Understanding Statistics and Statistics Education: A Chinese Perspective

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Abstract

In recent years, statistics education in China has made great strides. However, there still exists a fairly large gap with the advanced levels of statistics education in more developed countries. In this paper, we identify some existing problems in statistics education in Chinese schools and make some proposals as to how they may be overcome. We hope that our study can benefit the development of statistics education in China, and encourage statistics educators and researchers in other countries to help address these important issues in China and possibly in other developing countries.

1. Introduction

We all recognize the importance of teaching statistical thinking at all levels. In recent years, statistics educators in China, like those of other countries, have focused attention on rethinking the process of statistics education. At the elementary and secondary levels, attempts are being made to integrate statistics education into the mathematics and science curricula (Gal and Ginsburg, 1994). Unfortunately, statistics is often seen as a daunting subject, and "mathematical anxiety" occurs commonly among students. Statistics is one of those subjects with which students can have a hard time. It is a new language, and a different way of thinking. College professors who teach probability and statistics are all familiar with the high level of anxiety often exhibited by students at the beginning of a course (Perney and Ravid, 1991).

Mathematics is undoubtedly one of the most important and basic subjects students have to learn. Partly because of this, students are often influenced by a deterministic way of thinking. Serradó, Azcárate and Cardeñoso

(2005) present interesting findings about the influence of deterministic thinking on probability learning. Schoenfeld (1992)
lists some of typical student beliefs about the nature of mathematics and mathematical activities:

- Mathematics problems have one and only one right answer.

- There is only one correct way to solve a mathematics problem---usually by the rule the teacher has most recently demonstrated to the class.

- Ordinary students cannot expect to understand mathematics; they simply memorize something and apply it rigorously.

- Mathematics is a solitary activity, often done by individuals in isolation.

Although statistics shares some characteristics with mathematics, there are some features unique to statistics (see, e.g., Garfield, 1995).

- Statistics can prove very little conclusively.

- There are often different ways to formulate a statistical problem.

- People may come to different conclusions based on the same data if they use different methods of analysis.

Our experience gained during years of teaching and research shows that it is very useful for students to understand the relationship among mathematics, probability, and statistics. This can help students grasp the essentials of probability and statistics.

With the rapid development of statistics education and the extensive application of statistical methods, a series of advances in statistics education has been made in China in recent years, and the gap with the world's premier counterparts has been narrowing somewhat. However, many problems remain. In this paper, we first present our view on the problems and challenges regarding statistics education in China. Accordingly, we make some proposals for improving how statistics is taught in China.

2. Some existing problems and their roots

China is a developing country and statistics education in China is also in its developing stage. Statistics education (especially at the college level or higher) in China has taken significant steps forward since the implementation of the "reform and opening-up policy" (Liang, 1990; Wang and Zhang, 2002). The graduate programs in statistics have expanded dramatically in response to increasing demands, but the current state of statistics education is far from perfect. In this section, we discuss some existing problems and their roots.

2.1. Bias in understanding statistics

Both the current state of statistics education and the employment prospects are worrisome. The adaptation of statistics education to national needs is inadequate if not poor, which consequently leads to employment problems for statistics graduates. Conversely, the employment problem leads to difficulties in recruiting new students. One of the main causes for such a vicious circle lies in the lack of understanding of statistics as a scientific discipline. There are still many who regard statistics as part of mathematics. Of course, they are not completely wrong, especially given how some the mathematical statistics was developed. However, it is necessary to point out that statistics should not be taught purely as a subject within mathematics. Teaching

statistics utilizes the knowledge of mathematics, but its basic objective ties in closely with applications (i.e. data analysis), even in its theoretical research. Teaching pure theory without applications in mind seems to put the cart before the horse. In China, there is an increasing demand for statisticians who can use statistics to solve or help solve problems in many other areas. Unfortunately, statistics education places too little emphasis on data modeling and analysis skills.

At the other extreme, there are some who support the view that statistics can be taught without mathematics. With the rapid development of computer science and technology, various kinds of statistical software, such as SAS, SPSS, MINITAB, and S-plus/R, are being used by statisticians or other professionals. To analyze data, they can obtain results easily by means of a popular software package. Throughout the process, they may not have to deal with any mathematical formulation, which leads some to think that no mathematics is needed.

Just several months ago, an ornithologist called on our Key Laboratory of Applied Statistics (KLAS) at the Northeast Normal University. She has devoted herself to finding new species of bats. She had captured two body-type groups of bat. One group contained 4 bats, and the other contained 9 bats. Based on the normal significance test (z-test) on some of the measurements, she concluded that there was a significant difference between the two groups, and consequently declared that she had found a new species of bats. Those who understand the theory behind the test have to ask whether the z-test is appropriate for the data at such small sizes, and whether the significance has been adjusted for multiple tests. We need to teach students to ask the right questions, not just to use routine software for all problems.

