

Science in the Course of Study

1. The Logical and the Psychological

By science is meant, as already stated, that knowledge which is the outcome of methods of observation, reflection, and testing which are deliberately adopted to secure a settled, assured subject matter. It involves an intelligent and persistent endeavor to revise current beliefs so as to weed out what is erroneous, to add to their accuracy, and, above all, to give them such shape that the dependencies of the various facts upon one another may be as obvious as possible. It is, like all knowledge, an outcome of activity bringing about certain changes in the environment. But in its case, the quality of the resulting knowledge is the controlling factor and not an incident of the activity. Both logically and educationally, science is the perfecting of knowing, its last stage.

Science, in short, signifies a realization of the logical implications of any knowledge. Logical order is not a form imposed upon what is known; it is the proper form of knowledge as perfected. For it means that the statement of subject matter is of a nature to exhibit to one who understands it the premises from which it follows and the conclusions to

which it points (See ante, p. 190). As from a few bones the competent zoologist reconstructs an animal; so from the form of a statement in mathematics or physics the specialist in the subject can form an idea of the system of truths in which it has its place.

To the non-expert, however, this perfected form is a stumbling block. Just because the material is stated with reference to the furtherance of knowledge as an end in itself, its connections with the material of everyday life are hidden. To the layman the bones are a mere curiosity. Until he had mastered the principles of zoology, his efforts to make anything out of them would be random and blind. From the standpoint of the learner scientific form is an ideal to be achieved, not a starting point from which to set out. It is, nevertheless, a frequent practice to start in instruction with the rudiments of science somewhat simplified. The necessary consequence is an isolation of science from significant experience. The pupil learns symbols without the key to their meaning. He acquires a technical body of information without ability to trace its connections with the objects and operations with which he is familiar - often he acquires simply a peculiar vocabulary. There is a strong temptation to assume that presenting subject matter in its perfected form provides a royal road to learning. What more natural than to suppose that the immature can be saved time and energy, and be protected from needless error by commencing where competent inquirers have left off? The outcome is written large in the history of education. Pupils begin their study of science with texts in which the subject is organized into topics according to the order of the specialist. Technical concepts, with their definitions, are introduced at the outset. Laws are introduced at a very early stage, with at best a

few indications of the way in which they were arrived at. The pupils learn a "science" instead of learning the scientific way of treating the familiar material of ordinary experience. The method of the advanced student dominates college teaching; the approach of the college is transferred into the high school, and so down the line, with such omissions as may make the subject easier.

The chronological method which begins with the experience of the learner and develops from that the proper modes of scientific treatment is often called the "psychological" method in distinction from the logical method of the expert or specialist. The apparent loss of time involved is more than made up for by the superior understanding and vital interest secured. What the pupil learns he at least understands. Moreover by following, in connection with problems selected from the material of ordinary acquaintance, the methods by which scientific men have reached their perfected knowledge, he gains independent power to deal with material within his range, and avoids the mental confusion and intellectual distaste attendant upon studying matter whose meaning is only symbolic. Since the mass of pupils are never going to become scientific specialists, it is much more important that they should get some insight into what scientific method means than that they should copy at long range and second hand the results which scientific men have reached. Students will not go so far, perhaps, in the "ground covered," but they will be sure and intelligent as far as they do go. And it is safe to say that the few who go on to be scientific experts will have a better preparation than if they had been swamped with a large mass of purely technical and symbolically stated information. In fact, those who do become successful men of science are those who by

their own power manage to avoid the pitfalls of a traditional scholastic introduction into it.

The contrast between the expectations of the men who a generation or two ago strove, against great odds, to secure a place for science in education, and the result generally achieved is painful. Herbert Spencer, inquiring what knowledge is of most worth, concluded that from all points of view scientific knowledge is most valuable. But his argument unconsciously assumed that scientific knowledge could be communicated in a ready-made form. Passing over the methods by which the subject matter of our ordinary activities is transmuted into scientific form, it ignored the method by which alone science is science. Instruction has too often proceeded upon an analogous plan. But there is no magic attached to material stated in technically correct scientific form. When learned in this condition it remains a body of inert information. Moreover its form of statement removes it further from fruitful contact with everyday experiences than does the mode of statement proper to literature. Nevertheless that the claims made for instruction in science were unjustifiable does not follow. For material so taught is not science to the pupil.

