From Phillips, Brian (Ed.), (1997) Papers on Statistical Education presented at ICME-8 (International Congress on Mathematics Education-8) Seville, Spain, July 14-21, 1996. Hawthorn, Australlia: Swinburne Press. ISBN 0 85590 753 3

STATE OF THE ART OF TEACHING PROBABILITY AT SECONDARY LEVEL

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Abstract

With the aim to determine the state of the art of the teaching of probability at secondary level, more than 200 copies of a questionnaire were distributed to several countries, excluding the USA. Responses are summarized in five tables with comments. We hoped that a list of institutions would emerge where research on teaching probability is going on in different countries, but this is not the case. It seems appropriate, however, to refer the reader to the "Newsletter of the international study group for research on learning probability and statistics" for more information. We planned to also collect information regarding the education of gifted students but as the reaction to this call was so weak we decided not to touch upon this question here.

Introduction

At the 8th International Congress on Mathematical Education, Sevilla, 1996, Topic Group 9 addressed the topic "Teaching Probability and Statistics at Secondary Level". The first part of the probability session was devoted to the State-of-Art of teaching probability throughout the world. In order to give a reliable report, we have distributed more than 200 copies of a questionnaire on pre-university probability teaching to several countries, excluding the USA. As for the USA, the NCTM Standards may provide a reasonable orientation. Responses are summarized in 5 tables with comments. (Responding countries are given in the tables.) Selected comments regarding individual countries are provided in the last section.

We hoped that a list of institutions would emerge where research on teaching probability is going on in different countries, but this is not the case. It seems appropriate, however, to refer the reader to the "Newsletter of the international study group for research on learning probability and statistics, presently edited by Carmen Batanero (Departamento de Didactica de las Matematicas Facultad de Ciencias de la Educacion, Universidad de Granada), with e-mail: batanero@goliat.ugr.es for continuing information in this area.

Our intention was to also collect information regarding the education of gifted students. For this reason we circulated another questionnaire to representatives of the competition community, including leaders of the Olympic teams. The reaction to this call was so weak that we decided not to touch upon this question here.

School system

Possibilities of teaching any subject are highly influenced by the specification of the school system. Especially, when speaking about "secondary education", we have to be sure that this means more or less the same for the countries being analysed. In most of these countries the last 4 years of pre-university education are considered to be secondary. In some countries this means the last 6 years (e.g. in the Netherlands, Thailand), in others 8 years (e.g. in Argentinia, England), even there are countries where hard to decide which could be classified as secondary (Denmark, Hungary). In this later cases we have chosen for our study the years which may be terminated as "upper secondary". The age when secondary education starts is given in Table S, column S1.

It is important to know what freedom have the teachers, the individual schools or larger areas in deciding on content and/or methods of instruction. In this respect one should know if there is an obligatory national curriculum in the given country, and if yes, then does it fully prescribe the subject matter, or for what percentage of the teaching time. A more basic, but earlier description is given in Howson (1991).

We were interested if probability is included in the pre-university curriculum (in any form) in the given country. All responses were YES, with some remarks like Yes, but very little.

Examination and assessment play a decisive role in implementing the intended curriculum. Without a national examination event a silent resistance on behalf of the teachers characterises even the countries where probability is an obligatory part of the intended curriculum. That is why we have asked the following 4 questions:

S4a. Is there a national/regional examination event at the end of the secondary education?

S4b. Is there a national/regional examination event at the time of turning to the secondary education?

S4c. Is university entrance conditioned on results of secondary years?

S4d. Are there nationally organised examinations for university entrance?

It should be noted that Assessment and Evaluation was the subject of a recent ICMI Study Group. Their proceedings, Niss (1993), should be consulted for further information.

Teachers' education, knowledge in stochastics is also a decisive factor. We were interested in their pre-service education, namely what stochastics

courses are obligatory for candidates for teaching at secondary level. The concrete questions were:

S5a. Must complete a basic course in probability?
S5b. Must complete a basic course in statistics?
S5c. Must complete a course in teaching probability?

