Selçuk J. Appl. Math.
Vol. 10. No. 1. pp. 95-106, 2009

Selçuk Journal of Applied Mathematics

On Some Reform Initiatives on Statistics Education throughout the World

Doğan Yıldız, Atıf Evren

Yıldız Teknik University, Faculty of Sciences and Arts, Department of Statistics, Davutpaşa-Esenler, 34210-İstanbul, Turkey
e-mail: dyildizr@yildiz.edu.tr, aevren@yildiz.edu.tr

Received: December 01, 2008

Summary. The discussions on the development of statistics education were intensified especially at the end of nineties in United States of America. In this respect, some means were taken into consideration to develop statistics education especially in undergraduate levels. Some ideas were put forward to evaluate the quality of statistics courses both offered in statistics departments and in other departments providing statistics as service courses. In these debates, the skills that the graduates of statistics departments were supposed to possess were also under investigation. Besides the roles of theoretical courses, applied courses , mathematics courses offered in statistics curriculum, the opportunities to collaborate with some of the departments including mathematics, and the effects of technology on statistics education were the other items on the agenda.

Key words: Statistics education, statistical thinking, foreign reform trials on statistics education.

2000 Mathematical Subject Classification: 97B40.

1. Introduction

"Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write." H.G. Wells

Minton (1983), in his article "The visibility of statistics as a discipline" emphasizes that any scientific area of research deserves to be qualified as "discipline" if it satisfies the following requirements:

1. the existence of a body and a literature of a theory,
2. the existence of a large number of professional people studying/ working on this area ,

3. the existence of a large number of periodicals publishing the contemporary discussions and innovations in this area ,

4. the existence of an external demand towards the services created by this field of study.

It is sure that statistics satisfied these requirements totally at the beginning of 20th century. Nevertheless Minton emphasizes that statistics was not then qualified as a discipline since there were not enough number of statistics department's suggesting/providing career opportunities for their students.
More than 20 years, ASA (American Statisticians' Association) has been organizing meetings, symposiums and round-table sessions to evaluate the quality of statistics education both in undergraduate and graduate levels of universities. In 1999 a group of statisticians came together to discuss the problems and difficulties of statistics education in Virginia, USA...
In these discussions the main professional responsibilities of statisticians were described as applying statistical methods and theory, collecting, analyzing and interpreting the data, general statistical consultancy, checking general procedures and constructing diagrams, preparing sampling plans and sampling.
Besides it was emphasized that in their work places the statisticians were responsible for writing statistical computer macros, utilizing data bases, performing web-based surveys. In addition they were expected to prepare some technical reports and presentations and to participate in some other jobs that needed collective action and team work.
In addition , they were expected to be proficient in the following topics: General linear models, ANOVA, elementary analysis techniques, reliability statistics, survival statistics, the analysis of principal components, acceptance sampling, moving averages, experimental design, graphical analysis, process control, sampling, the principals of statistics, survey sampling methodology and techniques, methods and techniques for research, data collecting.

2. Some proposals for statistics undergraduate programs

In 1999, a meeting which was held in United States yielded a very important document named as "Undergraduate Statistics Education Initiative". It will be useful to list some of the conclusions reached during this organization:

The vision of undergraduate statistics education initiative (USEI):

· To create opportunities for providing undergraduate students better quantitative techniques,

· To provide the students a more stronger background for statistical reasoning for more sophisticated and specialized areas of research,

· To increase quantitative literacy among modern work force.

The mission of USEI:

· To prepare guidelines for statistics programs by symposiums and workshops,

· To introduce public the potential and the products that the statistics education possesses currently,

· To support the current services and developments in statistics curricula.

Some of the topics that were held in these debates and which should be highlighted are the following:

i) The positions/ areas on which the statisticians are being currently employed.

