STATISTICS EDUCATION - BRIDGING THE GAPS AMONG SCHOOL, COLLEGE AND THE WORKPLACE

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In recent years statistics education has moved forward on three vital fronts, data analysis strands in schools, concept-based courses in colleges, and quantitative methods for product improvement in industry. Continued progress in all areas is essential, and this can be accomplished through the synergistic effects of these three arms working together. Building bridges among the three can expand the use of statistics in industry while producing a statistics curriculum in schools and colleges that can be defended and sustained on both academic and practical grounds.

STATISTICS - WHO CARES?

Charged with producing a more accurate count of the population, the U.S. Census Bureau decided to use sampling, in addition to enumeration methods, for the 2000 Census. A leading Senator responds that “sampling is another word for guessing” and a leading editorial writer states that “sampling is not enumeration” and sampling is “no science.”

In a survey of Fortune 500 companies, almost all stated that they had some quality plan in place, but about half have less than 40% of their mangers and workforce knowledgeable in quality management philosophy, concepts and tools (Lackritz, 1997).

“Racial Discrimination and Blood Pressure ” is the title of a recent work, one among many, that confuses research with the political, economic and social agendas of the researchers (Satel, 1997; Crossen, 1994).

Physical scientists, engineers and financial experts have been know to remark the statistics is not needed anymore as they have “discovered” neural networks.

In spite of these trends, there is more interest in statistical education today than ever before; it is wonderful to see so many people at this ICOTS. But, the fight for a quantitatively literate citizenry throughout the world is far from over - in fact, it might be quite appropriate to quote Churchill in saying that the progress made so far may be only “the end of the beginning.”

What are the roadblocks, then, to bringing about this education that those attending this meeting deem so important? Let me suggest a few. Those in charge of the systems that run our lives do not understand and are not committed to this goal. The general public has, at best, a weak grasp of the issues and is easily swayed. (Neal Lane, the Director of the U.S. National Science Foundation, recently remarked that 98% of the general public does not know what research means.) Technology, which should be an ally, is given to producing believable magic rather than to helping people think; black-box magic is running rampant. Teachers try to sort all of this out so they can do the "right thing," but they cannot accomplish this on there own.

What is the solution? We must continue to change the curriculum in both schools and colleges so that everyone learns something about quantitative reasoning and statistical thinking before moving to the workforce, and then continue education into the workforce so that the knowledge base persists and grows. Change is difficult to achieve and to sustain, and will not come about in a lasting way until the main forces - schools, colleges, businesses and industries, and government - agree on the main directions and ingredients of the change. We must identify the gaps that divide us, build on the strengths that unite us, and make this a group effort. It is the only way to sustainable progress.

WHAT DO THE GROUPS BRING TO THE TABLE?

Industry, for the most part, still believes in a TQM philosophy without the fluff that often surrounded it a few years ago. Of primary importance is bringing statistical thinking to bear on problems that need solution (Britz, et. al., 1996). Out of this thinking comes a strong commitment to solid areas of statistics like statistical process control, design of experiments, and modeling. Modern technology is used extensively; simulation of complex systems has become a way of life as it is often too expensive to build prototypes. Business and industry want employees who can solve problems, and the problems are so complex that this work must be done by teams. Industry has interesting examples of the uses of statistics to share with the others, and has jobs for those with quantitative ability. What the workplace is asking for in terms of skills necessary to fill those jobs can be summarized from one of the reports issued by Project MeaNs of the RSS Centre for Statistical Education: good grounding in basic statistics, courses with practical orientation, good communication skills, ability to work as part of a team, a positive attitude.

In colleges and universities more students than ever before are taking statistics courses. At least that is the case in the United States and, I think, in many other countries as well. After the introductory course, and sometimes even in it, the courses tend to dwell more on theory, with a heavy dose of probability, than on the applications of statistics.

Specialized techniques are taught to advanced undergraduates and graduate students as those skills become necessary in preparation for a degree in a quantitative discipline but, on the whole, statistics tends to be taught in isolated chunks that do not give the student an overview of statistical thinking. To many, statistics is a bag of tricks to be used on special occasions; it is not a systematic way to solve a problem. In addition, the communication aspect is virtually ignored. On the other hand, colleges have the students that will be the politicians, administrators and teachers of the future. It is important that this vital resource be reached with statistics education.

Schools have the most important resources - virtually all of the youth of the world and creative teachers with a willingness to learn - and to change. Although some teachers might argue the point, schools also have the time to educate these youthful minds, both in terms of the number of years in the system and the amount of attention that can be given a student within a particular grade. These are strong points in favor of introducing statistical concepts into the curriculum as early as possible, and building upon these concepts from year to year. Statistical education takes time.

