Degree Course	The existence in the University curriculum of probability and statistics (as a % of all disciplines)	Incidence of degrees among secondary school teachers teaching probability and statistics	Graduates in 1977
– Mathematics and Physics	0–2	very high	3186
– Informatics	0–2	low	324
– Engineering	0–2	very low	7107
– Law	0–2	low	6554
– Political Science	4–8	low	2861
– Economics and Business Administration	4–8	low	4209
– Statistics	40–60	very low	179

Table 5.3 The provision for probability and statistics in University curricula followed by teachers; the existence of different University degrees among secondary school teachers of probability and statistics.

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CHAPTER 6

Statistical Education in Schools in Sweden

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In the middle of the sixties when 'new maths' started in Swedish schools and abroad, statistics and probability became part of the general mathematics course. Certain topics were included in the mathematics curriculum whichever subject one took. Demands from universities and other institutes receiving students from the senior high school (*gymnasium*) (10–12th grade i.e. 17–19 year olds) also contributed to the decision to study these topics at school.

The work of the Scandinavian Committee for Modernizing School Mathematics was of great importance in the introduction of statistics and probability. The committee published experimental texts which were used not only in Sweden but also in other Scandinavian countries.

As there was no teaching tradition for these topics, at least not in the schools, great difficulties arose and many questions were posed: for example,

- which topics are realistic to teach to students and at what age,
- how should teaching methods and teaching aids be transferred from university to school,
- how should we train teachers for statistics? (Most of the teachers had not studied statistics or probability at the university at that time.)

The use of the experimental texts mentioned above was received with enthusiasm by the students. However, statistics and probability, as a part of the mathematics syllabus for everybody, encountered severe criticism. There are many reasons why interest subsided. A few of them are:

- probability theory seemed to be too theoretical for many students,
- growing demands from universities for other topics of mathematics left less time for statistics and probability,
- the standardized achievement tests in the 12th grade had not included any problems in statistics since the middle of the seventies.

The last point is of course very important and more about central tests appears later in this chapter. Although there have not been any principal changes made in the curriculum since the middle of the sixties, the general aim and direction have changed. We will try to interpret what is going on in statistics and probability education by giving examples from tests of different types. They will give a better indication of the standard and extent of contemporary teaching in statistics and probability than can be obtained from studying the curriculum.

It is appropriate, however, to first give some information about the Swedish school system before describing the teaching of statistics and probability.

6.1 SWEDISH SCHOOL SYSTEM

In Sweden all the children at the age of seven must go to school for nine years. In the 7th–9th classes (age 14–16) the students may choose between two courses in mathematics, a general (shorter) course chosen by about one third of the students and a special course chosen by the other two thirds. There are also different courses in English and French/German but during all the other lessons (history, physics etc.) all students learn together.

About 75 per cent (or more) of the students go to gymnasium (10th–12th grade or 10th–11th grade) after finishing compulsory school. Out of these about a quarter take theoretical options for three years. In turn about one half of these go to a science or technical class with a broader-based course in mathematics.

There is also the option of two years (10th–11th grade) in the gymnasium. Many of these classes prepare the students for work in offices and industry. Social sciences classes and economics classes can be either two and three years long.

The following diagram (Figure 6.1) clarifies the situation. (4 h/w means 4 hours mathematics per week, 5 + 5 + 5 etc. indicates the numbers of hours per week in successive years.)

There are very few children who receive their education outside the government school system.

The National Board of Education is the highest authority for the educational school system. The local education authorities follow for the most part the directions given by the National Board. The National Board draws up the curriculum, aims and basic elements in rather general terms and recommends the method of treatment of each topic. The directions are fairly detailed but the authors of the textbooks also influence the shaping of lessons.

6.2 CURRICULA

According to the school curriculum, statistics is studied in the 4th–9th grade, probability in the 9th grade (just a brief introduction to the concept). The aim is that 'the students will gradually be familiar with a few important concepts and procedures of descriptive statistics and become familiar with the probability concept'. The topics covered are:

4–6th grade: Collection of statistical materials. Tables and graphs. Mean.
7–9th grade: Descriptive statistics including frequency tables, graphs, mean, median and some measure of spread. Probability.

However, the directions suggest that the teachers in the 1st–3rd grade should let the children gather and represent information in pictorial form. Weather observations, traffic censuses, different activities during a day etc. are suitable sources of data.