Statisticians contribute in designing plans for data collecting in their institutions. They analyze data, as well as developing methodologies for data analysis. In these analyses they can improve mathematical and probabilistic models and use statistical and other softwares. At the same time, in cooperation with the scientists from the other fields, they can interpret or formulate some quantitative arguments.

ii) The relationship between statistics curriculum and possible career steps of young graduates

It should be noted that any curriculum should offer its graduates a variety of career opportunities. Therefore the statistics programs should be enriched to increase the number of different specialization or professional career opportunities for its graduates.

iii) The recognition of the existences of the differences between statistics and mathematics plays an important role in constructing statistics curriculum

Although mathematics provides what is theoretically essential for statistics, most of the time, statistical reasoning is different from mathematical reasoning. Hence statisticians utilize a lot of skills which are not mathematical in nature. Therefore a statistics curriculum does not solely provide a list of mathematical propositions or courses to its attendants. Rather an undergraduate statistics curriculum especially must focus on developing its students' abilities on data analysis.

iv) Basic subjects of statistics that must be learnt by the students

Statisticians are supposed to analyze and interpret the data. For these purposes, they have to carry out the main procedures such as summarization and desciption of data, performing graphical or visual analyses and basic formal

procedures. To be able to carry out basic formal procedures, they have to have a strong understanding on some basic statistical concepts like variability, probability, independence, correlation, causality, statistical confidence, the limitations of statistical analysis, etc. Basic subjects are the theory of statistics (probability, the distributions of random variables, estimation and hypothesis testing procedures), graphical data analysis, regression (simple, multiple, diagnostic techniques), collecting data (sampling, experimentation) and the analysis of variance.

v) Non-technical skills that statistics students must have.

The skills under this category are the ones most frequently neglected by the current statistics programs. These are the communication skills that are not directly related to mathematical reasoning. Statisticians must communicate with various scientists from the other fields of scientific study in business life. Therefore any statistics program must contribute a lot to the students' communication skills on efficient writing and speaking.

vi) Computer skills

It is highly recommended for statisticians to acquire a large list of computer abilities. The undergraduate students must learn to use word, spreadsheet programs, web applications, communications via electronic mail, and power point presentations. To be able to write macros, a student must possess the minimal mental ability to analyze the problem by the help of algorithms. In addition , it will be beneficial for the students to increase their abilities and experiences on softwares, and in the process of manipulating and managing the data , and to get accustomed to various aspects and difficulties of statistical calculation. Finally it will also be advisory to acquire the knowledge of different operating systems.

vii) Mathematical skills that the students of statistics departments must have

Mathematical skills are essential for understanding statistical theory. Statistics students at least must have a strong understanding on multivariable mathematics, derivative, integration, linear algebra (in which a special emphasis on matrix operations are going to take place). The methods for proving the theorems have also vital importance.

viii) A basic classification in suggesting the students elective courses

It may be useful to put a rough differentiation between the students who are planning to work in academic areas and who are not. Then some of the elective courses may or may not be offered the students depending on the future vision they have.

ix) The students intending to attend statistics graduate programs

A mathematical statistics course (following a course in real analysis and/or probability) must be recommended especially for the candidates of doctoral study in statistics.

x) A classification of course offerings for the students intending to work in business life just after graduation

· The lectures on quality control, experimental design, and the analysis of variance are especially important for the graduates intending to work in industry, or in production and engineering departments. It will also be beneficial for them to take courses on time series and reliability analysis.

· The lectures on statistical softwares, survival analysis, categorical data analysis and the analysis of variance will be crucial for those planning to work in medicine or in health sector.

· Sampling, survey studies, multivariate statistics, quality control, and time series courses are strictly recommended for those intending to participate in trade or in business administration.

