Preparing Graduate Students to Teach Statistics: Introduction

David S. Moore

Preparing graduate students to teach, first for assignment as teaching assistants but also because some will follow academic careers, is a major concern for mathematics and statistics departments. This article provides background and raises issues to keep in mind when reading the program descriptions in the articles that follow. Changing our understanding of what constitutes effective pedagogy, improving the use of technology, and placing an emphasis on working with data in elementary courses raise the standard that teaching assistants must meet. Many graduate students come from countries with cultures and education systems quite different from those in the United States. Training programs should themselves be models of good pedagogy.

KEY WORDS: Effective pedagogy; Teacher training.

1. INTRODUCTION

Graduate teaching assistants (TAs) play a major role in the teaching of statistics to undergraduates. Their presence is concentrated in first courses. The 2000 CBMS survey (Lutzer, Maxwell, and Rodi 2002) found that 21% of elementary statistics enrollment in Ph.D.-granting statistics departments and 24% in Ph.D.-granting mathematics departments was taught by TAs. More strikingly, TAs taught 43% of the enrollment in elementary statistics sections of less than 36 students and 53% of "statistics literacy" students in statistics departments. The role of TAs has decreased since the 1995 survey, perhaps a sign of increased concern about the quality of instruction, but clearly remains important.

Elementary courses are (certainly) harder to teach well and (arguably) more important to our field than more advanced courses. When Sir David Cox was asked what advice he would give to the chair of a new statistics department (Mehta 2004), he replied, "first the importance of aiming to make the first course in statistics that students receive of especially high quality and relevance." Many future users of statistics form their attitudes toward the subject in elementary courses. These courses are also a key recruiting ground for future statisticians among students who typically have little awareness of the discipline prior to being asked to take an introductory course. We ask TAs to staff a critical function.

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Another sign of increased concern about quality of instruction is growing attention to preparing TAs for their work as teachers, as well as near-universal screening of graduate students for language and teaching skills as a requirement for assignment to classroom duties. It should first of all be said that teaching is a *craft*, a collection of learned skills accompanied by experienced judgment (Moore 1995). Experience does build good judgment, but the craft can be learned by anyone. Competent teaching depends on this learned craft rather than the individual charisma or personality of the instructor. The issue before us is how to help graduate students learn the craft of teaching. The articles in this special section describe the training programs in place at several major statistics departments. This introductory essay provides general background and raises some issues.

2. HOW DO WE TEACH?

Thinking about preparing graduate students to teach ought to inspire reflection about how we teach elementary courses more generally. TAs operate within a framework established by the faculty of their department. If the framework is anachronistic, students will learn less well than we hope. The kind of pedagogy we employ in elementary courses, the use of technology, and the nature of the statistical content determine the goals of our programs for training TAs.

There is now good evidence that "active learning" strategies are superior to the "information transfer" model that underlies much traditional instruction. A distinguished group of scientists (Handelsman et al. 2004) recently urged all science disciplines to adopt evidence-based "scientific teaching" based on "teaching methods that have been systematically tested." The online supplement to their article contains much useful material.

Traditional teaching is primarily *presenting*, aimed at transferring information to students. The teacher's task is to manage the flow of information. The result is often a formal knowledge of facts and procedures divorced from intuition and from the student's knowledge of other subjects. Formal knowledge is fragile—students cannot solve problems formulated in unfamiliar ways and cannot apply the facts and procedures they have learned to higher-order tasks such as analyzing open-ended situations and solving problems that require several steps and selection from a wide body of available procedures. That is, teaching as information transfer tends to leave students with an algorithmic rather than a conceptual understanding.

The current understanding of effective teaching stresses that students are not empty memory arrays awaiting information transfer. They bring a complex mix of knowledge and intuition, both correct and incorrect. They learn by *their own activity*,

 DOI: 10.1198/000313005X20745

interpreting present experiences and integrating them with their existing understanding of their world. The teacher's task is to encourage and guide construction of correct statistical understanding. Telling by itself does not do this. Students must be active participants in learning. The teacher shapes an environment for learning through setting tasks, encouraging open discussion and group problem-solving, and insisting that students express clear conclusions from their work orally or in writing. (A number, a graph, or "reject H_0" is not a conclusion.) The teacher spends more time asking and showing and less time telling. An interactive classroom style is particularly important in statistics, where conceptual reasoning and interpretation as well as technique are central to analyzing data.

