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Problems of Science Teaching

TWO striking addresses dealing, *inter alia*, with the teaching of science in secondary schools have recently appeared—the Pedler lecture of the British Science Guild, by Prof. Irvine Masson,[1] and the presidential address to the Science Masters' Association, by the headmaster of Harrow.[2] They go back once more to the views of Huxley, to those of the representative committees of the British Association of 1917 and 1928, under the chairmanship of Sir Richard Gregory,[3] and to those of the Prime Minister's Committee of 1916–18 presided over by Sir J. J. Thomson,[4] when they suggest that for the vast majority of boys (and girls) what is needed is an all-round training in science, broad and simple, and including not only physics and chemistry, but also biology, geology, and astronomy.

The change would involve sacrifices both on the literary side and, for pupils who already take science, on the scientific side. On the scientific side, Prof. Masson suggests that the prematurely intensive study of a particular science at school is directly harmful to the later study of the science itself. This proposal, however, raises other problems, and some of fundamental importance not obvious at once, both in education, in its narrower sense, and also in citizenship. Like Dr. Norwood, we hear the contemptuous 'Smattering!' of some of our readers; nor are we unmindful of 'H. E. A.'s' courageous and reiterated demand that what should be taught in secondary schools is 'scientific method',[5] and his plea that in the right kind of scientific teaching the principle must be insisted on that 'nothing may be taken for granted'.

The doctrine is a simple one—unfortunately, too simple for truth. Even the author of the epoch-making "Discours de la méthode", Descartes, did not suspect all the things he took for granted; and the 'deductions' cheerfully made by a schoolboy from the simplest scientific experiment may be matters still under discussion by the keenest scientific intellects of our time. Imagine a teacher working through the more important books on method published since Mach's "Science of Mechanics"—we have in mind authors like Karl Pearson, Poincaré, James Ward, Russell, White-

[1] Published by the British Science Guild, 6 John Street, Adelphi, W.C.2. 1*s*.
[2] *School Science Review* for March 1932.
[3] Report on Science in School Certificate Examinations, with syllabuses by various teachers. London: British Association for the Advancement of Science. 1*s*.
[4] Natural Science in Education (§§ 41, 49, and *passim*). London: H.M. Stationery Office. 1*s*. 6*d*. net.
[5] See "The Teaching of Scientific Method, and Other Papers on Education", by H. E. Armstrong (2nd edition, 1925, pp. 1-10, and 256-7), and the two articles on "National Needs" by 'H. E. A' in NATURE for Nov. 14 and Dec. 26, 1931.

head, T. P. Nunn, N. R. Campbell, Meyerson, H. Levy, and the quite recent books by Dr. Herbert Dingle on "Science and Human Experience" and by Dr. Harold Jeffreys on "Scientific Induction"—and then trying to tell a class of schoolboys what is meant by such phrases as 'cause and effect', 'scientific explanation', or 'error of experiment' (purposely omitting the old terms we used to think so simple, such as 'mass', 'energy', 'atom'). Could he possibly assure them that in his teaching 'nothing was taken for granted'?

In every example of scientific experiment which a teacher will give to his pupils, not few but many assumptions will be made, if he is not utterly to bewilder them at this stage. Newton's famous "hypotheses non fingo" is probably largely responsible for the notion that 'nothing is taken for granted' in teaching physical science. The phrase occurs in the penultimate paragraph of the "Principia"; it was intended by Newton only to apply to part of his work; and it is in striking contrast with the final paragraph of the "Principia" itself, and with what Priestley calls the "bold", "eccentric" notions of the "Opticks", with its "Queries". The fundamental distinction between verifiable and unverifiable hypotheses drawn by writers like Nunn [6] and Dingle,[7] and the fruitfulness of the great 'unverifiable' hypotheses, such as those of the atom and electron, elevated by some of our most distinguished men of science to the rank of 'ultimate realities'—all these are things which the school-teacher of science ought to have at the back of his mind. To explain them in detail to his pupils would, however, be an impossible task. The 'common-sense' of science is the most elusive of concepts.[8]

While differing from 'H. E. A.' in his views of scientific method, we are in warm agreement with his recent utterances on the artistic aspects of science, aspects of the utmost value to the teacher trying to secure the interest of his pupils. If we agree with Dingle that the material of science consists of the elements of our experience actually or potentially common to all normal people (whereas art and religion are concerned with experiences which may or may not be shared by others), we nevertheless see the *advances* of science have in them something individual, giving to many pupils, if adequately presented, an artistic emotion. In the Report of the British Association Committee of 1917 on Science Teaching in Secondary Schools, of which Prof. Armstrong himself was a member, it is suggested that teachers should not fail to give scope in their teaching to the 'wonder-motive', the 'utility-motive', and the 'systematising-motive'. By 'wonder-motive' is not meant the desire to wonder at astronomical immensities or the infinitely small, but at the achievements of individual men in overcoming difficulties; a wonder to be excited as much by the binomial theorem as by the cure for hydrophobia or by wireless telephony. "Execution", says Blake somewhere, "is the chariot of genius." The achievements of genius may be inspiring to many a boy or girl who would be unable to follow a logical analysis of method, of which the author himself may have been unconscious in making his discovery. Prof. S. Alexander has recently put forward views of which Blake's may be an anticipation.

