technique saves time! Also students will discuss the question, and some students will understand another student's explanation better than mine. Do not answer all of the questions of the first student, then all of the questions of the next student, et cetera.

N) Treat your graduate assistants fairly.

If you have a grader who is supposed to average 5 hours a week, try to have the grader average about 5 hours a week. I once had an instructor give me 10 hours a work when I was paid for 5 (and I was very fast so it would have been 20 for most graders), I balked at grading the last assignment because I needed to study for the qualifying exam and I wanted to let the professor know that I resented the work load. I was doing part

of the instructor's job and he was taking the money for it. It was a graduate course, and perhaps because I balked I was not asked to grade a graduate course again.

I worked in the consulting lab at NIU, and my supervisor gave me almost all of the student work, ignoring the other students (and he gave me the work unless he could solve the problem himself in a few minutes without a computer). The lab was just starting so I could do the work in a reasonable amount of time, but near the end of the semester I had several projects when a head of a department and a new member of the same department both came with problems. The head had a data set so large that I could not get it into the computer, so I told him that we would not charge him any money and told him where he could go on campus to get his data analyzed. He called my supervisor with numerous complaints and his junior colleague withdrew her project (which could have been done). I later wrote my supervisor a letter stating that he was not spreading the work. Then I went to talk to him and he said I was not doing all of the work (like I can't tell whether or not I did all of the work). Then he yelled at me to "get the hell out of his office." I got work reassigned outside of the consulting lab and my supervisor quit the next year since he no longer had me to run the lab for him.

O) When grading, consider grading problem 1 for everyone, then problem 2, et cetera instead of grading person 1's homework, then person 2's homework, et cetera. Grading by problem is faster because you memorize the answer. Also grading will be more consistent and it is easier to avoid hidden biases.

P) On homework collection days, before class ask students if they have questions and solve them, perhaps taking at most one question per student if there are many questions. This is like "extra office hour time" that helps a lot of students.