· The lectures on sampling, survey studies, bootstrapping, multivariate statistical analysis and some issues of law should be taken by those aiming at the sector of public services.

xi) The importance of data analysis in statistics education

Students must encounter with a sequence of difficulties arising from the data and thus acquire a set of abilities on data manipulation and data management during their education processes. These abilities include especially the ones related to manipulating (and summarizing) messy data. The continuous emphasis on the importance of data analysis will make students experienced and appreciate the interdisciplinary character of statistical studies.

xii) The importance of mathematical statistics course in statistics undergraduate education

The mathematical statistics courses which are developed in "traditional" ways deserve a careful inspection and/or a new design. A classic mathematical statistics course is taught from the point of view of large sample theory. Nowadays this approach does not satisfy the practical needs of statistical studies. A modern mathematical statistics course should also be based on nonparametric and computer-intensive methods as well as the traditional equipments it already has got.

xiii) On the rights of statistics graduates to get different titles

A lot of specialists think that statistics should be considered in a broader sense. In this context it may be much more convenient for the statistics' graduates to

have the titles such as "data scientist" or "data specialist". Because these titles refer to precisely the jobs such as collecting, designing, managing , manipulating and transforming data as well as performing exploratory and basic analyses most of which have already been carried by the statisticians. This necessity for the redefinition of statistical jobs also arises from some legal problems. (Higgins, 1999)

3- On some debates on introductory statistics /or service courses

Within last 20 years many issues have been discussed about the introductory statistics courses. Historically, these courses were qualified as hard, boring, discouraging, and frustrating. These frustrations encountered among both the students and the instructors resulted in a variety of sessions and workshops in which a lot of pedagogical issues were taken into consideration. (Hogg, 1992) and (Cobb, 1992) Year by year, the number of students taking these courses increases considerably while the debates on changing the format and the content of the courses are still going on.

A significant number of statisticians participated in the reform efforts on introductory statistics courses in the near past. National Science Foundation of America supported a lot of projects in this respect. Moore (1997a) analyzed these reform efforts under three categories: Content (more data analysis, less probability), pedagogy (less number of classes or sessions, more efficient learning methods) and technology (emphasis on data analysis and simulation)

Hoaglin and Moore (1992) referred to a variety of reading documents and statistics to give instructors the knowledge of new contents and techniques. Garfield (1995) proposed a research perspective on why, how and in which direction, the teaching methods should be changed. Besides, a lot of statisticians put forward a great number of proposals to increase the usage of technology especially in introductory levels.[1]

3.1. A focus on statistical thinking

It should be emphasized that the reform movement focuses on some concepts, modes of reasoning and some ideas. Butler (1998) on his study, "On the failure of the widespread use of statistics" shows that although more and more people take introductory statistics courses, these people don't have the skill to use statistical methods in their jobs. The reason for this phenomenon should lie on the traditional methods of teaching statistics. These methods depend on compartmentalized nature of statistics education. Of course the students who have taken introductory courses are not supposed to be experts of statistics but at least they are supposed to use their mental abilities on statistics whenever they encounter real world phenomenon.

Snee (1990) describes statistical thinking as the speculated process in which variability is taken into account as an inevitable phenomenon which exists all

[1] For instance Velleman, P.F., Moore, D.S (1996), "Multimedia for teaching statistics: Promises and pitfalls." The American Statistician, 50, 217-225.

the things that surround us. According to this definition all statistical study is perceived as something that consists of a set of interconnected processes. Definition, quantization, control, and reducing variation are the parts of this overall process which provides opportunities to advance the analysis. Snee while appreciating statistical thinking as a tool for developing products and/or services of the business world, also emphasizes that the acceptance of the presence of variation as a fact, at least, increases the ability to suit new conditions.
Wild and Pfannkuch (1999) emphasizes the ambiguity present in the concept "statistical thinking". For them, the projects given to the students by their instructors do not, unfortunately, help reducing this ambiguity.
Hogg (1992) discusses the perspective of a statistics course which is supposed to focus on the processes of collecting, summarizing and interpreting data, and also on emphasizing the limitations of statistical inference. This course should highlight the following issues:

1. The emphasis on the elements of statistical thinking:
    a. The need for data,
    b. The importance of data production,
    c. the omnipresence of variation,
    d. measuring and modeling the variation.
2. The more emphasis on data and concepts, the less number of formulas whenever possible. Automatization of calculations and displays. An introductory statistics course should
    a. be not only realistic but also be based on real data,
    b. take some crucial concepts like association, causation, observation, experimentation, panel data, time series into consideration,
    c. utilize computers instead of computational descriptions,
    d. give less importance on formula derivations.
3. As an alternative to classical teaching method , active learning should be encouraged by the following means:
    a. collective discussions and problem solving,
    b. exercises in laboratories,
    c. presentations based on data produced in classrooms,
    d. written or oral presentations,
    e. projects for individuals or for groups.