From these general considerations we turn to another aspect of the matter, not less important. Dr. Norwood demands that "windows should be opened in the pupils' minds in all directions". The blindness of the average man to the problems of biology apparent in our educational and administrative systems may, to quote a recent utterance of Dr. H. H. Dale, "become a real danger to our civilisation". "An intelligent appreciation of the fundamental facts of biology is not yet regarded as a necessary part of the equipment of an educated man." [9] About the fact there can be no doubt. The statistics of the School Certificate Examination published by the second British Association Committee under the chairmanship of Sir Richard Gregory, and by Dr. Masson, show that only about one per cent of the candidates present themselves in biology or zoology (though a much larger proportion, mostly girls, take botany); and under present conditions the examination-room may be regarded as an approximate reflex of the class-room. There are some schools in which this is not the case, but they are few. We have quoted several authorities in favour of the policy advocated by Dr. Masson and Dr. Norwood: one other may be cited—the recent Report of the Prime Minister's Committee on the Education and Supply of Biologists, presided over by Lord Chelmsford.[10] "We hold strongly", the Report says, "that no boy should be allowed to leave school without having been introduced to biology" (loc. cit., p. 23).

Are there in English education at this moment

[6] "The Aims of Scientific Method" (1907), pp. 129, 130.
[7] "Science and Human Experience" (1931), pp. 46-50.
[8] In his interesting B.B.C. pamphlet on "Science in Perspective" (1931), Prof. H. Levy gives what he himself terms "the dim outline of a method".

[9] "Biology and Civilisation", the Norman Lockyer Lecture for 1931 (p. 17). British Science Guild, John Street, Adelphi, W.C.2. 1s.
[10] Published by H.M. Stationery Office, 1932, for the Economic Advisory Council. 1s. net.

any powers capable of securing this result? The Chelmsford Committee is conscious of the impotent, not to say ridiculous, delay that has followed the recommendations of its predecessors. The Committee wants steps to be taken by the Board of Education, in concert with the other Government departments. It wants the universities and great public schools to be consulted; but it strangely omits to mention by name the bodies which of all are the most important, if any large number of pupils are to be affected, the local education authorities. Is anything being done? P. J. H.

Seismology

Handbuch der Geophysik. Herausgegeben von Prof. Dr. B. Gutenberg. Band 4 (Lieferung 1): *Theorie der Erdbebenwellen; Beobachtungen; Bodenunruhe.* Von Prof. Dr. B. Gutenberg. Pp. 298. 30 gold marks. Lieferung 2: *Seismometer, Auswertung der Diagramme,* von Dr. H. P. Berlage, Jr.; *Geologie der Erdbeben,* von Prof. Dr. A. Sieberg. Pp. 299-686. 45 gold marks. (Berlin: Gebrüder Borntraeger, 1929–1930.)

PROF. B. GUTENBERG, a very distinguished seismologist, is general editor and chief author of what our German colleagues call a handbook of geophysics, in ten mighty volumes. There are more than forty other contributors. The two parts under review form the first instalment. The whole, when complete, should be a very comprehensive account of the whole of geophysics, particularly welcome on account of the scattered nature of the literature of the subject.

The first part is entirely by Prof. Gutenberg, and half the second by Dr. H. P. Berlage. These cover the whole of instrumental seismology, beginning with the theory of elastic waves, and proceeding to an account of the use of the instrumental records to infer the structure of the earth. The types of seismograph used are described in detail. The accounts given are very full. In places the reviewer might wish them fuller, and a few items are included, with little or no comment, which scarcely seem worth preserving in a work of permanent value. But on the whole we must welcome the most complete account of modern seismology yet published. Very little of any importance has escaped mention and discussion, and the references to original papers in all languages are abundant. This will be the standard work of reference for many years.

The remaining half of the second part, by Prof. A. Sieberg, is entitled "Geology of Earthquakes", and deals with macroseismology, or, as the author says, the study of earthquakes in the popular sense: their destructive effects on buildings, the visible effects on the earth's surface features, the movements felt by man, the sea waves produced, and so on. If I devote most attention to this part it is because I have learnt most from it.

The connexion between the local effects in the 'shaken region', that is, the region where motion can be felt, and the movements produced in instruments at a safe distance, has received very little discussion hitherto; and it seems to me that most important advances in both sides of the subject must develop from the study of their interrelations. As a specimen of the degree of separation that exists, it may be mentioned that Dr. C. Davison's excellent book, "The Founders of Seismology", contains no reference to Poisson or Rayleigh, who predicted theoretically the three principal types of elastic waves; and Davison might justly reply that none of my own works mentions Mallet or Mercalli. Yet the movement that is felt and in many cases shakes down houses is merely an elastic wave of great intensity; and on the other hand, the waves observed at a great distance have been produced in the shaken region, and must show traces of its properties.

The relation is already becoming an acute problem in instrumental seismology; hitherto we have concentrated attention on the various plutonic layers, but it is becoming clear that the sedimentary layer produces a controlling influence on some phenomena. I hinted very tentatively that some pulses observed in the Jersey earthquake of 1926 might be compressional waves in the sedimentary layer. Tillotson and Mourant have obtained confirmatory evidence, while Stoneley detects signs of an influence of the sedimentary layer on the shorter distortional waves. Now if there are bodily waves transmitted horizontally in the sedimentary layer, the focus must be in that layer. But most continental seismologists (including Gutenberg), in the cases they have investigated, claim to have found foci in the granitic layer at depths of the order of 30 km. I consider these estimates excessive, even on the actual data used; but clearly they are out of the question if the foci are not in the granitic layer at all.

It is here that macroseismology may provide a criterion, and abundant data are given by Prof. Sieberg. If the crust were uniform, the intensity would be greatest at the epicentre, and would fall off steadily with distance. This is not confirmed