FUNDAMENTAL IDEAS IN TEACHING STATISTICS AND HOW THEY AFFECT THE TRAINING OF TEACHERS

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The preparation of teachers in the United States of America is essentially very loosely structured with little coherence or consistency from institution to institution and from state to state. Teacher preparation and professional development also vary dramatically depending on the grade levels of teachers and prospective teachers. With a few exceptions, training for teaching statistics is not part of teacher preparation programs and primarily occurs as ‘catch up’ in the form of professional development, where teachers are actually teaching and are asked or choose to take workshops related to teaching and learning statistics. Most state curriculum guidelines or standards in keeping with the *Principles and Standards for School Mathematics* (NCTM, 2000) have a data and statistics strand; accordingly most instructional materials have sections on statistics, but teachers are given little training in how to effectively implement these materials in their classrooms.

What follows is based on experiences from three different perspectives: integrating statistics into a teaching methods course for prospective secondary teachers, inservice workshops on data and statistics for practicing teachers, and more general workshops for school personnel. In each setting some common issues arise: 1) the distinction between mathematics and statistics and what this looks like in instruction; 2) the importance of graphs and their use as a way to gain insights into data; 3) the role of randomness; and 4) recognition that variation is critical in understanding the stories in data.

STATISTICS AND MATHEMATICS

As many statistics educators contend (Rossman & Chance, 2006; Scheaffer, 2006; Franklin et al., 2007), mathematics and statistics differ in their essential defining characteristics: the role of context, methods of reasoning, precision, the role of data and data collection. It appears, however, that to some, the use of statistical terms implies they are being used in developing and conveying statistical ideas. In fact, many common usages of statistical words involve nothing more than performing a mathematical computation; for example, the following question is typical of many that are categorized as statistics on state assessments: What grade would you have to score to end up with an average of 85 if your previous scores were 80, 72, 93, 88? Students might be given four collinear points as ‘data’ and asked to find the relationship. In many cases, the data are fabricated with no sense of context or the ‘messiness’ of real data; for example, a lesson in which the data indicate a large vehicle uses exactly two gallons of gasoline for every hour driven. When using real data, trends are not unambiguous, and the interpretation and analysis depend on and make sense within the context (Franklin et al., 2007).

GRAPHS

In all settings that serve as a resource for this discussion, pre- and inservice teachers did not intuitively think of a graph as a tool to explore and understand data. Both groups tended to ‘crunch numbers’ first and display the results in bar or circle graphs. For example, consider 24 preservice teachers (fourth year mathematics major); all but three had taken a compulsory university statistics course. In their teacher preparation course the students were asked to use both graphs and statistics to rank four regions of the USA according to secondary school graduation rates. Most calculated means or medians by region, displayed bar graphs of the averages and used the means to rank the regions (Figure 1). Three used side-by-side bar graphs for the states in each region (Figures 2), and of those three, one added a line representing the mean percent across all of the states. Only one student used box plots to display the data (Figure 3).

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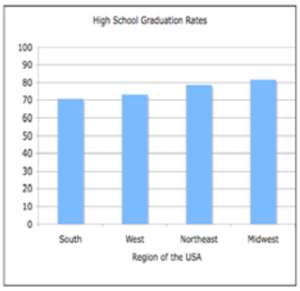

Figure 1. Bar Graphs

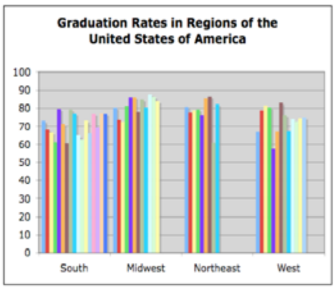

Figure 2. Bar graphs by region

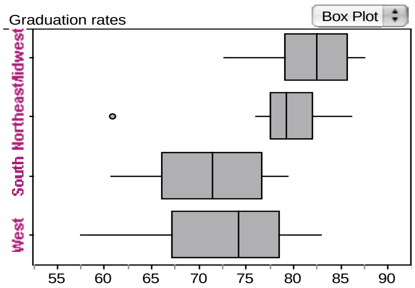

Figure 3. Box plots by region

When given two variables, the majority of the students still seem to choose bar graphs. For example, given the cholesterol counts before and after a special diet, the preservice students were asked to draw a graph that would help answer a question they might have about the effectiveness of the diet in reducing cholesterol. To answer the question: does the effectiveness of the diet depend on your initial cholesterol level, the majority made side-by-side bar graphs (before and after) for each person labeled by name or number (Figure 4), keeping the "person". None chose a scatterplot (Figure 5), which can show a line of equality, a least squares regression line, and a vertical line that suggest different ways to look at the data to answer the question.