It seems an internationally accepted view that students teachers should be informed about what kind of attitude can they expect in their future profession. Fishbein (1990), e.g. writes the following: "The training of the probability and statistics teacher should necessarily include methods for developing his intuitive background in this area". Other papers of the conference Proceedings Hawkins (1990) provide further insight.

Table S. Characteristics of the School system

Country	Question number								
	S1	S2	S4a	S4b	S4c	S4d	S5a	S5b	S5c
Argentina	11	N	—	—	—	—	Y	Y	N
Australia	11	N	Y	N	Y	N	—	—	—
Austria	11	50	Y	N	N	N	N	Y	N
Bulgaria	15	YF	Y	N	N	Y	Y	N	N
Denmark	D	65	Y	Y	Y	Y	Y	Y	N
England	11	75	Y	Y	Y	N	N	N	N
Estonia	15	75	Y	N	N	N	Y	Y	N
Finland	15	GL	Y	N	Y	Y	Y	N	N
France	15	YF	Y	N	Y	N	N	N	N
Ghana	11	YF	Y	Y	Y	Y	Y	Y	Y
Hungary	?	50	Y	N	Y	Y	Y	N	N
Italy	15-19	YF	Y	Y	OfS	OfS	N	N	N
Lebanon	15	YF	Y	Y	Y	N	Y	Y	N
Libya	15	N	Y	Y	Y	N	N	N	N
Netherl.	13	YF	Y	N	Y	N	Y	Y	N
Poland	15-19	N	Y	N	Y	N	Y	N	Y
Spain	11	MR	N	N	Y	Y	N	N	N
Thailand	13	YF	Y	Y	Y	Y	Y	N	N
Turkey	14-17	YF	Y	N	Y	Y	inS	Y	inS

Note.
Column S1 lists age when secondary education starts.
Column S2 summarises responses with the following codes:
N: No, YF: Yes, and it fully specifies the subject matter, Number: Percentage of the teaching time, GL: Guidelines are given, only.
Columns S4a-S4d summarise responses with Y (yes), N (no) answers, and with — if no answer was received. In Italy, OfS means: Only for Some (universities, or faculties).
Columns S5a-S5c summarises responses with Y (yes), N (no). In Turkey, inS means that probability is dealt with within the statistics courses, mainly.

Curricular issues

There is an old tradition to include Descriptive Statistics in the pre-university teaching, in many countries that goes back to the middle of the last century. This tradition is followed now in all the countries who responded to our survey. On the other hand, Exploratory Data Analysis is a new unit, and gaining space, as shown by the data of Table C, column C1b. Probability Calculus, Probability Theory is part of the intended curriculum at many countries, but "What is taught varies a great deal". Column C1c concerns the implemented curriculum in most cases. We were also interested about the inclusion of units on the Methods of Statistical Inference (Rudiments, at least). Answers from Bulgaria and Denmark were the only positive, and to some extent, Spain.

Table C. Curricular Issues.

	Probability											Distributions						
	C1		C2		C3													
	b	c	a	b	a	b	c	d	e	f	g	uf	Bi	ge	hy	Po	ui	no
Argentin	N	N	N	N	N	N	N	N	N	N	N	–	–	–	–	–	–	–
Austral	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	Y
Austria	Y	?	Y	N	N	Y	Y	Y	N	N	N	Y	Y	N	N	N	N	Y
Bulgaria	N	Y	N	N	–	–	–	–	–	–	–	Y	Y	N	N	N	N	Y
Denmark	N	Y	–	–	Y	Y	N	N	N	N	Y	Y	Y	N	N	Y	Y	Y
England	Y	N	N	Y	N	a	a	a	N	Y	N	a	a	a	a	a	a	a
Estonia	N	Y	–	–	N	Y	–	N	N	N	N	N	Y	N	N	N	Y	Y
Finland	N	N	N	N	N	Y	Y	N	N	N	N	N	Y	N	N	N	N	Y
France	N	Y	N	Y	N	N	Y	Y	N	N	N	Y	Y	N	N	N	N	N
Ghana	N	N	N	N	Y	N	N	N	N	N	N	Y	Y	N	N	N	Y	Y
Hungary	N	Y	Y	N	N	N	Y	Y	N	N	N	Y	Y	N	N	N	N	N
Italy	N	Y	N	Y	N	Y	Y	N	N	N	N	Y	Y	N	N	N	N	N
Lebanon	N	Y	Y	N	N	Y	N	N	N	N	N	N	Y	N	N	N	N	N
Libya	N	Y	Y	N	Y	Y	Y	Y	N	N	N	Y	Y	N	N	N	N	N
Netherl–a	N	Y	Y	N	N	Y	Y	N	N	N	N	N	Y	N	Y	N	N	Y
Netherl–r												N	Y	N	Y	N	N	Y
Poland	N	Y	Y	N	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
Spain1	N	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	Y	N	N	Y	N	Y
Spain2												Y	Y	Y	N	N	Y	Y
Thailand	N	N	N	Y	–	–	–	Y	–	–	–	Y	Y	N	N	N	N	N
Turkey	N	Y	–	–	–	–	–	–	–	–	–	Y	Y	N	N	N	N	Y

