STATISTICS EDUCATION OF PRIMARY CHILDREN IN THE TWENTY-FIRST CENTURY

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Predicting the future is, at any time, a precarious business. At a time in history when technological and political change is moving so rapidly it is even more precarious. In spite of the difficulties, it is essential that the role of statistical education in the twenty-first century be addressed. Without a vision of the future it is impossible to effectively develop a blueprint for the present. Children entering primary school **now** will be working in the first half of the twenty-first century and their primary education will be the foundation for their future.

Within the framework of the title of this article there are many questions that could have been addressed. Statistics for whom? What role will technology play? What will classrooms look like in the 21^{st} century? etc. The author has chosen to address two interrelated questions facing statistical educators, namely:

Why teach statistics in the primary grades?
How should statistics be taught in the primary grades?

These two questions are sequentially ordered. Only after having addressed the question of why statistics should be taught is it possible to address the issue of how statistics should be taught. The purpose of the remainder of this article is not to provide a detailed statistical curriculum for the 21^{st} century, but to focus on the underlying rationale for statistical education and to generate a debate on what we are trying to accomplish through the statistical education of young children. Once the framework for teaching statistics has been developed, there will be a brief discussion of the second question.

A comment before proceeding. At the primary level it is impossible to totally separate mathematics and statistics. Primary children do not internalise separate entities called statistics and mathematics. The nature of primary education does not, and should not, involve the teaching of statistics and mathematics as distinct entities. In fact, as Dunkels has suggested, mathematics is statistics. The distinctions we, as educators, might draw are not meaningful for young children. Consequently, this article will draw strongly on an analogous development with mathematics.

Why Teach Statistics in the Primary Grades?

Pereira-Mendoza and Swift (1981) presented a three-component model for teaching statistics and probability. They stated:

> *Even though the role of both statistics and probability in our lives is significant, it is not the only rationale for including them in the school curriculum. A model of a more complete rationale contains three components: utility, future study, and aesthetics. (p. 2)*

In discussing a rationale for the teaching of mathematics, D'Ambrosio (1991) suggested a five-component model. He summarised these components as a utilitarian value, ethical value, aesthetic value, cultural value and socio-political value. These two models result in the framework presented in Figure 1, which places the utilitarian, futuristic and aesthetic components within a social and cultural context. It provides a rationale for the teaching of statistics in the primary grades. Within this framework, the aesthetic dimension includes the appreciation of the role mathematics plays in history. Figure 1 stresses the interrelatedness of the utilitarian, futuristic and aesthetic components.

These components can only be

What does this framework mean for statistical education? Current curricula tend to emphasise, at best, two components of statistical education: the utilitarian and futuristic. What happens if you ask young children about the purpose of studying mathematics (remember that they do not develop a conceptualisation of statistics as a separate discipline)? They will discuss its usefulness (e.g., shopping) or they may mention the fact that they will need it later in their school career (e.g., to do more mathematics, science). They will not identify the aesthetic role of mathematics nor the social and cultural value. If one asks the same children about why they take music they will often mention words such as fun, liking, terms that appear to be absent from their reasons for taking mathematics. Each of the components will now be discussed.

Utilitarian

For young children much of their early experiences and interests concern their world. They wish to discuss, explore, describe, understand, etc., those situations they face on a daily basis. The abstract concepts that will be encountered later in their careers or education (if they continue with their education) are, in most cases, not yet developed or of interest. Their drive is an intellectual curiosity to understand their surroundings, or for some just to survive their surroundings. Later this may be replaced with, or at least modified by, the desire to please a teacher, obtain a mark, progress through the system, etc. If this curiosity is to be satisfied, the education provided must be of such that it is meaningful to them, within their horizons. Rationales based on considerations appropriate to adult life, or even for high school, have little basis within children's reality. Consequently, utilitarian considerations play a major role in shaping the basis of the primary curriculum. The actual components that constitute the "content" from a utilitarian perspective will be culture dependent. What might be considered utilitarian in a developing country? Is utilitarian the same in the UK as Bangladesh?

Implication1: The primary statistics curriculum must reflect the needs of children to understand **their** world.

Futuristic

In the context of this framework, futuristic refers to both future schooling and career directions. However, when applied to the primary level of education the issue of career choice (as determined by the children) is not a major consideration. Statistics is interrelated with all the other sciences, both hard and soft, and many of the social sciences. Much scientific work deals with gathering, interpreting and predicting from data. This is the essence of statistics. In this sense one could rephrase the classic statement, "Mathematics - Queen or servant of science" as "Statistics - Queen of science". Therefore, statistical education in the 21st century will become increasingly more important.

Implication 2: The primary statistics curriculum must provide the basis on which to build, both in terms of the school curriculum and their lives.

Aesthetic

The concept of aesthetics in statistics is difficult to define. It is hard to define in mathematics, but discussions with colleagues indicate that they all have particular examples of mathematics that they find aesthetically appealing. In some cases this relates back to high school experiences. They are diverse in nature, including everything from classic ideas such as the traditional proof of 1+2+3...+100 attributed to Gauss, the Golden ratio, the proof of the uniqueness of the additive identity within the number system, to an appreciation of specific theorems or axioms. So, for many mathematicians, particular proofs or results contain an inherent beauty that for them represent aesthetics. For statisticians aesthetics is not clearly identified with specific proofs or results. The examples seem to be more oriented towards an appreciation of the power of the application of statistics. It would seem that this appreciation is most appropriate for primary children. In statistical education we need to develop an appreciation of statistics through its applications to their world. We need to show primary children how statistics is relevant to their reality.

