ELEMENTARY SCIENCE
IN THE
SECONDARY SCHOOLS
OF ONTARIO

BY

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CHAPTER I.

THE PLACE OF ELEMENTARY SCIENCE.

State schools prepare for citizenship. Citizenship is concerned with future social activity. State education in correspondence with social activity is partly general, partly special. Elementary science is an essential feature of general education; it is in accord with the native interests of the child; it provides a training for the activities of ordinary life; it gives the pupil a knowledge of his physical environment; it enables him wisely to choose a vocation.

"EDUCATION is not a mere development, it is training, and training implies an end clearly conceived by the trainer."*

In every formal system of education some tendencies in the child's nature are carefully fostered, others are either greatly modified or entirely arrested. While the school cultivates the child's disposition to perform his various tasks neatly and to work at each industriously, it also checks his inclinations to do some things in a slovenly manner or to neglect his work along certain lines. Not only are evil tendencies arrested, but many good ones must be restrained. A man becomes a surgeon chiefly because at the same time he does not become a lawyer, merchant, farmer or mechanic. If development were the end of education, distinction among tendencies could not be made. The good and bad would be alike cultivated, and specialisation would be impossible. But in formal education this distinction is made, development is controlled. Development, then, can only be a means to an end, not the end itself. The real, ultimate end of formal education must be that which determines what tendencies in the child's nature are to be developed, and to what extent their development shall proceed.

This determinant of development is not constant, but varies with the nature of the school. The schools with which this thesis deals are maintained and controlled by the state; their function and product must thus be social in character. Since secondary schools cannot engage in research work, the only line of social activity open to them is the production of good citizens. But good citizenship

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*J. Welton: "Logical Bases of Education", p. 251.

embraces many fields of social activity. While each individual has the right to choose his particular sphere of social activity, and to develop those tendencies of his nature which will enable him to engage successfully therein, it is the right and duty of the state to see that those living within its boundaries and enjoying its privileges are educated in such a way that they may assume state duties and receive state benefits. The state should insist upon each individual attaining certain minimum requirements of good citizenship. A civilised state may demand justly that all children in the state learn to read and write. The state may set up certain standards of proficiency to which physicians, teachers and others engaged in special social duties shall attain before practising their respective professions. With an increased state solidarity all social activities become more special and more important. Since the state makes certain demands from the individual, it is the duty of the state to provide institutions in which the individual may be trained in such a way that he can satisfy these demands

The question arises, whether good citizenship refers to the present social activity of the boy, or to the future social activity of the man. The former position places emphasis upon the development aspect of education, the latter upon the social aspect. An ideal pupil in an ideal school of an ideal community, given full freedom of development, might develop into a good citizen. But the present pupil is not ideal, and certain standards have to be set up that will enable us to judge which tendencies in his nature should be encouraged and which restricted. These standards are derived from an examination into the lives of men and women of past and present times. Even if we could set up standards of boy and girl citizenship, we would have to refer to the adult lives of pupils in order to test the correctness of these standards. Otherwise these standards of boy and girl citizenship might lead us astray. A fruit farmer who leases a peach orchard for twenty years will prune the trees quite differently from one who leases an orchard for one year only. The ultimate end of education is found in man and woman citizenship, though for practical purposes of teaching immediate standards that gradually grade up to ultimate standards may be used.

Apart from theoretical considerations, this may be proved true by actual tests applied to any school community. I recently asked some eighty secondary school pupils whether they would continue at school if they knew that at the end of six months they were going to die. The majority answered in the negative. A few thought that they might come, but would not work hard, or would study some special subject only. As a rule the parents of these pupils told me that their children were being sent to high school to fit them for making a living. A few wished their children to acquire culture, meaning, I found, that they wished them to become ladies and gentlemen. Some of the school supporters, who were sending no children, told me that they were glad to see the boys and girls "have a chance"; others thought a good high school a town asset; a few were strongly opposed to being taxed for secondary school purposes. There is no doubt that at the present time pupils are attending high schools, parents are sending them there, and ratepayers are supporting these schools with a view to the future rather than the present welfare of these pupils. In a democratic country social institutions must function in accordance with the wishes of those who maintain them. Thus, from both a theoretical and a practical point of view, we may conclude that the school is given control of the child's present activity that it may prepare him for future social activity.

Social activity for which state schools make preparation is either vocational or non-vocational. Society requires the services of physicians, engineers, and artisans; and for its own sake, rather than the sake of the individual receiving the training, the state establishes vocational institutions. Society also sets up certain mental, moral, and physical standards of citizenship, to secure which non-vocational schools are instituted. While each vocation requires a special educational preparation, there are many activities common to all occupations. Every occupation demands some knowledge of language and mathematics, some conception of the physical properties of things, a certain familiarity with human nature, and a training in general methods of thought and action. Likewise, in every condition of life many non-vocational activities are common. Every one must learn to care for his body, and must be fitted for the duties of domestic, social, and political life. Since certain aspects of both vocational and non-vocational life are common to all men, social activity may be divided into that which is general and that which is special. In correspondence with these divisions, education must be general or special.