Co-operation with other subjects such as geography and (later) economics are recommended (as is the case also in the gymnasium).

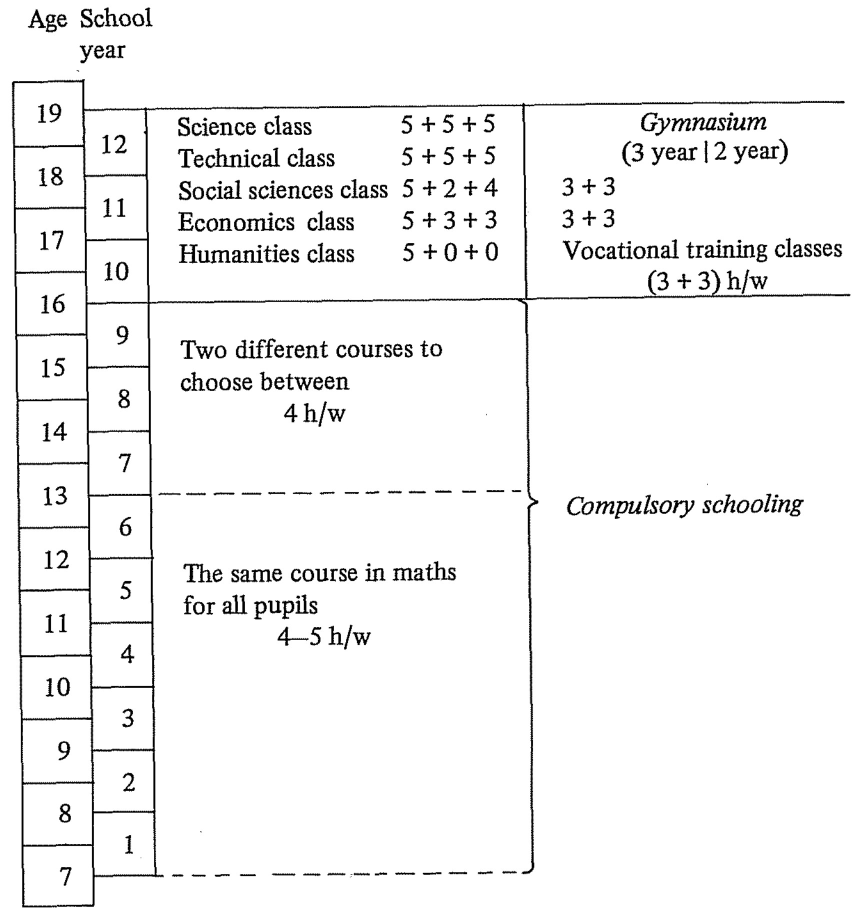
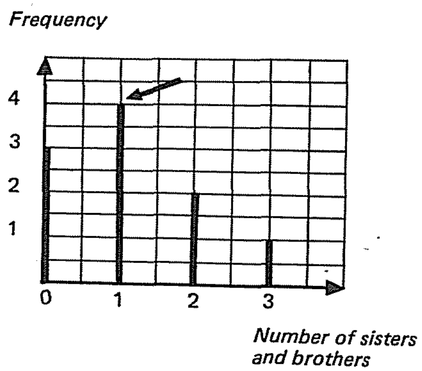


Figure 6.1 Mathematics classes in the Swedish school system.

Most of the statistical work in the school involves simple data collection constructing frequency distributions and representing the data by using charts of different type (bar chart, pie chart, etc.). The teaching of statistics is based partly on study of the environment and on experiments conducted in the classroom or in the school. The interpretation and understanding of the relevant concepts are also important elements in the statistics teaching but receive only limited attention.

The following example (grade 8) illustrates the type of exercises given.



John asked some of his class-mates how many sisters and brothers they had. He represented the data in the form of a graph as shown alongside.

(a) How many class-mates did John ask?

(b) How many sisters and brothers had John's class-mates in total?

(c) What is indicated by the arrow on the graph?

During compulsory schooling, and in the gymnasium too, time available for statistics and probability teaching has decreased during the last five years. The teachers have complained about the children's lack of computational and manipulative skills when they enter the gymnasium. Time for more practice in this matter has been taken from time previously devoted to statistics and probability teaching.

It is rather difficult to estimate the time spent on teaching statistics and probability at school but it might be of the order of 30 hours in the secondary school and 60 hours in the social sciences option in the gymnasium (assuming the broadest choice of courses).