2.2. Quality of teaching in high schools is unsatisfactory

We shall take the average score in the 2007 National University Entrance Examination as an example. It is well-known in China that the National University Entrance Examination is the baton to a band. For all the examinees of liberal arts subjects in Jilin Province, the average score on Question 17, a problem in probability and statistics, is 1.9 out of 12. This low score doesn't imply low ability of the students, but rather clearly indicates that it is very urgent to improve the teaching of statistics in Chinese high schools. Two possible reasons for the unsatisfactory current situation are:

a. College-level material in statistics and probability is now being included in the high school curriculum. However, high school teachers are inadequately prepared both in their knowledge of statistics and probability, and in pedagogy. Although most high school teachers learned statistics and probability in college, they are not familiar with a numerical and experimental teaching approach. Some of them cannot grasp the essentials of statistical thinking. They misunderstand statistical ideas, and sometimes even give students inappropriate guidance.
b. The employment prospects of undergraduates is uncertain.

In the School of Mathematics and Statistics at the Northeast Normal University, 50 undergraduate students were enrolled to in the statistics class in 2007. For these freshmen, a survey was taken, only to show that most of them were not familiar with statistics. The students didn't know what statistics meant and what they could do with it. In addition, our undergraduate students who majored in statistics did not know whether they could find jobs in small to medium cities in China. More than 80% of the graduates were encouraged to go to graduate schools, but only a few found satisfactory jobs upon graduation. The uncertainty in employment prospects will undermine the development of statistics in China in the near future.

There are at least two hidden factors that affect the employment of undergraduate students in statistics. One is that statistics is taught at a theoretical level, rarely connected to real world applications. The other is that at the current stage, statistics is not as much used as it is in developed countries. For example, the value of statistics is yet to be fully recognized in educational and psychological measurements, environmental assessment, drug development, and so on.

2.3. Master Degree Programs in Statistics have a narrow focus

Major universities in China now offer Master degrees in statistics, but unlike in the developed countries where the students often complete MS degrees in 1 to 1.5 years after college, a 2-year or 3-year program is still common in China, where the MS program is viewed as a first step towards the PhD. The MS students in China are generally required to complete a thesis, and sometimes a publication. As a result, students focus more on research in a narrow area. Their exposure to statistical methods in applications is often minimal.

3. Countermeasures and Proposals

3.1. The cultivation of statistics literacy in primary and junior high schools

In the current system with a 9-year compulsory education, the core of statistics teaching should focus on secondary schools.

The basic practice of fulfilling quality-oriented education requires us to cultivate statistics literacy among teenagers. We should implement quality-oriented education and change from the "double basics" (i.e., basic knowledge and basic skills) to the "four basics" (i.e., basic knowledge, basic skills, basic ideas, and basic experiences), from the "double abilities" (i.e., abilities to analyze and solve problems) to the "four abilities" (i.e., abilities to analyze, solve, discover and question), and from the training of unilateral deductive thinking to the training of both deductive thinking and inductive thinking (Shi and Liu, 2007).

3.2. Some suggestions to improve statistical teaching in high schools

3.2.1. Changing the thinking mode

There is no doubt that mathematics, mainly as a deterministic science, plays a leading role in developing the ability of thinking and reasoning for young students. The deterministic thinking mode implies that the same conclusion should be drawn under the same conditions. If different conclusions are drawn, at least one conclusion must be incorrect. However, probability and statistics, as a science that studies stochastic events, needs to be taught differently, and needs to help students to develop a new thinking mode --- a stochastic thinking mode, which is quite different from the deterministic one.

The differences, if not properly understood in early education, can hinder the teaching of statistics. By understanding and accounting for the differences between mathematics, probability and statistics, we can better help students overcome some obstacles to statistics learning. We believe that statistical learning should start at earlier stages: at the pre-college (mainly secondary school) level, we should encourage the adoption of a probabilistic "way of thinking." In the introductory stage of teaching statistics, it is important to make clear what is deterministic and what has a degree of uncertainty.

3.2.2. Building real statistical understanding through activity-based statistics

Regarding the cultivation of statistics literacy in primary and junior high schools, the work of Scheaffer and others under the name of "activity-based statistics" (Scheaffer, Gnanadesikan, Watkins, and Witmer, 1996; Gnanadesikan, Scheaffer, Watkins, and Witmer, 1997) is an excellent resource. Activity-based courses can help students overcome some misconceptions about probability and enhance the learning of statistical concepts.

3.2.3. Clarifying some issues and avoiding misunderstandings

In many old versions of statistics textbooks in China, the following problem is discussed: suppose a fair coin has been tossed several (even many) times in succession and has come down Heads each time, then what is the chance of it coming down Heads on the next toss? A standard answer is expected to be one in two, regardless of what has happened. Of course, it is correct from the theoretical point of view, because the coin is assumed to be fair, and the next toss is independent of the previous ones. However, we may think differently from a statistical perspective. The observations of, say, twenty consecutive heads should lead us to doubt that the coin is fair. With every coin toss, we can update our belief in what the next toss might be. After obtaining twenty Heads in twenty tosses, we should have less faith in the assumption $P(\text{Heads}) = 0.5$. We should have more faith in the alternative $P(\text{Heads}) > 0.5$. As statistics educators, we should realize the importance of evidence-based analysis, even though a change from a mathematical exercise to a statistical problem can be challenging (Garfield and Ahlgren, 1988; Garfield, 1995). Furthermore, activity-based courses and the use of small groups appear to help students overcome some misconceptions about probability and statistics.