The point of this brief review of "scientific teaching" is that *the styles of teaching thought to be most effective place a greater burden on the instructor than simply presenting material*. Perhaps for this reason, university departments have not been enthusiastic about changing teaching methods. The 2000 CBMS survey found that only 25% of students taking elementary statistics in Ph.D.-granting statistics departments were given writing assignments, and only 16% did group projects. These percentages are comparable to those for Ph.D.-granting mathematics departments, but are roughly half those for elementary statistics taught in undergraduate college mathematics departments. If the combination of evidence for effectiveness and pressure to teach better results in more widespread use of new pedagogy, TAs must be trained to guide classroom discussions that emphasize interpreting real data in their context, to grade writing assignments, and to supervise group projects.

Statistics departments do better, but not well, in using technology: 61% of their elementary statistics students do computer assignments (versus only 48% in Ph.D.-granting mathematics departments). This percentage was unchanged between the 1995 and 2000 CBMS surveys. It is too low. It is almost essential that a relevant introduction to statistics incorporate use of statistical software, both to allow work with substantial real data and to form good habits of practice. Modern content greatly increases the need for adequate computing. This is true even if we avoid contemporary topics such as resampling methods and Bayesian inference. Effective exploratory analysis of data is in practice only feasible when graphics and calculations are automated. Even inference is in practice characterized by back-and-forth movement between data and models, with models providing a basis for inference and the data allowed to criticize and even falsify models via diagnostics. The modes of thinking needed for working statistics are quite different from the "derivations down from models" mode of mathematical statistics. These modes of thinking, and the tools that implement them, are best learned in the context of actually working with data. In the absence of adequate computing, a first course in statistics is in the nature of "dry swimming." The presence of adequate computing sets another goal for preparing instructors. No matter how clear the software menus may seem, students will encounter difficulties and ask unexpected questions. Instructors must be fully fluent in the course software, which will often not be the software that they themselves regularly use.

Even if the courses they will staff eschew explicit reform elements such as writing assignments and projects, we must prepare TAs to interact with students in the classroom, not simply to present material. Ask how each of the specific programs described in the following articles encourages interaction and equips inexperienced teachers to lead students who may themselves be reluctant to speak in class.

3. WHOM ARE WE TRAINING?

Graduate students at most universities are more diverse, and much more international, than undergraduate students. They come from all parts of the world and from all types of undergraduate institutions. The diversity of student backgrounds increases the challenge of planning effective preparation for teaching undergraduates whose view of the world may be somewhat constricted. Though what follows will concentrate on international students, American graduate students also encounter difficulties: I once heard a proper Bostonian (with regional accent to match) describe his struggles to make himself understood by students at a Southern college.

The most recent studies by the National Science Foundation tell us that 39% of graduate students in the mathematical sciences hold temporary visas (Thurgood 2004) and that 49% of Ph.D. degrees in mathematical and computer sciences are earned by foreign citizens (NSF 2002). There is some concern that post-9/11 security measures may reduce the "brain gain" that fuels American science, but it appears that the effect to date has been small (Mervis 2004). We can expect that a substantial proportion of our graduate students will continue to come from overseas, and that a majority of these will not have English as their first language. Teaching in a second language and in an unfamiliar culture is a challenge that few Americans would care to accept.

Language training per se is not a primary concern for mathematics or statistics departments, though we should be aware of the resources available at our universities. We might advise individual graduate students that, for example, a summer intensive English course may be essential preparation for teaching. We should also be aware that effective communication does not rest on language fluency alone. I have seen an Indian TA whose English was perfect fail in the classroom because he spoke very quickly and softly with non-American accent and usage. His students are still wondering what "dacoits" are. Dacoits aside, we had failed to teach him some basics of classroom presentation: slow down, project your voice, write main points on the blackboard, ask frequent questions. I have also seen a Chinese TA whose English was less perfect so inspire students with his enthusiasm and obvious concern that they sent a delegation to the department head to praise him.

Cultural differences *are* part of our concern. University students in many other nations are assumed to have met in secondary school much of the material taught in the first year or two of American university curricula. Student preparation and motivation at many American universities may therefore appear substandard to international graduate students. American undergraduates are in general not as self-reliant as university students in other countries. They expect to be told exactly what is expected of them, to be given clear rules, to have the course material explained to them in detail. The informality of American culture carries over into the classroom. American linguistic provincialism is notorious. We must prepare international TAs for all of this, and show them some specific ways to cope.

We must also consider that the undergraduate academic experience of international students often differs substantially from the experience we want them to provide for our undergraduates. They may be accustomed to the "information transfer" model and sufficiently able and self-reliant to find it acceptable. In developing nations, and even in overcrowded European universities, information transfer is favored because it requires fewer resources than more interactive teaching. For example, Park Chan-mo, president of Pohang University of Science and Technology, remarks that most science programs in South Korean universities "tend to focus on book learning rather than more costly hands-on training" (Russell 2004). In statistics, this tendency takes the form of an overemphasis on the mathematical aspects of the subject at the expense of experience with data. That is, until their graduate studies have had an effect, the very conception of the nature of statistics held by international TAs may not match a contemporary elementary course. Because computing resources in particular are expensive, graduate students from developing countries may have little experience with computer use as a routine part of instruction.

