25. THE ROLE OF TECHNOLOGY IN STATISTICS EDUCATION: A VIEW FROM A DEVELOPING REGION

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INTRODUCTION

Although statistics education has been a concern of statisticians for over a century, it was only following the establishment of the Educational Committee within the International Statistical Institute at the end of 1948 that serious efforts began to stimulate international research and debate on the needs for education and training in statistics, as well as measures and programs to meet these needs. A detailed survey of how actively this committee and its recent successor, the International Association for Statistical Education, took up this challenge appears in Vere-Jones (1995).

In this paper, we examine the role of technology in statistics education from the viewpoint of a developing country. We begin with a brief overview of the developing region in question. We next provide a definition of statistics education which, in our view, may be used to identify in general who needs statistics education, who should provide it, and at what level statistics education should begin.

The role of statistics education is explored in relation to three broad areas where it plays an important role, namely, in business and industry, some aspects of government, and overall socioeconomic and scientific progress. Following this, technologies for effective teaching and learning statistics at different levels are explored. This paper ends with a discussion of the questions to be addressed regarding the role of technology in statistics education. Recommendations for research are suggested, especially in relation to developing regions.

BACKGROUND

South Africa is a multicultural, multiethnic, and multilingual country. Since April 1994, it has moved from being a country with 4 provinces, 2 official languages, and 19 education departments, to a country with 9 provinces, 11 official languages, and 9 provincial education departments within a new integrated national education system. The new education system aims to provide "equal opportunities to all irrespective of race, colour, sex, class, language, age, religion, geographical location, political or other opinion" and is directed toward "the full development of the individual and the community" (African National Congress, 1994, p. 60). At the national level, there is now a single, unified ministry of education whose overall assignment is "to set national policies, norms and standards throughout the system" (African National Congress, 1994, p. 61), but which includes the particular responsibility for tertiary education (i.e., post-secondary education), but the nine provincial education departments are responsible for all aspects of

primary and secondary education. At present, all pupils who complete 12 years of schooling write matriculation examinations set either by one of the provincial education authorities or by the Independent Examinations Board. A recently published government white paper (Department of National Education, 1995) has proposed significant changes in the education system and its examination structures, while the entire school curriculum and the numerous subject syllabi are currently in a process of revision.

Statistics, with some introductory elements of probability theory, has been taught in South African schools for a number of years. It has not appeared as a separate subject at either the primary or the secondary school level because it forms part of the mathematics curriculum. During the 1980s, proposals were made for a revised mathematics curriculum that included a coherent program of statistics and probability at all levels from Standard 5 (Grade 7) to Standard 10 (Grade 12) (Juritz, 1982). Unfortunately, these proposals were never implemented, despite the supporting recommendations from the South African Statistical Association, the South African Mathematics Society, and the Association of Mathematics Educators of South Africa.

The present situation is that the provision of statistics within the school system is noticeably unbalanced. At the primary school level, the new syllabuses for Standards 3 and 4 (Grades 5 and 6) include the topic, "Graphical representation and interpretation of relevant data," which focuses on gathering and presenting information and involves simple pictorial graphs, column or bar graphs, and pie charts. In junior secondary schools [i.e., Standards 5-7 (Grades 7-9)], items of statistics and probability taught include the collection, presentation, and interpretation of data; the calculation of the mean, median, and mode, and simple measures of dispersion (range and mean absolute deviation); as well as elementary ideas of probability of equally likely outcomes and mutually exclusive events. For the equally likely outcomes model, teachers are encouraged to use experimentation with dice, coins, and so on, although the more formal view of probability of events in discrete sample spaces is also included.

There is no mention of statistics or probability in the new syllabi for Standards 8-10 (Grades 10-12), although some compensation is offered in the form of a statistics and probability option in the Standard 10 (Grade 12) Additional Mathematics syllabus. As its name suggests, this is a more advanced course in mathematics, but historically only a small proportion of students take the course. Clearly, the teaching of statistics at school level in South Africa appears to share the same approach as some of the European countries reviewed by Holmes (1994).

At the tertiary level, specialist statistics courses up to at least first degree (bachelor) level are offered by most of the 21 universities in the region, with the better endowed institutions offering MSc and PhD programs. Courses in applied statistics are also provided for students pursuing majors in education, psychology, sociology, business studies, medicine, and natural sciences in these universities, the 15 technical institutes, and several private colleges in the country.