For the natural sciences class and technical class in the gymnasium, the syllabus directions for probability teaching in the 12th grade are as follows: (The instructions to the social sciences class are rather similar.) See [4].

'The introduction of the probability concept can be made by using experiments which illustrate relative frequencies and the stability of relative frequencies. It is appropriate that the students themselves perform trials of some simple experiments such as tossing of coins and tacks. Experiments having both symmetry and non-symmetry should be performed and discussed.

'The study of probability and probability distributions start with experiments having a finite number of outcomes. The concepts of elementary probability, random variables and frequency functions are introduced. The case in which the elementary probabilities are equal (uniform probability distribution) is discussed carefully. The relation between the probability of an event and its complementary event is considered. Independent events are defined. Problem solving should be limited to simple applications of the probability laws. In addition to the multiplication principle some combinatorial reasoning should be introduced.

'Emphasis should be given to the normal distribution. Methods of descriptive statistics can be discussed here again including the notion of the standard deviation. The theory is extended to the case with finite outcome sets and the frequency function of a continuous random variable is defined. In connection with the study of the distribution function, the importance of the cumulative-distribution polygon is stressed. The connection between the form of the normal probability density curve and the two parameters in its equation

is discussed. The students learn how to use a table dealing with the normal probability distribution and how to solve application problems where a normal distribution is assumed to be approriate.

'The binomial distribution, the Poisson distribution, combinatorial reasoning and statistical inference do not belong to the basic course. However, all pupils should be informed about different sampling methods.

'All students should know how to
apply the multiplication principle in simple cases
solve simple problems connected with the uniform probability distribution
calculate a mean and standard deviation
solve problems dealing with the normal probability distribution such as
The weight of a special type of can has a normal distribution with mean 1000 g and standard deviation 25 g. What percentage of the cans are expected to weigh less than 950 g?'

Suggestions for further studies
Permutations
Calculation of the number of subsets
Binomial coefficients
Binomial development
Binomial distribution
Poisson distribution
Expected value and variance
Examples of statistical inference.

For further illustration, a test in probability is presented below. The test is taken from an ordinary class in the 12th grade, social sciences option, and constructed by the mathematics teacher.

S 3, 16 May 1979, 8.10 am–11.20 am. (Social Science class, 3rd year.)

1 *The weight of a special kind of jar is normally distributed with mean 450 g and standard deviation 10 g. Find the probability that the weight of a jar is*
(a) less than 460 g (b) less than 445 g (c) between 448 g and 452 g.

2 *Three cards are drawn from an ordinary deck. What is the probability that (a) all are black (b) all are kings?*

3 *A green and a red die are rolled. Find the probability that*
(a) at least one of the faces is a 6,
(b) the face number of the red die is higher than that of the green one,
(c) the sum of the faces exceeds six.

4 *The height of the doors of a war ship is 190 cm. The height (cap and shoes included) of a member of the crew is supposed to be normally distributed with mean 180 cm and standard deviation 8 cm. What percentage of the crew can walk upright through the doors with hitting the top of a door?*

5 *A box contains 5 blue and 4 yellow balls. Three balls are taken at random without replacement. Find the probability that*
(a) all three will be blue
(b) at least one will be yellow
(c) two will be blue, one yellow
(d) they will be the same colour.

6 *Let us suppose that 10 per cent of all drivers have cars with defective brakes, 10 per cent have cars with defective tyres and 10 per cent with defective headlights. What is the probability that a car chosen at random will have at least one of the defects? The defects are supposed to be independent of each other.*

7 *The probabilities that the two most skillful players in an ice-hockey team score a goal during a match are 0.6 and 0.8, respectively, according to an examination of the past records of the club. The probability that both score is 0.5. Find the probability that in a match*
(a) one of them will score *(c) exactly one of them will score.*
(b) none of them will score

8 *The probability that a skittle player has a strike is 0.2. If he hits 10 balls, what is the probability that he will get*
(a) exactly three strikes *(b) at least one strike?*

9 *The life-time of a certain fluorescent tube is assumed to be normally distributed with mean 8000 hours and standard deviation 1000 hours. In a factory there are 2000 tubes.*
(a) Estimate the number of tubes with a life-time shorter than 6000 hours
(b) How many tubes will be expected to function between 6500 and 9500 hours?
(c) After how long will only 400 tubes function?

