6. Traditional teaching of mathematics.

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With regard to some critical remarks on the traditional teaching of mathematics in secondary schools, which will be made now, it must be remarked before that they apply to the situation in the Netherlands, but that the author has some strong misgivings that 1° the situation in many other countries is not essentially different, that 2° probably analogous remarks could be made about several other subjects of teaching, and 3° that the teachers in secondary schools are not to be blamed for it, as they usually have had no opportunity, at least since the time of their study, to become acquainted with the many uses of and needs for mathematics in modern life. [1]

The trend of the following remarks is to state that the teaching of mathematics (we shall further omit the words " in secondary schools ") must in several respects be considered as superannuated and badly adapted to modern needs.

This holds in particular for the choice of subjects. These belong in Dutch schools to: Euclidean geometry in the plane and in space, elementary algebra, plane trigonometry, descriptive geometry, and in some schools the elements of analytic geometry in the plane and/or of the calculus. With exception of the two last mentioned these fields are treated to such an extent that, with a few exceptions, neither a modern " producer " nor a " consumer " of mathematics ever meets the larger part of them. So e.g. in plane geometry some of the congruence theorems of triangles (and practically all of those added as exercises), the concurrence of perpendiculars in a triangle and of bisectors, the formulae for the lengths of perpendiculars and medians, the properties of quadrangles inscribed or circumscribed to a circle and of the regular pentagon and decagon are rarely met with in later life. Similar remarks hold for the other branches of mathematics. E.g. in trigonometry the only things one regularly meets later are: the periodicity and addition properties of the

[1] (Added in proof) Recently Dutch teachers' organizations have accepted a renewal plan for the teaching of mathematics, which by removing several superannuated superfluities and introducing elements of statistics, may be considered as an important step in the right direction.

trigonometric functions and their consequences (e.g. duplication and bisection formulae) and the cosine rule and, a few times, the sine law. Similar remarks hold for the other fields. There are, of course, exceptions, where one meets one of the other subjects, but, unless one works in very special fields like geodesics, nautics, astronomy, etc., these are rare. Moreover, most of the subjects which a professional mathematician meets in later life, he meets in a quite different context, in which it is far easier for him to understand them than by way of the elementary treatment (e.g. the formulae for the volume of a sphere, a spherical segment and a spherical sector, which belong to integral calculus rather than to geometry).

Considering on the other hand the needs of a modern " consumer " of mathematics, which vary, of course, over the several branches of sciences one can say that they contain: 1° a clear idea of the testability or non-testability of a statement, 2° a clear idea of the concept of a mathematical model for some part of empirical science, and of the uses which can and which can not be made of it; 3° a good working knowledge of using graphs and algebraic computing, to such a degree that it becomes a natural habit to translate a problem in symbols (this is often not obtained because of the " fear of mathematics ", often raised by the excessive amount of exercises made); 4° the fundamentals of statistics and probability theory; 5° a few elementary methods of testing the most frequently occurring hypotheses (e.g. sign test, rank correlation test, Student's test, Wilcoxon's test); 6° a working knowledge of elementary calculus, etc.

Teachers sometimes seem to believe that a subject should not be taught, unless it can be taught in relatively great completeness and in a rigorous way, containing proofs of all statements. The consequence of this opinion, however, is that many scientists are prevented from obtaining a good working knowledge of statistics and differential calculus, if they are not (or not thought to be) capable of grasping the socalled " exact " concept of a limit. It also disagrees with the attitude of all classical mathematicians up to Riemann, for whom it always was more important to find new results and new methods

(" rules ") than to prove them. This reminds of the English school-boy having to learn " Euclid ", and saying to his teacher " Bother the proofs. Tell me the results ! "

Another prevailing opinion holds that the secondary education should restrict itself to " pure " mathematics, without bothering much about the applications. This, however, disregards the fact, mentioned already before, that most of " pure " mathematics is old " applied " mathematics. In particular this holds for school mathematics, with the exception of geometry in its Euclidean form: logarithms were introduced purely as a computational method; the solution of algebraic equations by means of roots is due to the fact that roots (from positive numbers) were originally almost the only onevalued functions one could master (this same fact gave rise later to Galois' theory; from a modern computational point of view it is without the slightest importance whether an equation can be reduced to successive extractions of roots, whereas formerly this was highly relevant); trigonometry was introduced as an expedient for astronomical, nautical and geodesical problems; descriptive geometry was introduced by Monge as a method to avoid the at that time very clumsy computational methods. Descriptive geometry is, by the way, the only subject on the mathematics curriculum which is less than about 300 years old; it is even less than two centuries of age !

In this context the fact should be mentioned that the Educational Institute at the University of Utrecht has successfully initiated an experiment in teaching elementary probability theory and history of mathematics in the highest classes of literary gymnasia, and to abolish the teaching of solid geometry and of broken linear functions in these schools. The experiment will be continued with other school-types also.

7. Desirability of a new orientation of mathematical teaching.

The large extent of obligatory mathematical education for *all* pupils in most schools is usually justified, apart from its applications, by 1° stating that " instruction in mathematics