3.2.4. Training of "backbone teachers" in primary and middle schools

With the implementation of the New Mathematics Curriculum Standards in China, many middle school teachers are inadequately prepared both in their knowledge of statistics and probability, and in pedagogy (Li, 2004). A necessary step is to implement a plan for training middle school teachers. The objective of the training is not only to teach theory and methods, but also to improve the trainees' abilities in statistical thinking when it comes to statistical practice. The main topics include survey design, data collection and summarization, computation, analysis and interpretation of results. In order to achieve this goal, we must help the trainees understand the statistical ideas.

3.2.5. Encouraging postgraduate students to teach in primary and middle schools

 Although this is a long term solution for improving the quality of teaching at those levels, we must start this today.

3.3. National Proficiency Examinations or Competitions in Statistics

Young learners in China are often highly motivated to study to achieve high levels in national or regional proficiency examinations or competitions. This happens in many other highly visible subjects including mathematics, English, and music. National proficiency examinations or competitions can promote the visibility of statistics as an independent subject, and motivate and challenge more young learners. In China, there are currently no counterparts to the Advanced Placement Program in the US. We think that an examination system that allows younger learners to attain higher levels on competitive basis would receive better attention from both parents and students in China. Parental support is a critical part of the Chinese education system. Under the current conditions, considerable effort is needed to initiate such examinations or competitions, but if done well, it will be worth the effort.

Currently, a new program on the qualification examination and the training of "Data Analysts," jointly hosted by the Testing Centre of the Ministry of Education, local government statistical agencies, and universities or research institutes, could establish the ground work for this initiative.

3.4. Two suggestions for undergraduate statistics education

3.4.1. Innovative teaching methods

We must change our teaching mode from a lecture-and-listen format to one that engages students in active learning. Appropriate computer-aided tools can stimulate students' interest, and cultivate their experimental

ability. Using software that allows students to visualize and interact with data appears to improve students' understanding of random phenomena and their appreciation of data analysis. Universities can now afford more software and hardware purchases in China, so we are optimistic that they will be utilized well.

3.4.2. Deepening the application of statistics in many fields and widening the employment channel of statistics majors

Since 2005, under the approval of the Chinese Ministry of Education, the School of Mathematics and Statistics at Northeast Normal University has prepared to establish the first laboratory of applied statistics in China. Currently, the authors are all associated with this development. The main goal of our laboratory is to promote the development of applied statistics in China, driven by practical problems in the fields of bioinformatics, educational and psychological measurements, economics and finance, communication systems and so on (Shi et al., 2008). We hope that this will set an example in the right direction.

It is important to update statistical methods to meet the needs of society. In the past several decades, the development of statistics in China has over-emphasized mathematical theory and under-emphasized the connections to applications. We need to take a more balanced approach, and make sure that our research and education reflect the emerging trends in modern statistics.

3.5. Expanding interdisciplinary cooperation and strengthening international exchanges

In recent years, many institutions of higher education and scientific research institutes in China have held a series of large-scale international conferences, such as the 2006 International Conference on the Frontiers of Statistics ---- Biostatistics and Bioinformatics, which stimulate research at the interface between statistics and biomedical and biological sciences. Through the sustained efforts of Chinese statisticians and their friends, including many from developed countries, we see a positive trend in international collaboration and exchange activities, which in turn will help statistics education in China. This trend should continue.

4. Concluding remarks

In the developed countries such as the United States and Canada, statistics education is highly respected; graduates in statistics are in high demand and well paid. Statisticians are employed in pharmaceutical companies, banks and insurance companies, and high tech companies, in addition to academia. They play an important role in many areas of government statistics, such as population census, educational and psychological measurement, economics policies, and environmental policies.

There have been admirable achievements in statistics education in China. Statistics has already been classified as one of the basic subjects in some schools. If we use the United States as an example, we expect that in China as the demand for statistics applications rises, the demand for statisticians will rise to exceed supply. Schools and educators at all levels must ensure that we are well-positioned for a bright future.

We believe that the most important challenge in statistics education is to connect statistical thinking with real world applications at every level. This is true in most other countries, but especially so in China today. We realize that it is hard for many students to grasp the essentials of statistics, and we believe that it helps to explore the differences between mathematics, probability, and statistics. In other words, an excellent statistics educator must teach students what statistics does, but also what it means.

It must be realized soberly that there is still a long way to go for statistics education in China to catch up with that in some developed countries such as the US and UK. Through extensive international cooperation and exchanges, we can use the successful experience of other countries as a guide. Of course, we must understand

and adapt to the special characteristics of the education system in China. We hope that our analysis and proposals can stimulate the interest of other educators in the future of statistics education in China.

Acknowledgements

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