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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SCIENCE AS SUBJECT-MATTER AND AS METHOD[1]

ONE who, like myself, claims no expertness in any branch of natural science can undertake to discuss the teaching of science only at some risk of presumption. At present, however, the gap between those who are scientific specialists and those who are interested in science on account of its significance in life, that is to say, on account of its educational significance, is very great. Therefore I see no other way of promoting that mutual understanding so requisite for educational progress than for all of us frankly to state our own convictions, even if thereby we betray our limitations and trespass where we have no rights save by courtesy.

I suppose that I may assume that all who are much interested in securing for the sciences the place that belongs to them in education feel a certain amount of disappointment at the results hitherto attained. The glowing predictions made respecting them have been somewhat chilled by the event. Of course, this relative shortcoming is due in part to the unwillingness of the custodians of educational traditions and ideals to give scientific studies a fair show. Yet in view of the relatively equal opportunity accorded to science to-day compared with its status two generations ago, this cause alone does not explain the unsatisfactory outcome. Considering the oppor-

[1] Address of the vice-president and chairman of Section L, Education, American Association for the Advancement of Science, Boston, 1909.

tunities, students have not flocked to the study of science in the numbers predicted, nor has science modified the spirit and purport of all education in a degree commensurate with the claims made for it. The causes for this result are many and complex. I make no pretense of doing more than singling out what seems to me one influential cause, the remedy for which most lies with scientific men themselves. I mean that science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking, an attitude of mind, after the pattern of which mental habits are to be transformed.

Among the adherents of a literary education who have contended against the claims of science, Matthew Arnold has, I think, been most discreetly reasonable. He freely admitted the need of men knowing something, knowing a good deal, about the natural conditions of their own lives. Since, so to say, men have to breathe air, it is advisable that they should know something of the constitution of air and of the mechanism of the lungs. Moreover, since the sciences have been developed by human beings, an important part of humanistic culture, of knowing the best that men have said and thought, consists in becoming acquainted with the contributions of the great historic leaders of science.

These concessions made, Matthew Arnold insisted that the important thing, the indispensable thing in education, is to become acquainted with human life itself, its art, its literature, its politics, the fluctuations of its career. Such knowledge, he contended, touches more closely our offices and responsibilities as human beings, since these, after all, are to human beings and not to physical things. Such knowledge, moreover, lays hold of the emotions and the imagination and modifies character, while knowledge about things remains an inert possession of speculative intelligence.

Those who believe, nevertheless, that the sciences have a part to play in education equal—at the least—to that of literature and language, have perhaps something to learn from this contention. If we regard science and literary culture as just so much subject-matter, is not Mr. Arnold's contention essentially just? Conceived from this standpoint, knowledge of human affairs couched in personal terms seems more important and more intimately appealing than knowledge of physical things conveyed in impersonal terms. One might well object to Arnold that he ignored the place of natural forces and conditions *in* human life and thereby created an impossible dualism. But it would not be easy to deny that knowledge of Thermopylæ knits itself more readily into the body of emotional images that stir men to action than does the formula for the acceleration of a flying arrow; or that Burns's poem on the daisy enters more urgently and compellingly into the moving vision of life than does information regarding the morphology of the daisy.

The infinitely extensive character of natural facts and the universal character of the laws formulated about them is sometimes claimed to give science an advantage over literature. But viewed from the standpoint of education, this presumed superiority turns out a defect; that is to say, so long as we confine ourselves to the point of view of subject-matter. Just because the facts of nature are multitudinous, inexhaustible, they begin nowhere and end nowhere in particular, and hence are not, just as facts, the best material for the education of those whose lives are centered in quite local situations and whose careers are irretrievably partial and specific. If we

turn from multiplicity of detail to general laws, we find indeed that the laws of science are universal, but we also find that for educational purposes their universality means abstractness and remoteness. The conditions, the interests, the ends of conduct are irredeemably concrete and specific. We do not live in a medium of universal principles, but by means of adaptations, through concessions and compromises, struggling as best we may to enlarge the range of a concrete here and now. So far as acquaintance is concerned, it is the individualized and the humanly limited that helps, not the bare universal and the inexhaustibly multifarious.