Contact with things and laboratory exercises, while a great improvement upon textbooks arranged upon the deductive plan, do not of themselves suffice to meet the need. While they are an indispensable portion of scientific method, they do not as a matter of course constitute scientific method. Physical materials may be manipulated with scientific apparatus, but the materials may be disassociated in themselves and in the ways in which they are handled, from the materials and processes used out of school. The problems dealt with may be only problems of

science: problems, that is, which would occur to one already initiated in the science of the subject. Our attention may be devoted to getting skill in technical manipulation without reference to the connection of laboratory exercises with a problem belonging to subject matter. There is sometimes a ritual of laboratory instruction as well as of heathen religion. 1 It has been mentioned, incidentally, that scientific statements, or logical form, implies the use of signs or symbols. The statement applies, of course, to all use of language. But in the vernacular, the mind proceeds directly from the symbol to the thing signified. Association with familiar material is so close that the mind does not pause upon the sign. The signs are intended only to stand for things and acts. But scientific terminology has an additional use. It is designed, as we have seen, not to stand for the things directly in their practical use in experience, but for the things placed in a cognitive system. Ultimately, of course, they denote the things of our common sense acquaintance. But immediately they do not designate them in their common context, but translated into terms of scientific inquiry. Atoms, molecules, chemical formulae, the mathematical propositions in the study of physics - all these have primarily an intellectual value and only indirectly an empirical value. They represent instruments for the carrying on of science. As in the case of other tools, their significance can be learned only by use. We cannot procure understanding of their meaning by pointing to things, but only by pointing to their work when they are employed as part of the technique of knowledge. Even the circle, square, etc., of geometry exhibit a difference from the squares and circles of familiar acquaintance, and the further one proceeds in mathematical science the greater the remoteness from the everyday empirical thing. Qualities which do not count for the pursuit of knowledge

about spatial relations are left out; those which are important for this purpose are accentuated. If one carries his study far enough, he will find even the properties which are significant for spatial knowledge giving way to those which facilitate knowledge of other things - perhaps a knowledge of the general relations of number. There will be nothing in the conceptual definitions even to suggest spatial form, size, or direction. This does not mean that they are unreal mental inventions, but it indicates that direct physical qualities have been transmuted into tools for a special end - the end of intellectual organization. In every machine the primary state of material has been modified by subordinating it to use for a purpose. Not the stuff in its original form but in its adaptation to an end is important. No one would have a knowledge of a machine who could enumerate all the materials entering into its structure, but only he who knew their uses and could tell why they are employed as they are. In like fashion one has a knowledge of mathematical conceptions only when he sees the problems in which they function and their specific utility in dealing with these problems. "Knowing" the definitions, rules, formulae, etc., is like knowing the names of parts of a machine without knowing what they do. In one case, as in the other, the meaning, or intellectual content, is what the element accomplishes in the system of which it is a member.

2. Science and Social Progress

Assuming that the development of the direct knowledge gained in occupations of social interest is carried to a perfected logical form, the question arises as to its place in experience. In general, the reply is that science marks the emancipation of

mind from devotion to customary purposes and makes possible the systematic pursuit of new ends. It is the agency of progress in action. Progress is sometimes thought of as consisting in getting nearer to ends already sought. But this is a minor form of progress, for it requires only improvement of the means of action or technical advance. More important modes of progress consist in enriching prior purposes and in forming new ones. Desires are not a fixed quantity, nor does progress mean only an increased amount of satisfaction. With increased culture and new mastery of nature, new desires, demands for new qualities of satisfaction, show themselves, for intelligence perceives new possibilities of action. This projection of new possibilities leads to search for new means of execution, and progress takes place; while the discovery of objects not already used leads to suggestion of new ends.

That science is the chief means of perfecting control of means of action is witnessed by the great crop of inventions which followed intellectual command of the secrets of nature. The wonderful transformation of production and distribution known as the industrial revolution is the fruit of experimental science. Railways, steamboats, electric motors, telephone and telegraph, automobiles, aeroplanes and dirigibles are conspicuous evidences of the application of science in life. But none of them would be of much importance without the thousands of less sensational inventions by means of which natural science has been rendered tributary to our daily life.