10 *A, B, C and D play golf. The probability that A beats B is 2/5, that A beats C is 5/6, that A beats D is 7/10 and that C beats D is 3/8.*
To win the contest, A must first beat B and afterwards beat the winner of the match between C and D. Find the probability that A will win the contest. The results of the different matches are assumed to be independent.

11 *To obtain a specific certificate the applicants have to take a test with five questions, each with four alternative answers, one of which is correct. Four correct answers is the nimimum requirement for passing the the test. What is the probability of a person passing the test if he chooses his answers at random?*

12 *The digits 1, 2, 3, 4, 5 are written in random order. What is the probability that the written number is (a) even (b) divisible by 5 (c) greater than 30000?*

6.3 CURRENT TRENDS

6.3.1 *A new syllabus*

The National Board of Education is now working out new curricula for mathematics teaching at school. No drastic changes are proposed but there are a few novelties. As the proposition is most detailed for the social sciences 2-year option (10^{th}–11^{th} grade) in the gymnasium we will take a particularly close look at these syllabuses. One of the novelties is that about one fifth of the mathematics course is classified as 'freely chosen topics': the purpose

being that the teacher together with his students chooses one or more topics of their own choice. Time devoted to these topics will be about 40 hours (3 hours a week during a term).

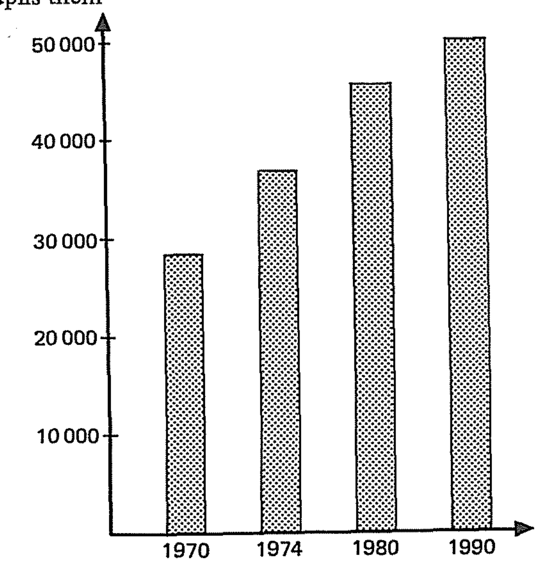
The syllabus circulated for comments among the schools, and many teachers, proposed a reduction or even the removal of the probability course. That course was regarded as too difficult for the students taking mathematics as a minor subject.

According to the proposition, statistics and probability will be studied for about 15 and 20 hours, respectively. This should be compared with the overall total amount of 200 hours; 40 of the hours are devoted to the 'freely chosen topics' mentioned above. The content matter is principally a review of what was studied in the compulsory school, but the probability course is somewhat broadened. In addition more statistics and more probability can be studied in the 'freely chosen topics'. More about that will come later in this report.

The following is an extract from the proposed syllabus concerning statistics and probability for students in the 10^{th}–12^{th} grades in the social sciences and the economics classes of the gymnasium (2-year option). See [5].

Descriptive statistics

Topics	*Comments*	*Examples*
Bar graphs	Both construction and interpretation are important. Sources of data can be found in the environment of the pupils themselves.	The population development in Kungsbacka community appears from this graph.



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(a) By what percentage did the population increase from 1970 to 1974?
(b) By what percentage might the population be expected to increase between 1980 and 1990?

Thirty people were asked how many ice-hockey matches they had watched during the world championship in 1977. The answers were as follows:

0	11	8	4	6	7	7	9	5	7	8	4
3	10	9	10	10	9	8	9	6	11	0	6
7	8	9	5	8	7						

(a) Display the data in a frequency table.
(b) Draw a bar graph to show the data included in the table (a)

Circle graphs (pie charts)

The following table contains information from the election in 1976.

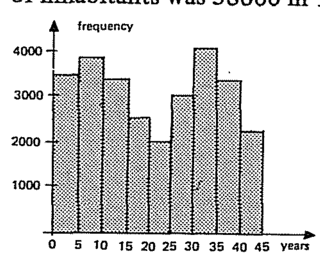
Party	*Number of members of Parliament*
Socialdemokraterna	152
Centern	86
Moderaterna	55
Folkpartiet	39
Vänsterpartiet kommunisterna	17

Make a circle graph which presents the information in the table.