These considerations are highly theoretical. But they have very practical counterparts in school procedure. One of the most serious difficulties that confronts the educator who wants in good faith to do something worth while with the sciences is their number, and the indefinite bulk of the material in each. At times, it seems as if the educational availability of science were breaking down because of its own sheer mass. There is at once so much of science and so many sciences that educators oscillate, helpless, between arbitrary selection and teaching a little of everything. If any questions this statement, let him consider in elementary education the fortunes of nature-study for the last two decades.

Is there anything on earth, or in the waters under the earth or in the heavens above, that distracted teachers have not resorted to? Visit schools where they have taken nature study conscientiously. This school moves with zealous bustle from leaves to flowers, from flowers to minerals, from minerals to stars, from stars to the raw materials of industry, thence back to leaves and stones. At another school you find children energetically striving to keep up with what is happily termed the "rolling year." They chart the records of barometer and thermometer; they plot changes and velocities of the winds; they exhaust the possibilities of colored crayons to denote the ratio of sunshine and cloud in successive days and weeks; they keep records of the changing heights of the sun's shadows; they do sums in amounts of rainfalls and atmospheric humidities—and at the end, the rolling year, like the rolling stone, gathers little moss.

Is it any wonder that after a while teachers yearn for the limitations of the good old-fashioned studies—for English grammar, where the parts of speech may sink as low as seven but never rise above nine; for text-book geography, with its strictly inexpansive number of continents; even for the war campaigns and the lists of rulers in history since they can not be stretched beyond a certain point, and for "memory gems" in literature, since a single book will contain the "Poems Every Child Should Know."

There are many who do not believe it amounts to much one way or the other what children do in science in the elementary school. I do not agree, for upon the whole, I believe the attitude toward the study of science is, and should be, fixed during the earlier years of life. But in any case, how far does the situation in the secondary schools differ from that just described? Any one who has followed the discussions of college faculties for the last twenty-five years concerning entrance requirements in science, will be able to testify that the situation has been one of highly unstable equilibrium between the claims of a little of a great many sciences, a good deal (comparatively) of one, a combination of one biological and one exact science, and the arbitrary option of the pupil of one, two or three out of a list of six or seven specified sciences.

The only safe generalization possible is that whatever course a given institution pursues, it changes that course at least as often as the human organism proverbially renews its tissues. The movement has probably tended in the direction of reduction, but every one who has followed the history of pedagogical discussion will admit that every alteration of opinion as to what subjects should be taught has been paralleled by a modification of opinion as to the portions of any subject to be selected and emphasized.

All this change is to some extent a symptom of healthy activity, change being especially needed in any group of studies so new that they have to blaze their own trail, since they have no body of traditions upon which to fall back as is the case with study of language and literature. But this principle hardly covers the whole field of change. A considerable part of it has been due not to intelligent experimentation and exploration, but to blind action and reaction, or to the urgency of some strenuous soul who has propagated some emphatic doctrine.

Imagine a history of the teaching of the languages which should read like this: "The later seventies and early eighties of the nineteenth century witnessed a remarkable growth in the attention given in high schools to the languages. Hundreds of schools adopted an extensive and elaborate scheme by means of which almost the entire linguistic ground was covered. Each of the three terms of the year was devoted to a language. In the first year, Latin and Greek and Sanskrit were covered; in the next, French, German and Italian; while the last year was given to review and to Hebrew and Spanish as optional studies."

This piece of historic parallelism raises the question as to the real source of the educational value of, say, Latin. How much is due to its being a "humanity," its giving insight into the best the world has thought and said, and how much to its being pursued continuously for at least four years? How much to the graded and orderly arrangement that this long period both permitted and compelled? How much to the cumulative effort of constant recourse to what had earlier been learned, not by way of mere monotonous repetition, but as a necessary instrument of later achievement? Are we not entitled to conclude that the method demanded by the study is the source of its efficacy rather than anything inhering in its content?

Thus we come around again to the primary contention of the paper: that science teaching has suffered because science has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject-matter.