It must be admitted that to a considerable extent the progress thus procured has been only technical: it has provided more efficient means for satisfying preexistent desires, rather than modified the quality of human purposes. There is, for example,

no modern civilization which is the equal of Greek culture in all respects. Science is still too recent to have been absorbed into imaginative and emotional disposition. Men move more swiftly and surely to the realization of their ends, but their ends too largely remain what they were prior to scientific enlightenment. This fact places upon education the responsibility of using science in a way to modify the habitual attitude of imagination and feeling, not leave it just an extension of our physical arms and legs.

The advance of science has already modified men's thoughts of the purposes and goods of life to a sufficient extent to give some idea of the nature of this responsibility and the ways of meeting it. Science taking effect in human activity has broken down physical barriers which formerly separated men; it has immensely widened the area of intercourse. It has brought about interdependence of interests on an enormous scale. It has brought with it an established conviction of the possibility of control of nature in the interests of mankind and thus has led men to look to the future, instead of the past. The coincidence of the ideal of progress with the advance of science is not a mere coincidence. Before this advance men placed the golden age in remote antiquity. Now they face the future with a firm belief that intelligence properly used can do away with evils once thought inevitable. To subjugate devastating disease is no longer a dream; the hope of abolishing poverty is not utopian. Science has familiarized men with the idea of development, taking effect practically in persistent gradual amelioration of the estate of our common humanity.

The problem of an educational use of science is then to create an intelligence pregnant with belief in the possibility of the

direction of human affairs by itself. The method of science engrained through education in habit means emancipation from rule of thumb and from the routine generated by rule of thumb procedure. The word empirical in its ordinary use does not mean "connected with experiment," but rather crude and unrational. Under the influence of conditions created by the non-existence of experimental science, experience was opposed in all the ruling philosophies of the past to reason and the truly rational. Empirical knowledge meant the knowledge accumulated by a multitude of past instances without intelligent insight into the principles of any of them. To say that medicine was empirical meant that it was not scientific, but a mode of practice based upon accumulated observations of diseases and of remedies used more or less at random. Such a mode of practice is of necessity happy-go-lucky; success depends upon chance. It lends itself to deception and quackery. Industry that is "empirically" controlled forbids constructive applications of intelligence; it depends upon following in an imitative slavish manner the models set in the past. Experimental science means the possibility of using past experiences as the servant, not the master, of mind. It means that reason operates within experience, not beyond it, to give it an intelligent or reasonable quality. Science is experience becoming rational. The effect of science is thus to change men's idea of the nature and inherent possibilities of experience. By the same token, it changes the idea and the operation of reason. Instead of being something beyond experience, remote, aloof, concerned with a sublime region that has nothing to do with the experienced facts of life, it is found indigenous in experience: - the factor by which past experiences are purified and rendered into tools for discovery and advance.

The term "abstract" has a rather bad name in popular speech, being used to signify not only that which is abstruse and hard to understand, but also that which is far away from life. But abstraction is an indispensable trait in reflective direction of activity. Situations do not literally repeat themselves. Habit treats new occurrences as if they were identical with old ones; it suffices, accordingly, when the different or novel element is negligible for present purposes. But when the new element requires especial attention, random reaction is the sole recourse unless abstraction is brought into play. For abstraction deliberately selects from the subject matter of former experiences that which is thought helpful in dealing with the new. It signifies conscious transfer of a meaning embedded in past experience for use in a new one. It is the very artery of intelligence, of the intentional rendering of one experience available for guidance of another.