WHAT IS STATISTICS EDUCATION?

For the purposes of this paper, the term statistics is used to mean the branch of scientific method that deals with the study of the theory and practice of data collection, data description and analysis, and the making of statistical inferences. It follows, therefore, that statistics education refers to the art of teaching and learning these statistical activities. In this definition, data collection is taken to encompass both the design and execution of data collection activities as well as data editing; data description refers to the summarizing of data by quantitative measures of central tendency, including weighted indexes, measures of dispersion, or

by means of tables and frequency distributions or pictorial means such as histograms, line graphs, bar graphs, pie charts, and so on. Data analysis refers to exploring data tables, trends, and shapes, as well as statistical modeling; statistical inference refers to point and interval estimation and hypothesis testing, as well as decision theory in so far as the latter deals with the set of actions or decisions open to the statistician.

To many people, statistics is regarded as a branch of the older discipline of mathematics and takes its place alongside analysis, calculus, number theory, topology, and so on. This view has its parallel in the idea that statistics education is a component of mathematics education. Recently, however, statistics education has come of age (Vere-Jones, 1995) and is recognized internationally as an identifiable and important field of knowledge, one which is not simply a subset of either statistics or education. It is certainly more than "methodology" and embraces such important matters as the nature of statistics, its place in human life, its function in schooling, how students acquire statistical concepts, as well as strategies for teaching and learning statistics and evaluating the results. With this in mind, together with the insights afforded by the mathematics education community (e.g., Burton, 1978; Howson, 1977), we suggest that the art of teaching and learning in our definition of statistics education should additionally include activities that attempt to:

- Understand how statistical methods are created, developed, learned, communicated, and taught most effectively at different levels of schooling, student ability, student attitude, and student needs.
- Design statistics curricula that recognize the numerous constraints induced by the students, their society, and its educational system.
- Effect changes in curricula (where curricula are taken to include not only content, but also teaching methods and procedures for assessment and evaluation).

By defining statistics and statistics education as we have done, we hope to identify the wider issues involved in statistics education in a modern society. In turn, this allows us to put forward fundamental reasons for introducing statistics to learners from the primary level through the tertiary level. This sets the stage for addressing the question of effective means of teaching and learning both the theory and practice of statistics using appropriate technology. Note that our definitions of statistics and statistics education in this paper go further than the two traditions proposed by Holmes (1994).

THE ROLE OF STATISTICS EDUCATION IN MODERN SOCIETY

The growth of statistics is multidisciplinary, with its roots in such diverse fields as agriculture, astronomy, economics, engineering, genetics, and so on (Bickel, 1995). Statistics, as the science of collecting, analyzing, and interpreting empirical data, has a central place "in scientific research of any kind; in government, commerce, industry, and agriculture; in medicine, education, sports, and insurance; and so on for every human activity and every discipline" (Kish, 1978, p. 1). Statistics education is relevant for these areas also, with its main role focusing on teaching and learning activities considered necessary for the production and development of statistically literate people and professionally competent statisticians.

The importance of providing statistics education throughout the entire education spectrum cannot, therefore, be overemphasized. Virtually every economic and scientific activity in the modern world relies on statistics in one way or another. By way of example, we review this claim briefly in relation to three broad areas in which statistics plays a prominent role: business and industry, aspects of government, and scientific and economic progress.

Business and industry

Modern trade and industry rely exclusively on statistical techniques in such activities as forecasting; optimal allocation of limited resources among competing demands; quality control in production; stock control in production and retail sale (using, e.g., inventory theory); management (using techniques such as critical path analysis); and the use of acceptance sampling in auditing and accounting. Without the use of statistics in these vital areas of modern technological endeavor, many of the efficiencies achieved in the commercial world in recent history would be nonexistent.

Aspects of government

Social statistics

A major part of any government's primary responsibility is the provision of social services. Government involvement in this regard produces a large pool of statistical records relating to social affairs such as housing; social class; personal incomes; living standards; crime; education; accidents; registration of births, marriages, and deaths; population size; and population projections. The availability of these myriad sets of data is essential for any modern government's strategic planning and efficient operation.