Note.
Yes and No answers are given. Letter "a" in England means "in optional part of A-level".

As for the curricular position of probability we have asked two questions provided if it is included at all:

C2a. Probability is the central core of the stochastics part of the curriculum (Descriptive Statistics would come later, Inferential Statistics is based on a firm probability foundation).

C2b. Probability is an optional exactification of inferential procedures (Inferential methods are derived from Descriptive Statistics, a naive notion of probability is used for motivation, with the option of making statistical arguments more r rigorous later).

There are several approaches to teaching probability. We have identified some of them, asking if these applies to the given country

C3a. Probability is developed by axiomatic set-up.
C3b. It is essentially combinatorics, disguised as probability.
C3c. Probability is restricted to urn-models and games.
C3d. Probability is extended to applications.
C3e. Probability is developed as a model-building device.
C3f. Probability is developed through experimental and project work.
C3g. Inferential reasoning is emphasised.

Probability calculus and theory

The following 4 questions aimed at an insight on how far Probability calculus is developed.

op. Operations among events
de. Dependence, independence of events
cp. Conditional probability
Bf. Bayes' formula

Operation among events, dependence, independence is generally included in the subject matter, while conditional probability, the Bayes' rule varies even within the same country. Table P provides insight to these later two areas.

It is rather informative to know what distributions are dealt with in the classroom. The questionnaire specified the following ones:

uf Uniform on a finite set
bi Binomial
ge Geometrical
hy Hypergeometrical
Po Poisson
ui Uniform on an interval
no Normal
ex Exponential
ot Others (specify)

Our list seems to be complete, since nobody specified any other distribution. In all cases, binomial distributions were included, exponential

never appeared. For merely technical reasons, the answers are listed in Table C, columns "Distributions".

From the responses we can conclude, that the notion of a random variable is discussed in almost all countries. Some of the location parameters are also introduced, columns ev, mo, me gives the data on the Expected value, Mode and Median. The case is not uniform on Variance and standard deviation (Table P, Column va), either. The Interquartile range seems to be missing everywhere. It is interesting to note, that France differs from the other European countries.

It is interesting to learn that the joint distribution (jd) of two (more) random variables is generally not treated, while their correlation (co) usually is included. Furthermore, independence and dependence of more random variables are usually not defined.

It was surprising to learn how little is included from theoretical aspects of Probability. Table P gives information on the inclusion of: Mc. Markov- and Chebisev inequality sr. Square-root-n law for the standard deviation of

Table P Calculus and Theory of Probability.