Science might well take a leaf from the book of the actual, as distinct from the supposititious, pursuit of the classics in the schools. The claim for their worth has professedly rested upon their cultural value; but imaginative insight into human affairs has perhaps been the last thing, save *per accidens,* that the average student has got from his pursuit of the classics. His time has gone of necessity to the mastering of a language, not to appreciation of humanity. To some extent just because of this enforced simplification (not to say meagerness) the student acquires, if he acquires anything, a certain habitual method. Confused, however, by the tradition that the subject-matter is the efficacious factor, the defender of the sciences has thought that he could make good his case only on analogous grounds, and hence has been misled into resting his claim upon the superior significance of his special subject-matter;

even into efforts to increase still further the scope of scientific subject-matter in education. The procedure of Spencer is typical. To urge the prerogative of science, he raised the question what knowledge, what facts, are of most utility for life, and, answering the question by this criterion of the value of subject-matter, decided in favor of the sciences. Having thus identified education with the amassing of information, it is not a matter of surprise that for the rest of his life he taught that comparatively little is to be expected from education in the way of moral training and social reform, since the motives of conduct lie in the affections and the aversions, not in the bare recognition of matters of fact.

Surely if there is any knowledge which is of most worth it is knowledge of the ways by which anything is entitled to be called knowledge instead of being mere opinion or guess-work or dogma.

Such knowledge never can be learned by itself; it is not information, but a mode of intelligent practise, an habitual disposition of mind. Only by taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry, does one ever get a knowledge of the method of knowing. Because participation in the making of knowledge has been scant, because reliance on the efficacy of acquaintance with certain kinds of facts has been current, science has not accomplished in education what was predicted for it.

We define science as systematized knowledge, but the definition is wholly ambiguous. Does it mean the body of facts, the subject-matter? Or does it mean the processes by which something fit to be called knowledge is brought into existence, and order introduced into the flux of experience? That science means both of these things will doubtless be the reply, and rightly. But in the order both of time and of importance, science as method precedes science as subject-matter. Systematized knowledge is science only because of the care and thoroughness with which it has been sought for, selected and arranged. Only by pressing the courtesy of language beyond what is decent can we term such information as is acquired ready-made, without active experimenting and testing, science.

The force of this assertion is not quite identical with the commonplace of scientific instruction that text-book and lecture are not enough; that the student must have laboratory exercises. A student may acquire laboratory methods as so much isolated and final stuff, just as he may so acquire material from a text-book. One's mental attitude is not necessarily changed just because he engages in certain physical manipulations and handles certain tools and materials. Many a student has acquired dexterity and skill in laboratory methods without its ever occurring to him that they have anything to do with constructing beliefs that are alone worthy of the title of knowledge. To do certain things, to learn certain modes of procedure, are to him just a part of the subject-matter to be acquired; they belong, say, to chemistry, just as do the symbols H_2SO_4 or the atomic theory. They are part of the arcana in process of revelation to him. In order to proceed in the mystery one has, of course, to master its ritual. And how easily the laboratory becomes liturgical! In short, it is a problem and a difficult problem to conduct matters so that the technical methods employed in a subject shall become conscious instrumentalities of realizing the meaning of knowledge —what is required in the way of thinking and of search for evidence before anything

passes from the realm of opinion, guess work and dogma into that of knowledge. Yet unless this perception accrues, we can hardly claim that an individual has been instructed in science. This problem of turning laboratory technique to intellectual account is even more pressing than that of utilization of information derived from books. Almost every teacher has had drummed into him the inadequacy of mere book instruction, but the conscience of most is quite at peace if only pupils are put through some laboratory exercises. Is not this the path of experiment and induction by which science develops?

I hope it will not be supposed that, in dwelling upon the relative defect and backwardness of science teaching I deny its absolute achievements and improvements, if I go on to point out to what a comparatively slight extent the teaching of science has succeeded in protecting the so-called educated public against recrudescences of all sorts of corporate superstitions and silliness. Nay, one can go even farther and say that science teaching not only has not protected men and women who have been to school from the revival of all kinds of occultism, but to some extent has paved the way for this revival. Has not science revealed many wonders? If radio-activity is a proved fact, why is not telepathy highly probable? Shall we, as a literary idealist recently pathetically inquired, admit that mere brute matter has such capacities and deny them to mind? When all allowance is made for the unscrupulous willingness of newspapers and magazines to publish any marvel of so-called scientific discovery that may give a momentary thrill of sensation to any jaded reader, there is still, I think, a large residuum of published matter to be accounted for only on the ground of densely honest ignorance. So many things have been vouched for by science; so many things that one would have thought absurd have been substantiated, why not one more, and why not *this* one more? Communication of science as subject-matter has so far outrun in education the construction of a scientific habit of mind that to some extent the natural common sense of mankind has been interfered with to its detriment.