Macroeconomic statistics

In the field of macroeconomics, it is well known that if the economic activities of the different economic agents that operate within the economy are not sufficiently well-coordinated, the outcome is likely to be a general disequilibrium. This condition reveals itself in a number of ways, many with undesirable effects such as underemployment of capital and labor, a rise in inflation, imbalance in the balance of payments, and so on. The failure of the market system on its own to coordinate all activities provides another primary responsibility for the modern state; namely, to collect and make available for the entire economy, economic and business statistics about such items as manpower, production, consumption, internal and external trade, money supply, domestic and foreign capital flows, national income and its distribution, and so on, which individual economic actors would otherwise find difficult or impossible to obtain. In many developing countries, including South Africa, data relating to many important economic sectors are unreliable. Numerous examples supporting this contention and the reasons for this unsatisfactory state of affairs have been presented by Kmietowicz (1995).

National and international economic and scientific progress

Statistics is almost unique among major disciplines of study in that a person trained in the use of statistical methods is more able to make advances in fields as diverse as health sciences, natural sciences, humanities, agriculture and forestry, technology, educational testing, marketing and management, and recently, even in the legal field, than one who is not. This diversity in applications of statistics makes the teaching of the subject at all levels an essential component of economic and scientific progress.

WHO NEEDS STATISTICS EDUCATION TODAY?

Over the last 50 years statistics education has grown "from a narrow focus on training professional staff for government departments, to a movement which stretches downward into the primary and even the kindergarten programme, and outwards, through training for a wide range of academic and technical disciplines, to programmes of adult or community education" (Vere-Jones, 1995, p. 16). Consequently, statistics education has few boundaries and is appropriate for students at elementary, secondary, and tertiary levels of education and beyond.

However, in today's modern world, much work involving data collection and data analysis is being conducted by nonstatisticians, many of whom have little knowledge of the range of appropriate methods of data collection, are unaware of the basic assumptions underlying the statistical methods of analysis they choose, and are unable to provide sensible interpretations of the results of their analyses. Only a relatively small proportion of datasets are collected and analyzed by professional statisticians. This situation is the result of the failure in the past of statistical communities worldwide to assert themselves and convince government authorities to recognize the need for a coherent statistics education curriculum. It is generally recognised that mathematics is the basis of quantitative disciplines; therefore, formal learning of mathematics should begin at the elementary school level. For this reason, it is a compulsory subject for everyone in virtually all countries. We wish to submit that the learning of statistics should also begin at the elementary school level and be made part of the school curriculum for all, because as argued above, statistics now plays an essential role in developing the ability and competence of the scientist, technician, manager, government worker, and ordinary citizen to use data and information constructively and effectively.

THE TEACHING OF STATISTICS

Primary and secondary schools

In the campaign to promote the introduction of statistics into the school curriculum worldwide, it has been argued that the statistical community should anticipate a "long, dour struggle" (Vere-Jones, 1995, p. 17). The first ingredient of this struggle relates to the teachers. The majority of present-day mathematics teachers are not likely to have studied statistics as students. “How can they teach this new subject,” asks Vere-Jones (p. 18), especially if it involves the kind of approaches statisticians would like to see implemented, “without being given time and teaching resources needed to overcome their deficiencies?”

The second related ingredient is the role played by teacher education institutions. If these institutions were to embrace statistics teaching resolutely and emphatically, then we could expect the next and future generations of teachers to be adequately prepared. It is strongly recommended (Vere-Jones, 1995) that statistics education organizations, particularly those with links to the wider statistical community, assist teachers and teacher education institutions. Help could be provided with such things as providing familiarization courses, providing teaching materials, assistance in the running of seminars and in-service courses, as well as giving teachers support in their efforts at curriculum development. In South Africa today, the restructuring of education at all levels has given impetus to such initiatives.

Universities and technical institutes

Jeffers (1995) stresses, rightly we believe, the need to distinguish between the training of statisticians per se and the training of scientists, managers, administrators, and nonstatistician researchers (i.e., people who will make use of statistical methods, but will not themselves be concerned with the further development of statistical theory). We wish to associate ourselves with the renewed call for this distinction, even though many university departments of statistics presently offer courses for other departments in addition to their main statistics teaching. One of the authors of this paper (KWB) is currently engaged in a project examining this question in South Africa.

If statistics education begins at the elementary school level, there will be adequate time to enable learners who eventually go on to university and technical institutions to develop understanding of the basic principles and assumptions of statistical inference, the use of analytical techniques and the corresponding interpretation of results.