	Prob'lty Calculus		Random Variables				2+ Random Variables		Probability Theory			
	cp	Bf	ev	mo	me	va	jd	co	MC	sr	w-	cl
Argentin	N	N	Y	Y	Y	Y	N	N	N	N	N	N
Austral	N	N	Y	N	N	Y	N	N	N	N	N	N
Austria	Y	Y	Y	N	N	Y	N	N	Y	N	Y	Y
Bulgaria	Y	N	Y	Y	Y	Y	–	–	Y	N	Y	N
Denmark	Y	Y	Y	Y	Y	Y	–	–	–	–	–	–
England	"Varies. Lots of alternative syllabi"											
Estonia	Y	N	Y	Y	Y	Y	Y	Y	–	–	–	–
Finland	Y	N	Y	Y	Y	Y	N	Y	N	N	N	N
France	Y	N	N	N	N	N	N	N	N	N	N	N
Ghana	Y	N	N	Y	Y	Y	N	Y	N	N	N	N
Hungary	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Italy	Y	Y	Y	Y	Y	Y	N	N	N	N	Y	N
Lebanon	Y	N	N	N	N	N	N	N	N	N	N	N
Libya	Y	N	N	N	N	N	Y	N	N	N	N	N
Netherl	N	N	?	?	?	?	N	?	?	?	?	?
Poland	Y	Y	Y	Y	N	Y	N	N	Y	N	–	N
Spain	Y	Y	Y	Y	Y	Y	N	?	?	?	?	?
Thailand	Y	N	Y	Y	Y	Y	N	N	N	N	N	Y
Turkey	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N

Note.
ev = Expected value, mo = Mode me = Median
jd = joint distribution of two (more) random variables, co = correlation
Mc.= Markov- and Chebisev inequality
sr. = Square-root-n law for the standard deviation of the arithmetic means
w-. = Weak law of large numbers without proof
cl. = Central limit theorem

the arithmetic means, w-. Weak law of large numbers without proof and cl. Central limit theorem.

Hungary and Poland are the only countries, where the weak law of the large numbers is proved. Wherever the Central limit theorem is communicated, then it is without proof. Data was collected on Simulation issues. It turned out that Generation of random variables is discussed in Australia and Finland, only. Simulation of probability games, use of computer generated random numbers was reported from Australia, only. These questions are optional in Spain.

Methodological Issues

We were interested to learn what kind of *orientation* governs pre-university probability teaching. In this respect the following questions were asked:

M1a. Probability is taught mathematically oriented
M1b. Probability is linked to applications
M1c. Probability is developed on a spiral way
M1d. Interpretations of probability are explicitly developed
M1e. Intuitive approaches of learners are welcome and utilised and integrated
M1f. Probability and statistics are interrelated in teaching
M1g. The role of inferential reasoning and probability in exploring reality is emphasised.

Responses showed a general attitude to teach probability with mathematics in background. The so-called "modern maths" movements, which characterise many countries' primary mathematics teaching, are not general at all, nevertheless they are gaining space in some new curricula.

The columns "Orientation" of Table M list the collected information.
Regarding *working form*, the following questions were asked:

M2a. Formal lecturing
M2b. Many illustrating examples
M2c. Running experiments in the classroom
M2d. Running computer simulations
M2e. Hands-on activity; Discovery method
M2f. Organised discussions in the classroom
M2g. Doing a project (in teams)
M2h. Reading information from textbooks
M2i. Watching films/ videos/ computer animations
M2j. Using Hypertext or other compute assisted teaching devices

Traditional methods are combined with the most recent ones. The

Table M Methodological issues.

	Orientation M1							Working Form M2								Teaching Means, M3				
	a	b	c	d	e	f	g	a	b	c	d	e	f	g	h	a	b	d	e	g
Argentina	Y					Y		Y												
Australia	Y								Y						Y	Y				Y
Austria	Y	Y						Y	Y							Y	Y		Y	
Bulgaria	Y	Y						Y	Y											
Denmark	Y	Y						Y	Y	Y		Y								
England		Y	+	+	+	Y		Y	+	+		Y		Y		+	Y		Y	+
Estonia	Y								Y	Y			Y				Y			
Finland	Y							Y	Y		Y					Y				
France	Y				Y	Y		Y	Y	Y						Y				
Ghana	Y		Y			Y		Y	Y	Y										
Hungary	Y	Y	Y		Y	Y		Y	Y	Y		Y	Y			Y	Y			
Italy	Y		Y					Y	Y							Y				
Lebanon		Y						Y	Y											
Libya	Y	Y						Y	Y	Y						Y	Y			
Netherl	+	+		+	Y			Y	+		+	+	+	Y		+	+		+	+
Poland	Y				Y			Y	Y	Y						Y	Y			Y
Spain	Y		Y	Y	Y	Y		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Thailand	Y	Y						Y	Y								Y			
Turkey	Y							Y	Y											

Yes answers, only.
+ refers to some advanced level.

responses show clear preference to formal lecturing supported by illustrating examples. Recent possibilities are hardly utilised. Application of hypertext were not mentioned, videos appear as rare occasion in Netherlands only, so that there is no corresponding column among the working form columns of Table M.