3.2. The evaluation of the attitudes of students towards statistics

To equip the students with the desirable results of courses is not only complicated but also depends on many factors. Schau (2000) proposes the following model to discuss this issue:

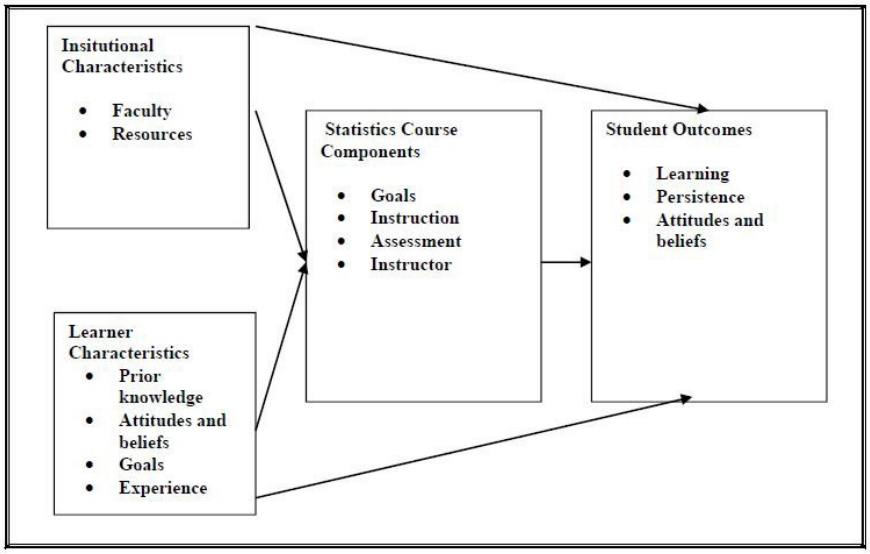


Figure 1. Model of factors influencing student outcomes

This model emphasizes that the instructor is only a factor in the success or in the performance of the course and it also interacts with other factors.

4- The future of statistics and undergraduate programs from an academic point of view

According to the figures of the Bureau of Labour Statistics, in 1998 there were 110 undergraduate programs, and 60 doctorate programs offered in statistics in USA. Apart from vocational schools programs, 7 million of students were registered for undergraduate programs. These students were attending more than 2300 undergraduate programs. A minority of these were statistics programs. Generally, mathematics departments were the hosts for statistics education. It was also known that most of the mathematics departments couldn't offer even more than a few statistics courses to its attendants. The resources were limited then as well.
It will be suitable to refer to Moore and Cobb's (2000) study which was presented in a meeting in which the cooperation opportunities between mathematics and statistics were taken into consideration. Some of the titles from this study are given below:

4.1) Statistics is culturally healthy but academically in danger

Some of the indicators of statistics for being healthier culturally than mathematics are as follows:

· The employment rate in non-academic positions is higher in statistics than in mathematics. Almost half of the students completing their doctoral education in statistics departments work in non-academic jobs. Apart from mathematics, graduate degree in statistics is very valuable indeed.

· The ratio of women studying /working in statistics is higher than that of working in mathematics.

· The ability to manage common studies with other fields of science is much higher than that of mathematics.

· By the virtue of current technological changes, the feasibility of statistical studies has been increased dramatically. This is of course an advantage for statistics.

· The growth rate of registration for introductory statistics courses is significantly higher and it indicates the common interest that arose dramatically in the society for statistics and statistical studies.