Implication 3: The statistics curriculum must develop an appreciation of the power of the subject.

Figure 1 implies that the utilitarian, futuristic and aesthetic components are embedded within a social and cultural context. It is this component that may well be the most significant for statistical education. Education empowers children to understand and question their world.

Cultural

The cultural aspects are difficult to specify. In mathematics for the primary level it is easier to identify aspects of culture that have a mathematical underpinning. This is often identified through the artistic endeavours of a society. For example, Zaslavsky's (1990) article on symmetry in folk art shows how mathematics can be related to art. Gerdes (1985, 1986) concept of "hidden" or "frozen mathematics" is a way of bringing cultural richness to the education of children. But cultural richness is far more than frozen or hidden mathematics. The numeration system of the Mayans Lara-Alecio, Irby, B. J, and Morales-Aldana, 1998) with its zero led to a richer mathematics than a system without a symbol for zero. The Greeks made a contribution of quantum proportions to the development of geometry; while the clumsiness of their arithmetic system hindered any parallel contribution in this area. It is important that children understand the contribution that culture, and in particular their culture, has made to the development of society.

The comments in the previous paragraph are just as valid for statistics. Furthermore, if one considers the collection and tabulation of data as statistics, the whole issue of numeration systems can be considered part of statistics. Shannon and Weber (1999) has an activity based on the size of States in the USA but it could easily be adapted (as they suggest) to other countries. The recording and interpreting of information has played a significant role in the development of society and such recording is one of the key steps in statistical education.

Implication 4: The statistics curriculum must use examples that lie with the cultural experience of the children.

Social

'Mathematised' versus 'statistised'

For young children numbers provide an important tool for them. It is difficult to interpret everyday experiences without a concept of number. This does not mean that children require a formalised mathematical system with symbols, operations and rules, although such a symbolisation can be usefully applied. Rather, it means the intrinsic embedding of number and number relationships within the child's world, whether it is the family, the street or the school. Children are confronted with situations that can be understood better through the application of mathematical ideas. The '*mathematisation*' of reality is one vehicle for understanding it. 'Is one being treated fairly' can often be better understood by using mathematics. In many countries, both developing and developed, survival is the major concern of families. Education provides one with an important key to survival, both in terms of everyday living and the opportunity to provide a better life for oneself and one's family.

However, an examination of many of the situations faced by primary children show that they often involve data. They have to organise, analyse, and make decisions based on this data. The collection, representation, interpretation, and prediction from data are the core of statistics at the primary level. The ability of children to understand and interpret the statistical information available empowers them. The application of their numerical skills is within a statistical context. For want of a better word, the author will use the term "*statistised*".

Implication 5: The statistics curriculum must empower children within their social context.

The author has suggested that the three interrelated components within a social and cultural context provide the rationale for teaching statistics in the primary school. At the end of the brief discussion of each of these an implication was drawn. However, the statistics curriculum in the primary school is, hopefully, a coherent whole. The implications need to be considered as a series of distinct but not disjoint implications for statistical education.

How should statistics be taught in the primary grades?

Figure 2 provides a pedagogical framework for teaching. This framework enables statistics to be taught in a manner that reflects the five implications stated earlier in the paper.

Data Collection, Representation and prediction and interpretation

The approach involves the collection of data that is meaningful to the children. It is sometimes necessary to present them with structured pre-determined data sets; but it is not sufficient.

Once the data has been collected decisions have to be made on how to represent the data. There are many forms of representation of data, including traditional forms such as picture graphs and bar charts. For young children there should be a developmental sequence starting with physical object graphs and development through bar graphs to the abstract graphical forms. An overall model for such a development can be found in Gallimore (1990). The value of other less commonly utilised graphical representations can be found in the work of Dunkels (1990).

Once the data has been collected and represented children must interpret and predict what does the data says. They do not have the statistical sophistication to utilise powerful inference techniques such as regression, discriminant analysis, etc. However, they can "view" the data and then conjecture on patterns and possibilities.

These three steps could be totally devoid of reality. Meaningless data can be collected, represented and analysed. For statistical education to be of value the problems need to be carefully chosen.

Children need to be engaged in the educational process and involvement is best achieved in a context that is of interest to them and where they have a sense of ownership of the data. Figure 2 refers to placing the stages of data collection, representation and interpretation and prediction within a meaningful environment. What makes a meaningful environment for primary children?

The components discussed in the first part of this article provide the answer. The environment should be concerned with a situation that reflects the need to understand their world. A child's world is embedded within the culture of the society. Meaningful problems reflect that culture. The ability to understand these problems enables children to appreciate the value of statistics as well see the power of statistics to solve problems that concern them.

Examples could involve the collection of information on their family, on expenditures needed to provide a minimum subsistence diet, etc. It needs to be stressed that many of these situations might lead to important questions regarding values and ethics. While the data collection on the cost of food would not inherently lead to difficult questions, it should lead to a discussion of why food prices are so high? Why can't "we" afford a nutritious diet? Such questions invariably lead to a discussion of values, ethical questions, etc. As educators we should not avoid questions that raise fundamental issues about concerns such as fairness and equity.

In conclusion, one can argue that statistics education in the 21st century will play a key role in meeting the needs of society. Although the exact content will depend on the particular society within which the curriculum is developed, statistics, with its emphasis on real data, provides a vehicle for the discussion of issues of significance to the society and the children.

Statistical education in the 21st century should provide an engine to explore, discuss and understand the significant questions facing society.

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