Questions about the *teaching means*, or perhaps better term would be problem-environments, are the following:

M3a. Games of fortune
M3b. Practical problems
M3c. Use of analogies
M3d. Visualization of difficult concepts
M3e. Discussion of existing or potential misconceptions
M3f. Ilustration of the relative merits of probability concepts
M3e. Project work

As it could be guessed, most Yes answer come to question a. and b. Positive answer to question c. and f. was given from Poland, only. For the others, see columns of Means in Table M.

Evaluation and research

E1. The first question concerned the typical examination methods:

- E1a Multiple choice test-questions
- E1b. Paper and pencil problems
- E1c. Project work
- E1d. Verbal problems

Table E shows that all countries use paper and pencil problems in assessment. Unfortunately, no question was explicitly asked about the ratio of written and oral examination. E2. The following questions relate to the computing aids which students may use during the assessments procedure.

- E2a. Tables
- E2b. Calculators
- E2c. Programmable calculators
- E2d. Simulation programs
- E2e. Spreadsheets
- E2f. None

Table E Evaluation and Research

	Exams E1				Aids E2						Research							
	a	b	c	d	a	b	c	d	e	f	R1	R2	3a	3b	3c	3d	3e	3f
Argentin		Y				Y												
Austral	Y	Y	Y	Y	Y	Y					Y							
Austria		Y			Y	Y					Y		Y	Y	Y			Y
Bulgaria			Y								NO RESEARCH							
Denmark		Y	Y	Y		Y					NO RESEARCH							
England	Y	Y	Y			Y	Y		Y		Y	Y		Y	Y	Y	Y	Y
Estonia		Y									NO RESEARCH							
Finland		Y			Y	Y					NO RESEARCH							
France		Y								Y	Y			Y	Y			Y
Ghana		Y	Y		Y	Y					NO RESEARCH							
Hungary		Y			Y	Y					Y	Y		Y		Y		Y
Italy		Y		Y		Y	Y				Y	Y						
Lebanon		Y				Y					NO RESEARCH							
Libya	Y	Y								Y	NO RESEARCH							
Netherl		Y	Y		Y	Y	Y	Y			NO RESEARCH							
Poland		Y			Y						Y			Y			Y	
Spain	Y	Y		Y	Y	Y			Y		Y	Y	Y	Y	Y	Y	Y	Y
Thailand	Y	Y								Y	NO RESEARCH							
Turkey		Y			Y						Y							

Yes answers, only.

Typically, Tables and Calculators can be used in exams. 3 countries (France, Libya and Thailand) does not tolerate any aids. Information about other possibilities is given in Table E, columns "Aids".

As for research, we simply list our questions and summarise the answers in the columns "Research" of Table E without comments.

R1. Is there any research going on in relation to teaching probability at school level?
___ Yes ___ No
If yes, please, provide us with the address of a contact person.

R2. Are there plans to introduce probability in the curriculum?
___ Yes ___ No
If yes, then please, describe them shortly!

R3. If there is any research in relation to teaching of probability, then check the corresponding line(s) of research fields
___a. Theoretical analysis of exposition of probability in teaching
___b. Investigation on students' understanding of probability
___c. Classroom observations
___d. Organization of students' work
___e. Assessment of students' achievements
___f. Teaching experiments

Country-specified comments

Argentina: It is a federal country, each province has its own educational system. Answers were given in accordance with the "Common Basic Contents for the General Basic Education" issued by the Federal Council of Culture and Education. It is not obligatory, serves as a guide. School teachers are not familiar with the importance of teaching stochastics. Probability appeared in 2 day school curriculum in 1972, but teachers never found time to teach it. Primary school textbooks started to contain probability topics in 1983.

Australia: The report is based on Victoria, but the pattern is similar in the whole country. The approach to teaching may vary from teacher to teacher.