Science carries on this working over of prior subject matter on a large scale. It aims to free an experience from all which is purely personal and strictly immediate; it aims to detach whatever it has in common with the subject matter of other experiences, and which, being common, may be saved for further use. It is, thus, an indispensable factor in social progress. In any experience just as it occurs there is much which, while it may be of precious import to the individual implicated in the experience, is peculiar and unreduplicable. From the standpoint of science, this material is accidental, while the features which are widely shared are essential. Whatever is unique in the situation, since dependent upon the peculiarities of the individual and the coincidence of circumstance, is not available for others; so that unless what is shared is abstracted and fixed by a suitable symbol, practically

all the value of the experience may perish in its passing. But abstraction and the use of terms to record what is abstracted put the net value of individual experience at the permanent disposal of mankind. No one can foresee in detail when or how it may be of further use. The man of science in developing his abstractions is like a manufacturer of tools who does not know who will use them nor when. But intellectual tools are indefinitely more flexible in their range of adaptation than other mechanical tools.

Generalization is the counterpart of abstraction. It is the functioning of an abstraction in its application to a new concrete experience, - its extension to clarify and direct new situations. Reference to these possible applications is necessary in order that the abstraction may be fruitful, instead of a barren formalism ending in itself. Generalization is essentially a social device. When men identified their interests exclusively with the concerns of a narrow group, their generalizations were correspondingly restricted. The viewpoint did not permit a wide and free survey. Men's thoughts were tied down to a contracted space and a short time, - limited to their own established customs as a measure of all possible values. Scientific abstraction and generalization are equivalent to taking the point of view of any man, whatever his location in time and space. While this emancipation from the conditions and episodes of concrete experiences accounts for the remoteness, the "abstractness," of science, it also accounts for its wide and free range of fruitful novel applications in practice. Terms and propositions record, fix, and convey what is abstracted. A meaning detached from a given experience cannot remain hanging in the air. It must acquire a local habitation. Names give abstract meanings a physical locus and body. Formulation

is thus not an after-thought or by-product; it is essential to the completion of the work of thought. Persons know many things which they cannot express, but such knowledge remains practical, direct, and personal. An individual can use it for himself; he may be able to act upon it with efficiency. Artists and executives often have their knowledge in this state. But it is personal, untransferable, and, as it were, instinctive. To formulate the significance of an experience a man must take into conscious account the experiences of others. He must try to find a standpoint which includes the experience of others as well as his own. Otherwise his communication cannot be understood. He talks a language which no one else knows. While literary art furnishes the supreme successes in stating of experiences so that they are vitally significant to others, the vocabulary of science is designed, in another fashion, to express the meaning of experienced things in symbols which any one will know who studies the science. Aesthetic formulation reveals and enhances the meaning of experiences one already has; scientific formulation supplies one with tools for constructing new experiences with transformed meanings.

To sum up: Science represents the office of intelligence, in projection and control of new experiences, pursued systematically, intentionally, and on a scale due to freedom from limitations of habit. It is the sole instrumentality of conscious, as distinct from accidental, progress. And if its generality, its remoteness from individual conditions, confer upon it a certain technicality and aloofness, these qualities are very different from those of merely speculative theorizing. The latter are in permanent dislocation from practice; the former are temporarily detached for the sake of wider and freer application in later concrete action. There is a kind of idle

theory which is antithetical to practice; but genuinely scientific theory falls within practice as the agency of its expansion and its direction to new possibilities.

3. Naturalism and Humanism in Education

There exists an educational tradition which opposes science to literature and history in the curriculum. The quarrel between the representatives of the two interests is easily explicable historically. Literature and language and a literary philosophy were entrenched in all higher institutions of learning before experimental science came into being. The latter had naturally to win its way. No fortified and protected interest readily surrenders any monopoly it may possess. But the assumption, from whichever side, that language and literary products are exclusively humanistic in quality, and that science is purely physical in import, is a false notion which tends to cripple the educational use of both studies. Human life does not occur in a vacuum, nor is nature a mere stage setting for the enactment of its drama (ante, p. 211). Man's life is bound up in the processes of nature; his career, for success or defeat, depends upon the way in which nature enters it. Man's power of deliberate control of his own affairs depends upon ability to direct natural energies to use: an ability which is in turn dependent upon insight into nature's processes. Whatever natural science may be for the specialist, for educational purposes it is knowledge of the conditions of human action. To be aware of the medium in which social intercourse goes on, and of the means and obstacles to its progressive development is to be in command of a knowledge which is thoroughly humanistic in quality. One