· Besies these positive developments, some aspects of the academic weakness of statistics can be listed as below:

· The existence of small departments, the limitations on resources, the phenomenon of compartmentalized education.

· "Statistics without statisticians". Hahn and Hoerl (1998) summarize the situation in industry by this motto. The situation in the academic world is more or less the same. Everybody uses statistical techniques but there are a few experts in statistics.

· The rate of new course offerings is very low except the introductory courses. A few students could go beyond introductory level and take more advanced courses.

· The core of this area should be discussed and defined clearly. What could be the common agenda that unites both statisticians dealing with marketing research and statisticians dealing with molecular biology? This question seems meaningful at the moment.

· Will statistics be swallowed by information technologies? Although technological development provides statistics a lot of opportunities to grow rapidly, the same development cause statisticians in being doubtful about the future of their fields.

4.2) Mathematics is organizationally healthy but insular.

Mathematics does not have the fragility that statistics has. Mathematics departments have existed for long time and hence they have managed themselves to be/keep institutional. This situation is not valid for statistics. There are not many statistics departments and it is not definite for them to be stronger in the future.

According to some experts, the main weakness of academic mathematics (infact every kind of mathematics) is its unwillingness (or narrow-mindedness) to participate in common scientific studies or projects with other disciplines. On the contrary, the statisticians generally show their eagerness to participate in such studies. Statisticians are generally in touch with other fields. A group

of mathematicians support the same idea. (Ewing, 1999) "The communication level between the mathematicians and other scientists is at the lowest levels globally." This problem which must be solved immediately also indicates that mathematics and statistics need each other strongly.

4.3) Mathematics and statistics need each other.

· On the conflict between automation caused by technological development and scientific thinking, mathematics and statistics are two natural allies. Both of these sciences claim that technological change have not made (and won't make) the conceptual framework they produce useless.

· Statistics undergraduate programs need mathematics courses. Besides graduate statistics courses needs some undergraduate mathematics courses.

· Statistics can serve mathematics itself as being an application area for mathematics, and a learning methodology based on technology.

5. Conclusion

1) Statistics is basically an applied science**.** Summer schools and camps, obligatory practices in industry or in business administration are natural and inevitable elements of this education process.
2) Statistics is interdisciplinary. The application opportunities should be increased in some other sciences (engineering, social sciences).
3) Statistical studies frequently need team work. Therefore statistics programs should aim to develop students' collective working abilities.
4) The results of the analyses realized by statisticians must be visible and readable by the scientists from the other research areas. For that reason the development of statisticians' communication skills is crucial in order to carry common studies or projects with other branches. This point is very important and should be emphasized once more.
5) A good statistics education must teach its students the methods of learning by themselves.
6) The abilities to use statistical softwares and to write macros are the necessary components of statistical abilities and the natural requirements of business life. A good statistics curriculum must aim to develop its students programming skills.
7) Applied statistics is dependent upon data. Students must be familiar with data bases and technologies. A good statistics education should motivate and manage its students to develop their abilities in this respect.
8) Students must learn thinking via graphics and displays. It is also vital for them to explain data visually for those who don't have any sufficient statistical background. (Hogg, 2000)
9) Every topic of statistics cannot be covered in detail especially when there are a number of students in sessions. On this matter the instructors must be realistic and not expect their students to learn every issue on statistics curriculum. The productivity percent is (and will be) always lower than one hundred.

10) None of the statistics programs were designed to cultivate professional statisticians. It is not realistic to expect the undergraduate students to acquire the knowledge of higher levels!
11) A lot of departments consider statistics as a minor. Therefore, for these students whose majors are not statistics, it will be wiser to offer some courses for their own specialization branches instead of a standard package of statistics courses. For example a regression course may be demanded greatly by the students whose majors are business administration, biology and psychology. It is sometimes wiser to take some facts as just facts without questioning the current situation.
12) To agitate interest or enthusiasm towards statistical studies among a wide range of scientists is possible by explaining the basic concepts and methodologies of statistics clearly. The legitimacy of any discipline or a science from the points of views of other fields depends on the wide-acceptance and usage of these concepts, ideas, and methodologies by other "users". The success mostly depends on that.