Histogram

Grouping data in suitable classes is difficult and should not be stressed.

The histogram below shows the age distribution from 0 to 44 years in Kungsbacka community in 1976. The ages have been put together in five-year groups. The total number of inhabitants was 38000 in 1976.



(a) What proportion of the total number of inhabitants are in the age range 10 and 15?
(b) Make a new histogram with intervals of ten years instead of five.

Measures of location; mean, median, mode

The members of a certain family are 3, 11, 7, 34, 42 and 13 years old. Determine (a) the median age (b) the mean age.

Time studies of the production of a special component gave the following results (times in seconds):

40	40	41	36	37	39	38	39	39	40
35	38	37	36	41	40	39			

(a) Make a frequency table.
(b) Find the mode.

Misleading statistics

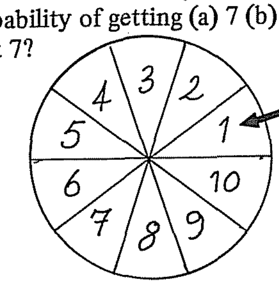
For example, misrepresentation of graphs and biased samples can be discussed.

Choice of graphs and measures of location

The purpose is that the students themselves have to choose a suitable graph and suitable measures of location to present statistical data.

Probability

Topics	*Comments*	*Examples*
Simple random experiments	Every outcome is assigned an (elementary) probability.	If the wheel is turned, what is the probability of getting (a) 7 (b) at least 7?



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Relative frequency		A die is tossed 100 times. How many times can you expect to get a 4?
Compound events (multiplication of probabilities)	The outcomes are illustrated by tree-diagrams.	A coin is tossed twice. (a) Illustrate the possible outcomes with a tree-diagram. (b) Complete the diagram with the probabilities. (c) Find the probability that the coin turns up 'tails' exactly once. Two balls are drawn at random without replacement from an urn containing 2 black and 3 white balls. What is the probability that they will be of different colours?
Relationship with statistical ideas	Examples are taken from society, technology, medicine.	87508 cars out of 625403 had defective headlights at the regular official car examination during the first quarter of 1975. What is the probability that (a) a car chosen at random had defective headlights? (b) two cars chosen at random both had defective headlights?
		The following table shows a frequency distribution of marks received by the pupils in a mathematical test.

Mark	1	2	3	4	5
Frequency	2	8	12	7	1

Find the probability that a pupil chosen at random has at least 4 marks.

'Freely chosen topics' concerning statistics and probability can be chosen from among the following:

Permutations
Generation of random digits
Problem-solving by simulation
Applications of statistics
Expected values

Thus whilst some students may have the chance to study a rather broad

course in statistics and probability, others will take the main course only, which evidently is very restricted in content.

6.3.2 *The ARK-project*

In 1976 a committee was set up by the National Board of Education to make recommendations on the use of pocket calculators at school. The committee, the members of which were school teachers, university lecturers and educational researchers, was called 'the ARK-group' (or the ARK-project). ARK stands for 'analysis and consequences of using pocket calculators in school'.

Within the framework of this project a subgroup has published experimental texts on probability which have been partly tried out in the 12^{th} grade. The main experimental text is called 'Probability and simulation' (Råde, 1978b). Characteristic of this material is the use of programmable minicalculators. It seems advantageous to develop an intuitive understanding of probability by solving problems using Monte Carlo simulation methods. The most interesting problems the pupils meet are beyond their analytical skills. The methods presented make it possible to obtain an empirical solution in many cases. The subgroup is working further on the teaching problems attached to the use of simulation methods.

These new ideas about simulation, with the help of a programmable calculator or with a table of random digits only, are now growing and permeating all the courses in probability. The method seems to originate from Engel (1975). The following example 'Family planning' is taken from the experimental text mentioned above (Råde, 1978b).

'Let us assume that the probability of the birth of a boy (girl) is 0.5. In a society, family planning is such that every family produces children until they have obtained at least one boy and at least one girl. (a) Will the population increase or decrease? (b) What will be the proportions of boys and girls?

Simulate 100 families by help of a coin (head-boy, tail-girl) and write down the number of children of different sexes. Answer the questions above. Compare your results with those of the whole class.

Study the effect of other 'stopping-rules'; for example, at least

1) one girl,
2) one girl but at most three children,
3) two girls but at most five children,
4) two girls and at least one boy and at least two children of the same sex.'