Something of the current flippancy of belief and quasi-scepticism must also be charged to the state of science teaching. The man of even ordinary culture is aware of the rapid changes of subject-matter, and taught so that he believes subject-matter, not method, constitutes science, he remarks to himself that if this is science, then science is in constant change, and there is no certainty anywhere. If the emphasis had been put upon method of attack and mastery, from this change he would have learned the lesson of curiosity, flexibility and patient search; as it is, the result too often is a blasé satiety.

I do not mean that our schools should be expected to send forth their students equipped as judges of truth and falsity in specialized scientific matters. But that the great majority of those who leave school should have some idea of the kind of evidence required to substantiate given types of belief does not seem unreasonable. Nor is it absurd to expect that they should go forth with a lively interest in the ways in which knowledge is improved and a marked distaste for all conclusions reached in disharmony with the methods of scientific inquiry. It would be absurd, for example, to expect any large number to master the technical methods of determining distance, direction and position in the arctic regions; it would perhaps be possible to develop a state of mind with American people in general in which the supposedly keen American sense of humor would react when it is

proposed to settle the question of reaching the pole by aldermanic resolutions and straw votes in railway trains or even newspaper editorials.

If in the foregoing remarks I have touched superficially upon some aspects of science teaching rather than sounded its depths, I can not plead as my excuse failure to realize the importance of the topic. One of the only two articles that remain in my creed of life is that the future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind; and that the problem of problems in our education is therefore to discover how to mature and make effective this scientific habit. Mankind so far has been ruled by things and by words, not by thought, for till the last few moments of history, humanity has not been in possession of the conditions of secure and effective thinking. Without ignoring in the least the consolation that has come to men from their literary education, I would even go so far as to say that only the gradual replacing of a literary by a scientific education can assure to man the progressive amelioration of his lot. Unless we master things, we shall continue to be mastered by them; the magic that words cast upon things may indeed disguise our subjection or render us less dissatisfied with it, but after all science, not words, casts the only compelling spell upon things.

Scientific method is not just a method which it has been found profitable to pursue in this or that abstruse subject for purely technical reasons. It represents the only method of thinking that has proved fruitful in any subject—that is what we mean when we call it scientific. It is not a peculiar development of thinking for highly specialized ends; it *is* thinking so far as thought has become conscious of its proper ends and of the equipment indispensable for success in their pursuit.

The modern warship seems symbolic of the present position of science in life and education. The warship could not exist were it not for science: mathematics, mechanics, chemistry, electricity supply the technique of its construction and management. But the aims, the ideals in whose service this marvelous technique is displayed are survivals of a pre-scientific age, that is, of barbarism. Science has as yet had next to nothing to do with forming the social and moral ideals for the sake of which she is used. Even where science has received its most attentive recognition, it has remained a servant of ends imposed from alien traditions. If ever we are to be governed by intelligence, not by things and by words, science must have something to say about *what* we do, and not merely about *how* we may do it most easily and economically. And if this consummation is achieved, the transformation must occur through education, by bringing home to men's habitual inclination and attitude the significance of genuine knowledge and the full import of the conditions requisite for its attainment. Actively to participate in the making of knowledge is the highest prerogative of man and the only warrant of his freedom. When our schools truly become laboratories of knowledge-making, not mills fitted out with information-hoppers, there will no longer be need to discuss the place of science in education.

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COLUMBIA UNIVERSITY

THE FUTURE OF THE MEDICAL PROFESSION[1]

Mr. President and Colleagues: We are here to rejoice over the union of the Ohio and the Miami Medical Colleges, which

[1] An address on University Day, December 1, 1909, at the University of Cincinnati.