References

1) Aliaga, M. (1998), "Re-thinking Stat 101." Paper presented at the Fifth International Conference on Teaching Statistics, Singapore.
2) Bryce, G.R., Gould, R., Notz, W.I., Peck, R.I., "Curriculum Guidelines for Bachelor of Science degrees in Statistical Science"
3) Bureau of Labor Statistics (2000), Occupational Outlook Handbook, 2000-01. Bulletin 2520.
4) Butler, R.S. (1998), "On the failure of the widespread use of statistics", Amstat News, March, 84.
5) Cobb, G. (1992), "Teaching Statistics, in Heeding the Call for Change", MAA Notes, 3-43.
6) Ewing, J., ed. (1999), "Towards Excellence: Leading a Mathematics Department in the 21st Century", Providence, RI: American Mathematical Society
7) Garfield, J. (1995), "How students learn statistics" International Statistical Review, 63, 25-34.
8) Garfield, J., Hogg, B., Schau, C., Whittinghill, D. (2000), "Best Practices in Introductory Statistics", Draft 2000.06.19
9) Garfield, J. (2000), "An Evaluation of the Impact of Statistics Reform". Final Report for NSF Project REC-9732404.
10) Hahn, G., and Hoerl, R. (1998), "Key Challenges for statisticians in business and industry", Technometrics, 40, 195-200.
11) Higgins, J.J. (1999), "Nonmathematical Statistics: A New Direction for the Undergraduate Discipline", the American Statistician, 53, 1-6.
12) Hoaglin, D.C., Moore, D.S., (Eds) (1992) "Perspectives on Contemporary Statistics", Mathematical Association of America, MAA Notes, Number 21.
13) Hogg, R. (1992), Report on Workshop on Statistics Education, in Heeding the Call for Change, MAA Notes, 34-43.

14) Hogg, R.V., Ritter, M.A.; Starbuck, R. (2000), "Advice from Prospective Employers on Training BS Statisticians", A paper prepared as part of the Undergraduate Statistics Education Initiative of the American Statistical Association, June 30 2000.
15) Loftsgaarden, D.O., Watkins, A.E. (1998), "Statistics teaching in colleges and universities: Courses, instructors, and degrees in fall 1995." The American Statistician, 4,308-314.
16) Marquardt, D.W. (1987), "The Importance of Statisticians", the Journal of American Statistical Association, 82, 1-7.
17) Minton, P.D. (1983), "The Visibility of Statistics as a Discipline", the American Statistician, 37, 284-289.
18) Moore, D.S. (1997a), "New Pedagogy and new content: the case of statistics", International Statistical Review, 65, 123-137
19) Moore, D.S. (1997b), Response, International Statistical Review, 65,162-165.
20) Moore, D.S.(2000), "Undergraduate Programs and the Future of Academic Statistics", An Adaptation of the keynote talk at a Symposium on Undergraduate Education held prior to the 2000 Joint Statistical Meetings in Indianapolis.
21) Moore, D.S., and Cobb, G.W. (2000), "Statistics and mathematics tension and cooperation", American Mathematical Monthly, 107, 615-630.
22) Niss, M. (1999), "Aspects of the nature and state of research in mathematics education", Educational studies in Mathematics, 40, 1-24.
23) Schau, C. (2000), Personal communication.
24) Snee, R. (1999), "Discussion: Development and use of statistical thinking: a new era. (Response to Wild and Pfannkuch. International Statistical Review, 67,255-258.
25) Wild, C.J., Pfannkuch, M. (1999), "Statistical thinking in empirical enquiry. International Statistical Review, 67, 221-248.
26) Zahn, D.A., Davis, N.A. (1996), "Toward creating a learning community in Large-sections, introductory statistics courses." Session 186 (poster) at the Joint Statistical Meetings, Chicago.