Austria: Poisson and exponential distribution are mainly taught in technical, professional schools In school the most frequent means are oral reports at the blackboard; exams have the written forms. At the final examinations, out of 4 exam-problems, 1 or no concerns probability. Topics, which appeared: tree diagrams, calculating probabilities, conditional probability, tests for means and proportions.

Bulgaria: Probability is a natural part of the Mathematical Curriculum since 1989. As such, it is included in all tests and home works.

Denmark: The curriculum is not described in terms of subject matter lists. No prescription is given on what percentage of time should be spent on different topics. There are two completely separated systems. The 'folk school' takes care of grades K-9 (6- 5/16 yrs.) whereas the 'gymnasium' takes care of age groups 10-12 (15/16-18/19 yrs.) In Denmark people would translate the 'foreign' term 'secondary' as 'lower secondary': ages 13-16, 'upper secondary': ages 16-19. There is a national examination event after grade 9 (10), one again after grade 11, and for those students who go on with mathematics one after grade 12. There are written examination papers at the end of LS which may contain very simple probability and statistics. tasks. There are written examinations papers at the end of grade 11 which are likely to contain. and statistics. problems. For some students there is also an oral examination with external examiners. Questions may include probability. and statistics. issues. Teachers at the lower secondary level are educated in four-year teacher training colleges, and there is no compulsory course in stochastics. Teachers at upper secondary level must get an extended Masters degree, and must attend a course in both probability and in statistics.

It is a characteristic feature of Denmark that variation across and between levels, classes, schools, etc. is considerable. For more impression consult the articles by Hans Nygaard Jensen and Kirsten Hermann & Bent Hirsberg in Niss (1993).

England: The National Curriculum involves some compulsory testing/ evaluation of students. What is taught varies a great deal. There are a lot of alternative syllabi, many of them modular in structure. Distributions and random variables are in the optional part of tA-level syllabuses. Probability theory is not included.

Finland: At the national examination there are 10 tasks, and maximum one relates to probability.

Hungary: Stochastics is included in the Syllabi of special mathematical classes and in certain professional schools

Italy: University entrance is conditioned on the achievements in the secondary schools only for certain faculties. For most faculties, including mathematics and physics, it is sufficient to pass the secondary school leaving final examination. At the national examination events, probability is present only in the final exam of the experimental schools. At the "middle" level exams are set up by teach school. Probability may be included, but usually not.

Probability is included in curriculum for the lower years of education. At secondary level, only experimental school inserted it (say 20 % of all schools).

Lebanon: Probability is part of mathematics, and is not considered as separate topic at the national exams.

Netherlands: In teacher training probability and statistics form a single course.

Poland: One illustrating exam-problems:

Part 1. From an urn with 6 balls numbered from 1 to 6 we draw 2 balls at the same time. Compute the probability

a/ that the sum of the two numbers is even
b/ the sum will be odd number

Part 2. Before drawing, a player has to choose one number between 3 and 11. if the sum coincides with this, then the player wins a point. Does this game remind you to the ordinary lotto? If yes, why? Suppose you enter this game. What number will you choose and why?

Spain: Plans to introduce probability to secondary schools (age 16-18): Axiomatic Probability, Laplace mechanism. Dependence, independence of event, Conditional probability. Bayes' formula.

Acknowledgments

This report could not be prepared without the support of many colleagues. We thank for the help of the following expert, as well as for a number of practising (classroom) teachers, whose views supplemented official versions (intended curricula) by real happenings (implemented curricula).

Dr Carlos Alberto Mansilla, Teresita Teran (Argentina), Brian Phillips and Kay Lipson (Australia), Jordan Stoyanov (Bulgaria), Mogens Niss (Denmark), Keith Hirst, Flavia Jolliffe, Susan Starkings (England), Eva Saks (Estonia), Erkki Pehkonen (Finland), Yves Ducel (France), B.A. Eshon (Ghana), Vinicio Villani (Italy), Murad Jurdak (Lebanon), Fred Simons (Netherlands), Antoni Pardala (Poland), Carmen Batanero, Eliseo Borras (Spain), Semehai Chvehat (Thailand), Yasar Ersoy (Turkey).

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