WHAT SHOULD CHANGE?

Gaps begin to be bridged at the elementary school level. Data is a natural way to work with numbers and builds on the curiosity of the students at this level. Sorting, counting, ordering and measuring are part of the elementary school curriculum. What statistical thinking adds is an orderly process for using these skills to solve specific problems. (Which types of story books should the teacher order? Should we have free play before or after lunch? Why is the bus late on cold days?) Children can become statistical thinkers quite naturally, with a little guidance from an informed teacher. The important point is to teach them to think of statistics as an orderly way to gain information, not as a set of disconnected gimmicks.

As students proceed to the middle grades, these same ideas can be set in slightly deeper contexts and informal inferential reasoning can begin. By the high school grades, studies of some sophistication can be designed and more formal techniques of inference can be introduced. Remember the bridge to industry; much emphasis should be placed on the design of studies, with less emphasis on theory, especially formal probability theory. Students should work on projects that lend themselves to group activity. Hands-on activities are viewed by many to be helpful to the learning process, but these seem to be little used above the elementary grades. One report (Weiss, 1997) states that nearly 30% of class time is devoted to activities in grades 1 through 4, but this drops to around 12% in grades 5-8 and to around 7% in grades 9-12.

This infusion of statistics into the mathematics curriculum of the schools has been going on for some time in many countries, with varying degrees of success. We might hope to look at the recently completed Third International Mathematics and Science Study (TIMSS) for information as to the successes or failures of these efforts. Alas, there seems to be less here than we would like, even though Data Representation, Analysis and Probability is one of the six areas tested in mathematics. The problem is that the questions in this category are not what many of us would consider to be good statistics questions. A few examples (from the test given to 13 year-old students) are in order.

As expected, too many of the questions are about relative frequencies, contrived as probability. A drawer contains 28 pens; some white, some blue, some red, and some gray. If the probability of selecting a blue pen is 2/7, how many blue pens are in the drawer? Nine chips, numbered 1 through 9 consecutively, are placed in a jar and mixed. Madeleine draws one chip from the jar. What is the probability that Madeleine draws a chip with an even number? Only about 50% of the students got the first question correct; about 52% got the second correct.

A series of questions relates to reading graphs. One graph shows stopping distance of a car as a function of speed. The question that asks about predicting distance from speed is answered correctly by about 56% of the students whereas the one that asks about predicting speed from distance is answered correctly by only about 46%. These results are discouraging on two counts - poor questions and poor responses. In fact, on these questions countries that do not attempt to teach statistics or data analysis as part of the school curriculum fared just as well as countries who do.

With regard to the latter point, a study sponsored by the American Federation of Teachers entitled *What Students Abroad are Expected to Know About Mathematics* contains interesting comparisons of France, Germany, Japan and the United States on the basis of national exams taken by high school students as graduation requirements or as preparation for possible acceptance into a university. The exams from France showed no questions relating to either statistics or probability. One German exam has a section on Stochastics, which contains some rather deep probability questions (even one relating to the normal distribution). Japan’s exams had one question that required interpretation of data from a table and one substantial probability (expected value) question. The exams from the United States contain a question on simple probability, two rather pedestrian questions on counting rules and one on averages. These results do not give exhaustive information on what the countries require of their high school graduates, but an over simplified answer seems to be “some probability but virtually no statistics.”

Throughout the curriculum, statistics education should be built around problem formulation, data collection, and data analysis. Students should be forced to make choices on procedures and to justify their decisions and their results through clear communication. Such ideals will not become an integral part of the taught curriculum unless creative assessment practices are adopted to measure student learning (actually, to measure the learning-teaching interaction). One of the leaders in the excellent UK program of statistics education in the schools reported that the program is becoming “fossilized” and “fragmented” by the assessment system. “Assessment drives everything.”

The recommended changes for colleges could be easily stated; do what was suggested for the schools but at a higher and more intense level. Time is short in the college curriculum; nevertheless, all students should have an organized and systematic exposure to statistical thinking and philosophy. This can be followed by specialized courses, depending on the interests and needs, but there should be strong applied flavor mixed in with appropriate theory. In commenting upon statistics education at the 1997 ISI meeting, C. R. Rao, a great theoretical statistician by any standard, placed sample survey design and design of experiments at the top of the list of recommended courses. Remember the bridge to industry! A study on educating engineers for the 21st century (Prados, 1997) reports that such education must include “probability and statistics, including applications in areas such as experimental design, data analysis, quality control, reliability, and risk assessment.” Prospective teachers compose a very important group that need special attention in the area of statistics, else the changes suggested for the schools can never be accomplished. Statisticians at colleges and universities must control their audacity and work with specialists in other areas so as to build quality statistical reasoning into all appropriate courses and programs.