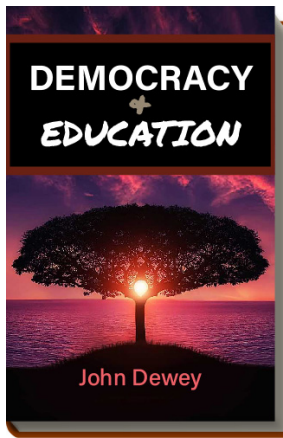
who is ignorant of the history of science is ignorant of the struggles by which mankind has passed from routine and caprice, from superstitious subjection to nature, from efforts to use it magically, to intellectual self-possession. That science may be taught as a set of formal and technical exercises is only too true. This happens whenever information about the world is made an end in itself. The failure of such instruction to procure culture is not, however, evidence of the antithesis of natural knowledge to humanistic concern, but evidence of a wrong educational attitude. Dislike to employ scientific knowledge as it functions in men's occupations is itself a survival of an aristocratic culture. The notion that "applied" knowledge is somehow less worthy than "pure" knowledge, was natural to a society in which all useful work was performed by slaves and serfs, and in which industry was controlled by the models set by custom rather than by intelligence. Science, or the highest knowing, was then identified with pure theorizing, apart from all application in the uses of life; and knowledge relating to useful arts suffered the stigma attaching to the classes who engaged in them (See below, Ch. XIX). The idea of science thus generated persisted after science had itself adopted the appliances of the arts, using them for the production of knowledge, and after the rise of democracy. Taking theory just as theory, however, that which concerns humanity is of more significance for man than that which concerns a merely physical world. In adopting the criterion of knowledge laid down by a literary culture, aloof from the practical needs of the mass of men, the educational advocates of scientific education put themselves at a strategic disadvantage. So far as they adopt the idea of science appropriate to its experimental method and to the movements of a democratic and industrial society, they have no difficulty in showing that natural science is more

humanistic than an alleged humanism which bases its educational schemes upon the specialized interests of a leisure class. For, as we have already stated, humanistic studies when set in opposition to study of nature are hampered. They tend to reduce themselves to exclusively literary and linguistic studies, which in turn tend to shrink to "the classics," to languages no longer spoken. For modern languages may evidently be put to use, and hence fall under the ban. It would be hard to find anything in history more ironical than the educational practices which have identified the "humanities" exclusively with a knowledge of Greek and Latin. Greek and Roman art and institutions made such important contributions to our civilization that there should always be the amplest opportunities for making their acquaintance. But to regard them as par excellence the humane studies involves a deliberate neglect of the possibilities of the subject matter which is accessible in education to the masses, and tends to cultivate a narrow snobbery: that of a learned class whose insignia are the accidents of exclusive opportunity. Knowledge is humanistic in quality not because it is about human products in the past, but because of what it does in liberating human intelligence and human sympathy. Any subject matter which accomplishes this result is humane, and any subject matter which does not accomplish it is not even educational.

Summary

Science represents the fruition of the cognitive factors in experience. Instead of contenting itself with a mere statement of what commends itself to personal or customary experience, it aims at a statement which will reveal the sources, grounds, and

consequences of a belief. The achievement of this aim gives logical character to the statements. Educationally, it has to be noted that logical characteristics of method, since they belong to subject matter which has reached a high degree of intellectual elaboration, are different from the method of the learner - the chronological order of passing from a cruder to a more refined intellectual quality of experience. When this fact is ignored, science is treated as so much bare information, which however is less interesting and more remote than ordinary information, being stated in an unusual and technical vocabulary. The function which science has to perform in the curriculum is that which it has performed for the race: emancipation from local and temporary incidents of experience, and the opening of intellectual vistas unobscured by the accidents of personal habit and predilection. The logical traits of abstraction, generalization, and definite formulation are all associated with this function. In emancipating an idea from the particular context in which it originated and giving it a wider reference the results of the experience of any individual are put at the disposal of all men. Thus ultimately and philosophically science is the organ of general social progress. 1 Upon the positive side, the value of problems arising in work in the garden, the shop, etc., may be referred to (See p. 200). The laboratory may be treated as an additional resource to supply conditions and appliances for the better pursuit of these problems.



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