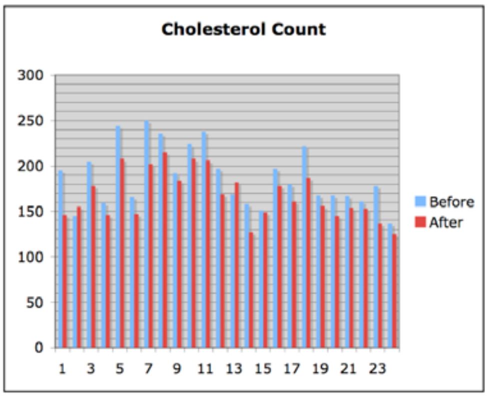

Figure 4. Bar graphs of effect of diet

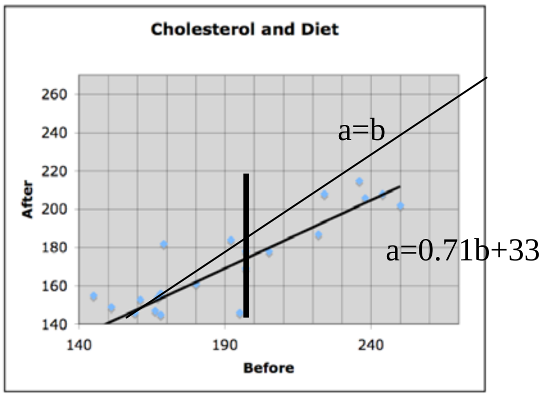

Figure 5. Scatterplot of effect of diet

Bar graphs were also used on this problem by middle school teachers in a two-day professional development workshop to review statistics a year after they had taken a university course on statistics as part of a specialized master's degree program. In one group of inservice teachers, one member suggested using a scatterplot, but the other three members argued against it in favor of the bar graphs and retaining each individual study participant by number.

VARIABILITY

Variability, probably because mathematics is about being exact and precise, is difficult to establish as critical to conversations about data. Typical summary measures of data in the media are measures of center. Nearly all of the instructional materials in the USA find measures of center absent any measure of spread. Inferences about samples are typically given as point estimates, not intervals. For example when given that 45% of people have type O blood and asked to estimate the number with type O blood you would see in a sample of 40 randomly chosen people, nearly all of the preservice students replied 18, rather than saying "about 18" or "18 more or less." In the graduation data described above, not one student commented on outliers: New York in the Northeast (Figure 4).

In yet another professional development program, school personnel were tasked with analyzing school achievement data and given box plots of their data as a resource (Burrill, 2007). Overwhelmingly, the participants were unable to interpret data represented in this way; in one site the plots were replaced by bar graphs of the medians and disseminated to the school staff; while in another the graphs were abandoned all together in favor of a table of means.

IMPLICATIONS FOR TEACHER TRAINING

What seems clear is that even when training opportunities are provided, teachers in the USA struggle with the 'spirit' of statistics. Documents such as the Principles and Standards for School Mathematics (NCTM, 2000), the Guidelines for Assessment and Instruction in Statistics (GAISE) K-12 Report (Franklin et al., 2007) and most state standards (e.g., Ohio Department of Education, 2000) provide convincing rationales for why statistics is important and are explicit about the content that should be in K-12 instructional programs. What is missing, however, is how the content should unfold in classrooms. When the content is taught as a set of procedures, where data, context and variability are incidental or irrelevant, students will not really learn statistics. Examples such as those cited in this paper will continue to be pervasive and the notion of a quantitatively literate society elusive. Our challenge as statistics educators is to identify and make visible in the K-12 arena the philosophy and principles involved in teaching statistics that informed the development of the Quantitative Literacy materials (1986); undergraduate courses such as the one developed by Rossman and Chance (2004), and are central in the work of Cobb (1992) that led to the recommendations in the GAISE college report (Garfield et al, 2007).

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