Industries interested in improving the workforce with regard to statistical thinking skills must be willing to enter into open and receptive dialogue with schools and colleges, bearing in mind that the goal of the schools (education) and the goal of the industry (productivity) are not the same. These goals can be compatible, however, so long as mutual respect is shown. Industry can provide guidance, moral support and perhaps monetary support as schools and colleges grapple with curricular changes, and the associations between the groups must be established for the long term. As stated earlier, change is not easy; neither is it quick.

WHAT IS THE HISTORICAL PERSPECTIVE?

The trend toward data analysis arising from designed studies, with emphasis on empirical analyses including simulation, is often portrayed as a forward-looking trend. In reality, it is a trend that looks backward to the very roots of the discipline of statistics. I regard any success that might be achieved in the modern movement toward statistics in the schools as emanating from Fisher, Tukey and technology, the first two because they were the giants who formed the essential ideas around which the current approaches are fashioned and the third because it is an essential ingredient for carrying out these ideas.

Two stories about Sir Ronald Fisher help make the point. In one of his many battles with Karl Pearson the argument centered around the appropriate number if degrees of freedom when using the chi-square test for independence for 2x2 tables. Fisher argued for 1; Pearson for 3. Fisher had good theoretical arguments, but the case was settled when Fisher discovered about 12,000 2x2 tables collected under conditions of near independence. Fisher calculated the average value of the chi-square statistic across these tables and found it to be 1.00001, which he announced in a now-famous phrase as being “embarrassingly close to unity.” To add insult to injury, the collector of the tables was E. S. Pearson, Karl Pearson’s son.

Fisher was responsible for introducing the notion of randomization into the design of experiments, a notion not widely accepted at the time. To him, randomization was the key, as seen in the following quote. “It seems to have escaped recognition that the physical act of randomization, which, as has been shown, is necessary for the validity of any test of significance, affords the means, in respect to any particular body of data, of examining the wider hypothesis in which no normality of distribution is implied. “ (Box, 1978, p.151.) In short, the t-test is an approximation for mathematical convenience to the randomization test. Independence of errors is more important than their normality. The practice of statistics would have taken a much different route had Fisher had a workstation!

John Tukey is the person who made exploratory data analysis not only respectable but almost essential to modern statistics. His philosophy and techniques are seen throughout the current trend toward data analysis in the school and college curriculum. The main problem is, however, that the techniques have outpaced the philosophy. We may have oversold data analysis *because* of the cute techniques with clever names (stem-and-leaf plots, box plots) rather than because of the philosophy that uncovering pattern in the data is essential to any scientific investigation. It might be instructive to look at the "definition" of data analysis implied in the following quote. "I thought I was a statistician, interested in inferences from the particular to the general, . . . I have come to feel that my central interest is in data analysis, . . . procedures for analyzing data, techniques for interpreting the results, ways of planning and gathering data, and machinery of mathematical statistics which apply to analyzing data." (Tukey, 1962.) His admonition that we must move from "cookbookery" to the "art of cookery" should not go unheeded, but it appears that we may be using Tukey's techniques to simply modernize the style of the cookbook rather than to improve the art of cooking.

BRIDGES - A SUMMARY

The process of building a solid core of statistics into the school and college curriculum is one of infusion for the many and specialization for the few. In the United States, infusion is resulting from the NCTM Standards, as influenced by the ASA's Quantitative Literacy Projects and others, and from the new school curriculum projects funded by our National Science Foundation. Specialization at the high school level can come about through the Advanced Placement Statistics program, now completing its second year. There are similar emphases and programs in many of your countries, and all of this is to be applauded. At the college level, infusion must come by way of all students being exposed to basic statistical thinking as a required part of their program. Specialization comes through more advanced courses given by statisticians or others well qualified for the task. One set of bridges must be built, then, among and between those statistics-teaching specialists at the school level and those at the college levels.

For educational change to be successful, it must have purpose, direction and support from outside the educational community, and so another set of bridges must be built between educational institutions and the business community. The latter has problems to solve, structures for solving them, and jobs to fill. All sides can benefit from this communication.

Bridges are sturdy, not prone to be blown down by the prevailing winds of the day. Bridges are built for movement, and are in danger of collapsing if traffic comes to a standstill on them. Bridges are built to go from someplace to someplace, and back; both ends are critically important. Happy bridge-building!

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