An important point to consider is how we should grade the students' efforts with the material. The matter is illustrated by the following, slightly amended, example (Gregor, 1971); we should bear in mind that different degrees of success must be expected depending on the student's ability.

Two men, M and N, are going to duel with pistols. M generally hits his target two times out of ten, N generally succeeds three times out of ten. M shoots the first bullet, N the second one if necessary, and so on until one of them hits the other.

(*a*) *What is the probability that M will win? (Do you want to be M or N?)*
(*b*) *How many bullets will be shot on average?*

Two people play by using a table of uniformly distributed random digits. 8 and 9 represent a hit for M; 0, 1, 2 for N. They shoot (take a number at random from the table) alternately. The experiment is repeated 20 times and with 30 students in the classroom, 300 duels have been performed in about ten minutes. The results generally coincide with the theoretical values surprisingly well.

All students are capable of doing the experiment. Many pupils can find the answer to (a) theoretically and the cleverest ones may establish the reasoning behind (b). For example the following solutions may be given by a few students:

(a) $$P(M \text{ will win}) = \frac{2}{10} + \frac{8}{10}\cdot\frac{7}{10}\cdot\frac{2}{10} + \frac{8}{10}\cdot\frac{7}{10}\cdot\frac{8}{10}\cdot\frac{7}{10}\cdot\frac{2}{10} + \ldots$$
$$= \frac{0.2}{1-0.56} = \frac{5}{11}$$

Despite of the fact that M fires first, N has the best chance of winning.

(b) Assuming that 1000 duels are performed and x is the expected number of shots in a duel, the total number of shots will be of the order of the solution of:

$$1000\,x = 1000 + 800 + 560\,x \quad \text{and} \quad x = \frac{45}{11} \approx 4.$$

The trend of using Monte Carlo simulation models in probability teaching will probably continue.

6.4 OFFICIAL TESTS AND EXAMINATIONS

In the sixties, when older types of school were replaced by the compulsory school and the gymnasium, the examination system was completely changed.

No examinations are set during the 9-years compulsory schooling. Marks are awarded by the teacher on a scale 1 to 5; 5 being the highest grade. The same scale is used in the gymnasium. Any pupil completing 9-years compulsory schooling may apply for admission to the gymnasium (10th grade) irrespective of the options he or she selected in the upper division. However, there are some exceptions. Pupils applying for the science course, for example, must have studied the special course in mathematics mentioned above.

No final examinations are taken in the gymnasium and there are no university entrance examinations.

In mathematics there are, however, a few official tests:

- Standard test (9th grade; the same test every year)
- Standardized achievement test (12th grade; science class and technical class take one test, economics and social sciences class another)

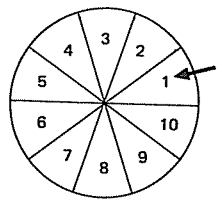
Some other subjects such as Swedish, English and physics also include standardized achievement tests.

As mentioned above, a couple of years ago the date of the standardized achievement tests in the 12th grade was altered to take place in February with the consequence that probability is now studied after the test. This has led to less emphasis on the topic than before. Furthermore the universities have complained about lack of technical knowledge and of poor skills in specific topics such as trigonometry when the students enter the university. So the study of probability has been reduced at the expense of preparing for further studies in mathematics and natural sciences.

However, it may be of interest to look at a few test items. *The first two questions below* are similar to those of the standard test in the 9th grade. As the same test is given year after year the actual test items cannot be published.

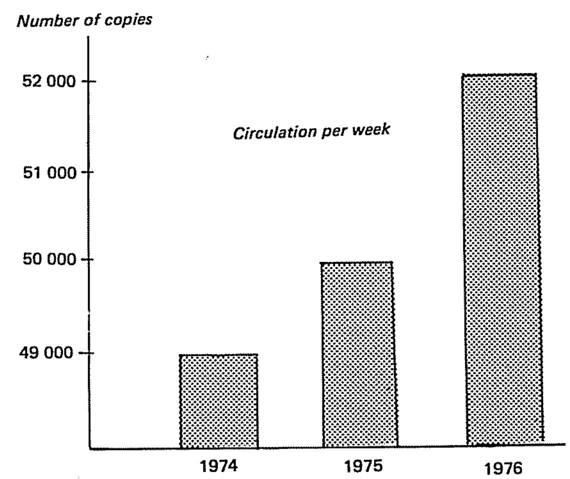
The other questions are taken from the last standardized achievement test given in the 10th grade for the social sciences classes. About four or five questions out of the twenty used to be within the area of statistics.