TECHNOLOGIES FOR EFFECTIVE STATISTICS EDUCATION

Technology, viewed as the use of science to make advances in all spheres of life, is a major cultural determinant that shapes our lives as surely as any philosophy, religion, social organization, or political system. At the time when science belonged to the realm of philosophy, technology was the domain of craftsmen who forged tools out of naturally occurring materials. Today, it is perceived as the application of scientific principles to the design and manufacture of tools as widely different as quartz watch batteries, computers, superglue, and combined harvesters (Makhurane, 1995).

In the field of statistics education, technology is commonly thought of in terms of computers and the associated statistical computing packages, which together have become every statistician's indispensable working tool, as well as video and other tools used in the teaching of probability and statistics. Technology, however, especially in developing countries, ranges from frequently used, low cost materials to the less used, expensive, and sophisticated equipment. We offer the following summary of examples of technological forms used in statistics.

- Data collection: questionnaire, clipboard, pen/pencil, maps, telephone, postal services.
- Data editing: summary forms, pen/pencil, computers.
- Data analysis: calculators, computers.
- Teaching aids: chalkboard, textbook, audio-visual equipment, computers.

Recent views expressed in the literature appear to be divided on the extent of using technology (Hawkins, 1997; Moore, Cobb, Garfield, & Meeker, 1995). Although there is no doubt that the impact of such technology has produced striking changes in the nature of both statistical research and statistical practice, its effect on the teaching and learning of statistics varies considerably (Moore et al., 1995). For example, Moore making a strong case for technology, argued that the computing revolution has changed neither the nature of teaching nor the productivities of teachers of statistics (Moore et al., 1995). Garfield (Moore et al., 1995), however, argued differently, pointing out that learning remains inextricably

interpersonal: "Human beings are by nature social, interactive learners. We check out our ideas, argue with others, bounce issues back and forth, and increase our understanding of ourselves and others" (p. 253).

In a separate contribution to the debate on the role of computers in statistical practice, Jeffers (1995) lamented that "contrary to many expectations, the development of the modern computer and the availability of statistical program packages has not improved the ways in which data are analyzed and interpreted" (p. 233). This, he pointed out, is because "the ability to perform a wide variety of statistical analyses with the aid of these program packages is not matched by adequate explanation for the non-statistician of the assumptions being made by those analyses, or of the underlying constraints that are imposed by the underlying theory of the analyses" (Jeffers, p. 229).

On the uses of multimedia technology, particularly the video, in the teaching and learning of statistics, Moore (Moore et al., 1995) has succinctly and lucidly presented the strengths and weakness of this method along with ideas about its future potential.

SOME QUESTIONS TO BE ADDRESSED

The introduction and ongoing development of technology in statistics education raises a number of important questions that relate to course content, the availability and affordability of the technology, teaching and learning methods involving technology, the general impact on the economy and society, and the quality of scientific research. In particular, the impact of technology on dual societies such as South Africa, Brazil, and India, in which both developed and developing regions coexist and reflect extremes of wealth and poverty, provides a basis for examining these issues.

Around the world, the rate of technological development is noticeably uneven and technology is sometimes charged with contributing to the gap between rich and poor nations, with a concomitant increase in international tensions. In contrast, an alternative view suggests that it is only through technology that the developing countries are likely to improve their lot. The usual underpinnings of technology, in the form of workshops, factories, training programs, agricultural and engineering colleges, basic science curricula, and a host of other facilities, are taken for granted in developed countries, but are in short supply in most developing countries.

The different technologies considered essential for effective teaching and learning of statistics at various educational levels, together with the problem of bridging the interface between the developed and the developing regions of the world, are issues that need to be discussed. For example, Jegede (1995) has argued that the theory and practice of science education in Africa takes place in the absence of informed knowledge about the structure of African styles of thinking, the duality of world views within Western and non-Western environments, the tensions placed on learners by conflicting ways of thought, especially when science teaching fails to take into account African ways of thought, and how the twin processes of teaching and learning in a second language affect these tensions.

There is a need for coordinated research to be conducted that focuses on several issues related to the role of technology in statistics education, especially in relation to developing regions of the world. Many possible research questions come to mind. For instance, what are the relative effects of different technologies on students' learning of statistics? Are there technologies that are more appropriate at the elementary school level versus the secondary school versus the university? How does teaching and learning in a second language affect the quality of learning statistics? What technological factors influence the learning of statistics? Which technologies can be used to enhance the teaching of statistics at different levels

in the education system? What effect does technology have on the learning of theoretical and practical aspects of statistics?

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