The graduate from the medical school takes post-graduate courses before he has his profession well in hand. There are many degrees of attainment in general as in special education. Something more than a knowledge of "Osler" separates the doctor from the ditcher; the lawyer must know more than law. A surgeon from a country village where he had established a successful practice, moved to the city. He found great difficulty in establishing himself there, because, while an excellent practitioner, he was lacking in those social qualities that attract and hold the confidence of city patients. Thus in the direct exercise of their professions, men of a higher calling require a higher form of general education adjusting them more perfectly to a wider range of life. They also have greater demands made upon their citizenship apart from their vocation. They are the social and political leaders in their communities and to a great extent mould and control public opinion. Speaking broadly, the extent of a man's fundamental education should increase in proportion to the extent of his special education. This means that general education cannot stop at the end of the primary school course, but must continue throughout the secondary and university systems.

Is the study of elementary science a feature of general or special education? Does it deal with phases of social activity forming part of the life of every one who takes a secondary school education, or is its usefulness limited to those who specialise in science? Our whole treatment of elementary science will depend upon whether we consider it an introductory subject in a special science course, or whether we consider it a fundamental subject, preparing the pupil for those common activities of life in which all will engage, no matter what their occupation may be. Not that these ends are mutually exclusive. A special course has a certain value as a factor in general education, and all special courses must evolve from fundamental courses; but the character of the course will depend to a great extent upon which aim the emphasis is placed.

To occupy a place on the general course of a secondary school a subject should fulfil four conditions. It must be suited to the child's interest and his stage of mental development. It must provide a peculiar field of training for methods of thought and action of general use in everyday life. It must organise the pupil's conceptions of a distinct and important portion of his everyday environment. It must be fundamental to the choice and study of a special occupation.

It may almost be taken for granted that a subject should accord with the present interest of the child and with his stage of mental development. If a subject be foreign to the native interest of the pupil, a colony of ideas may be planted, indeed, in the mind of the child, but since they bear no relation to the dominant tendencies of his nature, they will have little influence upon his personality, character and actions. Even if it were possible successfully to engraft foreign interests, it is not the function of the school to make plums grow on apple trees. The function of the school is to control and modify the growth of the individual in accordance with the requirements of good citizenship; but it has neither the right nor duty, even if it had the power, to substitute one individuality for another. As far as I know, no one has ever denied that the interest of the average boy or girl entering the secondary school is, to a fairly large extent, centred upon those topics of physical or biological existence dealt with in an elementary science course. We may safely assume, then, that this subject fulfils the first condition required for a place on the general course of a secondary school.

In the second place, is it possible to train the child in methods of thought and action of general use in everyday life? Experiments such as those quoted by W. C. Bagley (The Educative Process, chap. XIII) tend to show that a "generalised habit" is a psychological absurdity; that all habits are special and do not "carry over" or "spread" from one sphere of mental activity to another. I do not think that the arguments advanced support so sweeping a conclusion. Slovenliness in one's attire associated with neatness in one's work (p. 212) may result from the lapse of habit. Civil engineers who are well-groomed men at home tell me that, when railway building in the north, it requires constant effort to keep up the gentlemanly appearance necessary to maintain their position and authority over the workmen. The most slovenly woman upon my street was a neat, tidy girl three years ago, before she married a worthless husband. Many instances of incongruous habits existing side by side may be accounted for by partial lapse. One can easily account for the industrious school teacher finding difficulty in "carrying over" his habit of industry from the class room to the wood-pile or hay-field (p. 210, 211) by the mere physical exhaustion that rapidly follows new effort and makes it distasteful. Even a special habit may be bent or broken under novel conditions. One of the best spellers in the First Form made a miserable showing during the inspector's recent visit. When the furnace has gone out on a chilly winter morning, I may omit my regular cold shower bath. In many instances the failure of a habit to function may be due to the introduction of new conditions that tend to retard its activity. It would appear that the author considers the opposite of any habit to be merely a negative quantity. Such is not the case. A child in a primary school under a good English but poor mathematical teacher may form positive habits of accuracy in spelling, and equally positive habits of inaccuracy in mathematical operations. Incongruous habits existing side by side in the same person may represent a battlefield of conflicting tendencies in which the struggle between two opposite and nearly equal forces has not yet been decided. The development of habit is in any case a slow process; and the modification of a formed habit through "spread" would be doubly slow, since a habit already developed has to be overcome by indirect action. If the author would be consistent, he cannot speak of the habit of accurate spelling. The spelling of each word is a special, separate habit. Many people are good spellers, except when using words containing "ei" or "ie"; others stumble over "ee", "ea" and "ede". Thus to speak of the habit of accurate spelling is to refer to a "generalised habit". The same holds true in regard to accuracy in mathematical operations. Not only are addition, multiplication, etc., special habits, but each addition combination, such as $9+6=15$, is itself a separate habit. Every primary teacher can recall many instances of children who seemed to "stick" at certain combinations though otherwise fairly proficient in addition work. Though I have taught mathematics for fifteen years, I find that I can add a column in which the digit "9" frequently occurs, more rapidly and more accurately than if "8's" were substituted for the "9's". To speak, then, of a habit of quickness or accuracy in arithmetic is to refer to a "generalised habit".