1 *Here is a wheel of fortune. Every figure is as probable as another to appear. Find the probability (in per cent) that the digit 7 appears.*



2 *An alloy consists of 15 per cent nickel, 40 per cent zinc and 45 per cent copper. Draw a circle graph (pie chart) giving the same information.*

3 *A newspaper announces that the circulation 'increases and INCREASES'. According to the following graph the impression is that the increase is 100 per cent every year. Find the real increase (in per cent) from 1975 to 1976.*



4 *The following graph shows the numbers of applicants and the numbers of places on a course with restricted intake. In which year were there 150 applicants per 100 places?*

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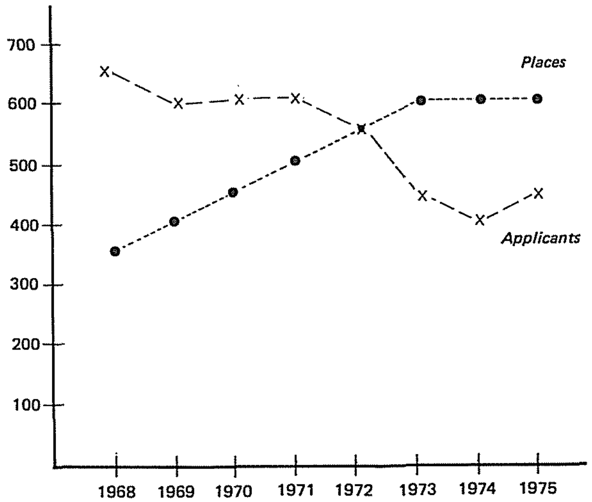

5 *In a factory, the number of defective articles among the perfect ones was noted. After some time, the following statistical data were collected:*

The number of defective articles per day	0	1	2	3	4	5	6
Frequency	15	30	40	70	30	10	5

Show the data in the form of a bar graph.

6.5 TEACHER TRAINING

Before 1966, few teachers had studied statistics and probability at university. Summer courses and correspondence courses were offered to all teachers. This contributed to solving the transitional problems. The courses covered most of the necessary background material for teaching statistics, but more extensive courses would have been desirable.

In Sweden, like most other countries, new topics have become part of the standard curriculum. Probability, statistics and topics from computer science are the most frequent.

The students who will go on to teach mathematics in the upper secondary school (7^{th}–9^{th} grade), or in the gymnasium, study for a period of four years at the university. One year is devoted to mathematics and the fourth year is a direct preparation for the profession; visiting classes, teaching under supervision, studies in education and didactics of mathematics, and so on. Of the remaining two years, one is devoted to physics, the other to chemistry or more mathematics or physics. Teachers in the gymnasium must have achieved 60 marks in mathematics or in physics. One year's study gives you 40 marks and the entire training process at least 160.

From one of the universities the first year topics in mathematics for prospective teachers are as follows (see [6]):

Programming (2 marks)	Analysis II (7)
Algebra (2)	Geometry (3)
Linear algebra (6)	Foundations of analysis (6)
Analysis I (10)	Statistics and probability (4)

We see that statistics and probability give you 4 marks only (just 10 per cent of the total time). At some small universities the mathematics students and the prospective teachers are so few in number that they study together during the first year. So it is difficult – if desirable at all – to balance the courses immediately directed to the training and professional life of mathematics teachers. Syllabuses are consequently slightly different at the universities. However, all of the syllabuses seem to be overcrowded and the courses in statistics and probability have decreased in recent years reflecting the universal tendency for students entering university to have much less manipulative skill than before and practically no insight into geometry. Remedial teaching is becoming an element of freshman education but available time is still limited to one year.

The course in statistics and probability (4 marks) mentioned above is described in the following way:

> Descriptive statistics, measures of location and measures of spread. Different kinds of graphs and diagrams.
> The probability concept and the notion of a random variable. Discrete random variables and combinatorial analysis. Expected value and variance. Normal distribution, for one variable. Statistical inference and confidence limits. Regression and method of least squares.

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There are no special textbooks for statistics and probability teaching, but the topics are included in the ordinary ones, usually one book for each school year and its course.