The cultural and linguistic gap between international graduate students and American undergraduates certainly requires attention. Ask how each specific program approaches this issue.

4. WHAT SHOULD WE DO?

The following articles answer that question by example. Here are a few principles.

"Don't shield your eyes, plagiarize." Tom Lehrer's advice is too widely followed on campuses, but it legitimately applies to designing a program to prepare graduate students to teach. The quality improvement world uses the gentler word "benchmarking." The articles that follow describe several excellent programs: borrow from them. Borrow as well from the programs of other departments on your campus, which may be well attuned to local needs. For example, you will want to provide detailed written descriptions of university policies on such things as academic dishonesty, adding and dropping courses, and student evaluation of teaching. You may not need to write this yourself.

Follow good instructional practices. Graduate courses are often models of rapid information transfer. That's acceptable because graduate students are assumed to be mature enough to construct their own interactions, with text, lecture, and each other. Preparation for teaching undergraduates, however, should be a model of good pedagogy. Is the presentation highly interactive? Is there variety in the presentation, such as videos of classroom situations followed by discussion or a panel of senior TAs speaking from hard experience? Are participants required to actually prepare and conduct typical classroom sessions? Is there detailed feedback on trial performances, such as discussion by the entire group or videotaping that can point out specific strengths and weaknesses? Is assessment, perhaps including judgment as to whether and what a TA is prepared to teach, integrated into the training?

Good instruction includes a text component. TAs need written (or in some cases, online) material to study and to carry away with them. I have mentioned a compendium of your university and departmental policies. Discussions work best when the students have first studied a common text presentation. There are good resources available, so don't write an amateur account of the basic elements of teaching. My single favorite resource is *Tools for Teaching* (Davis 1993). The author, Barbara Gross Davis, is assistant vice provost for undergraduate education at the University of California, Berkeley. The 49 short chapters in this book offer clear, competent, and intensely practical advice on almost any topic connected with college teaching. These include all the traditional issues such as course syllabi and effective lecturing as well as newer concerns such as responding to diversity. The book even concludes with a chapter on writing letters of recommendation. Even very experienced teachers will find "nuggets" here. In evaluating any program, ask: what do students take away for later reference?

Process monitoring, continuing improvement. Do ask the students to evaluate your program and suggest improvements—after they have had some teaching experience for which the program did or did not adequately prepare them. Do include a strong component of regular monitoring and mentoring of new teachers. Don't wait for disastrous student evaluations. In the language of quality improvement, that's relying on final inspection of the finished product, and it is not good practice. Is the training program integrated with a program of later classroom visits by experienced teachers (perhaps including other TAs) and a plan for corrective action if needed? Are there regular group sessions at which TAs share concerns, ask questions, get help from their peers, and perhaps continue more formal training?

It hardly needs saying that the following articles are not entries in a "best TA prep" contest. Different approaches may be equally effective, good ideas are not necessarily all in the same package, and varied local environments require varied programs. Read and profit.

REFERENCES

Davis, B. G. (1993), *Tools for Teaching*, San Francisco: Jossey-Bass Publishers.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., Gentile, J., Lauffer, S., Stewart, J., Tilghman, S. M., and Wood, W. B. (2004), "Scientific Teaching," *Science*, 304, 521–522. For the online supplement, see www.sciencemag.org/cgi/content/full/304/5670/521/DC1.

Lutzer, D. J., Maxwell, J. W., and Rodi, S. B. (2002), *Statistical Abstract of Undergraduate Programs in the Mathematical Sciences in the United States*, Providence: American Mathematical Society.

Mehta, S. (2004) "ISI Honorary Member Interviews," *ISI Newsletter*, 28, 9–10.

Mervis, J. (2004), "Is the U.S. Brain Gain Faltering?" *Science*, 304, 1278–1282.

Moore, D. S. (1995), "The Craft of Teaching," Mathematical Association of America *Focus*, 15, No. 2, 5–8.

National Science Foundation (2002), *Science and Engineering Doctorate Awards: 2001*, NSF 03-300, Washington: National Science Foundation Division of Science Resource Statistics.

Russell, M. (2004), "South Korea: Suddenly, Science Moves to the Top of the Government's Agenda," *Science*, 304, 1237.

Thurgood, L. (2004), *Graduate Enrollment in Science and Engineering Fields Reaches New Peak; First-Time Enrollment of Foreign Students Declines*, NSF 04-326, Washington: National Science Foundation Division of Science Resource Statistics.