4. Applications of mathematics

Objekttyp: **Chapter**

Zeitschrift: **L'Enseignement Mathématique**

Band (Jahr): **10 (1964)**

Heft 1-2: **L'ENSEIGNEMENT MATHÉMATIQUE**

PDF erstellt am: **17.09.2024**

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topological ideas. Such a unit should be entirely practical as long as it is closely tied to concrete examples familiar to the student.

Most of the reports contained frequent mentions of traditional topics whose teaching would be improved by the adoption of a more modern point of view. As one example, I shall use a unit discussed in the report from the United States. This is the treatment of equations, simultaneous equations and inequalities. An equation or inequality is treated as an " open sentence ". That is, it is a mathematical assertion which in itself is neither true nor false, but becomes true or false when its variables are replaced by names of numbers or points (or more abstract objects, in advanced subjects). Therefore, the solution of an equation is the search for the set for which the assertion is true. This set is commonly referred to as the " truth set " or the " solution set ".

Thinking of solutions of equations as sets has the advantage that a student is more likely to think of the possibilities of the solution having more than one element in it or, for that matter, being the empty set. Simultaneous equations may be thought of as conjunctions of several open sentences; hence their solution consists of the intersection of the individual truth sets. This point of view makes it much easier to explain the usual algorithms for solving of simultaneous equations. The attempt in any such algorithm is to replace a set of sentences by an equivalent set, i.e., one having the same truth set, but the latter being of a form in which the nature of the solutions is obvious. The approach also has the advantage that equations and inequalities may be treated in exactly the same manner. The graphing of equations and inequalities, then, simply becomes a matter of graphical representation of truth sets. In this case, the meaning of " intersection " of solution sets becomes particularly clear.

4. Applications of mathematics

It is painfully clear, in reading the 21 national reports, that relatively little attention has been given by our reformers to the teaching of applications of mathematics. The only notable exception to this is the inclusion of statistics in a majority of the recommendations. Aside from this, only scattered suggestions are made, none of them occurring in more than two reports. Indeed, some reporters have specifically complained that, while an enormous effort has been made in their nations to improve the teaching of pure mathematics, the topic of applied mathematics has apparently been forgotten. I would like to propose to ICMI that a study of the teaching of applications of mathematics should receive high priority in its studies of the next four-year period.

Aside from statistics, three types of applications have been mentioned. One is applications of mathematics to physics. I presume it differs greatly from country to country as to whether topics such as mechanics are included in the mathematics curriculum or are treated in separate physics courses.

A second area that was mentioned twice was that there are great possibilities in the future of improving the teaching of mathematics by making free use of computing machines. Of course, in the immediate future this may not be practical until highspeed computers are available in large enough numbers for high school students to be able to give sufficient time on them.

A third area mentioned was linear programming. This particular topic has the attraction that it ties up nicely with linear algebra and therefore can reinforce the teaching of a quite modern topic of abstract mathematics. It also lends itself to good numerical problems which are both interesting and will exercise the student's ability in the solving of equations. But, above all, it may be the only example the student will see of a genuine application to the social sciences.

The philosophy of teaching applied mathematics is particularly well described in the report from the Netherlands.

" It is an urgent problem whether secondary education must restrict itself to pure mathematics. Applications gain more and more momentum in the social system. If these applications were only operational, one could ask whether they should be taught at all in high schools. Teaching applied mathematics, however, implies developing new habits of thinking, which in many cases differ from those in abstract mathematics. For instance, in statistics it is difficult to acquire operational skill as long as one has not really and independently understood the fundamental notions. "

5. Further observations

Perhaps the major motivation for teaching modern mathematics, or mathematics in a modern spirit in high school, is to prepare the student for his university experience. The need for this is particularly well brought out in a quotation from the French report from Professor Lichnerowicz. The quotation (in translation) reads: " The classical teaching of our lycées in a large measure conditions our students to a certain conception of mathematics, a conception which is . . . derived from the Greeks, and . . . from the experience of mathematicians of the middle of the nineteenth century . . . At the university, the students suddenly encounter the spirit of contemporary mathematics, a painful shock . . . The student must totally ' recondition ' himself . . . and this is translated by an expression which I personally have often heard: ' What you are teaching is no longer mathematics ' . . . "

I am sure that many of us can testify to the same experience. Let us now examine a few pedagogical problems.

The Netherlands report recommends that " stress should be laid on thinking mathematically and more value attached to this ability than to knowledge of a variety of less important facts. " If this philosophy is adopted, then presumably the exact choice of topics is not nearly as significant as the manner in which they are presented in the high school.

An important pedagogical idea is expressed in the Portugese report: " For this introduction (of modern mathematics) it would be essential to bring out many concrete examples, well known and quite suggestive, as well as amusing, and one would be careful not to introduce formalism until one was sure that the student had grasped the ideas behind them. "

One question that arises in the introduction of new topics is what topics are reduced to make room for the inclusion of new