On the other hand, the complete rejection of the doctrine of formal discipline is modified very considerably in the latter part of the chapter. Professor O'Shea is quoted with approval as expressing the idea "that many lines of activity, differing in several characteristics, may yet have some characteristics in common. If such is the case, training in one may promote efficiency in the other . . . The method gained in the observation of plant life will be of assistance in observing human life."* This implies two things. If the material conditions of one line of activity are identical in some respects with the material conditions of another line of activity, habit will tend to "carry over". The child will benefit materially when he comes to learn the subtraction combinations, 9–6=3, if he has previously learned the addition combination, 6+3=9. Common general methods may also "carry over" from one subject to another. This term some members of my matriculation class who take the science option, on their own initiative adopted experimental methods of finding the key to the solution of problems in geometry dealing with loci or proportion, by using concrete positions or numbers. Those taking the moderns option I have never known to use this method unless it were pointed out; I invariably find them "turning back" to find the "rule".

Later on in the chapter we find the following: "The doctrine of formal discipline assumed that the mastery of a certain subject gave one an increased power to master other subjects. It is clear that there is a certain amount of truth in this statement, provided that we understand very clearly that this increased power must always take the form of an ideal that will function as judgment and not of an unconscious predisposition that will function as habit".† Or to put the case concretely, from the habit of being neat in one's attire may be derived an abstract idea of the general value of neatness, which idea will tend to modify habits in other directions. We may also note that in the cases of common material and common method, mentioned above, it is essential that the student recognise the possibility of applying the method under new conditions. All my science students did not of their own accord adopt experimental methods in the solution of the geometrical deductions. Many failed to see that an experimental method of solution was applicable. Since this recognition is an act of judgment, the "carry over" even in this case is not directly from habit to habit.

Space will not permit of a more prolonged discussion of the doctrine of formal discipline. The position adopted as a basis for the present work may be summarised as follows. All habits originate as specific reactions; hence all habits must be specially taught, and general habits as such cannot be taught. Muscular

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*W. C. Bagley: "The Educative Process", p. 209.

†W. C. Bagley: "The Educative Process", p. 216.

habits functioning in a similar manner the same bodily parts may "carry over" directly. Grace in dancing tends to promote grace in walking. Mental habits will not "spread" directly; but if either the material used or the method employed in one line of activity be recognised as available in another line, the training received in the former may be "carried over" to the latter by means of a recognition idea. Abstract ideas of the value of certain lines of action may be evolved from one or more habits, and serve to modify other habits.

Does elementary science provide a peculiar field of training for the development of mental habits, which by means of ideas may be "carried over" to the activities of ordinary life? We may note at once that the so-called general faculties, such as observation, cannot be developed at all, much less "carried over". But an idea of the value of drawing conclusions from real data, of careful observation, of exact work, of just judgment, things so essential in the study of science, may be abstracted and become so prominent in consciousness that it will react upon the habits of everyday life. In the study of science as in no other study are taught general methods of collecting, analysing, and classifying facts, general methods of testing inductions by means of experiments, in short, general methods of obtaining exact truths from experience. These same methods are applicable to the affairs of everyday life, if the pupil be taught to recognise the possibility of their application. "Every child ought to get a glimpse of the real mode of ascertaining truth in this world; ought to know how truth has, as a matter of fact, been come at in all the modern sciences, pure and applied . . . every child ought to learn what the scientific process of study and inquiry is, so that in after life when he is an adult, he shall know how to apply or how to get applied, in his own sphere or province, that invaluable method."*

Does the study of elementary science organise the pupil's conception of a distinct and important portion of his everyday environment? The life of every man is more or less concerned with physical and biological phenomena. Many vocations require a general knowledge of scientific conceptions, beyond what is given in the special training for those vocations. The lawyer handles cases in which scientific ideas are involved; the merchant and

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*C. W. Eliot: "The Concrete and Practical", p. 27.

manufacturer must understand the nature and preparation of the goods they handle; the minister should be acquainted with the tendencies of scientific thought. In non-vocational activities, every one should know how to care for his body, should be acquainted with the principles of domestic science and sanitation. The recreations of many are concerned with scientific things, nature study, gardening, the operation of motor machinery. Elementary science is the only subject in the lower school that attempts to prepare the pupil for this phase of his adult life.

A man's life is centred about his vocation. Every one should be in a position wisely to choose his calling. To do this he must have "tried out" in a general way at least, his ability along certain directions. He should find out whether he is a square peg before he tries the round hole. If he excels in English but is deficient in mathematics, the platform, bar, pupil or pen, according to the particular line of his talent, affords a more certain avenue to success than civil engineering. The incidental, rather than the fundamental features of a vocation so often determine a boy's choice. I remember a former student who wished to be a civil engineer because he liked "wild life", though he had never camped beyond his father's lawn, and made at least one blunder in every mathematical problem he attempted to solve. A failure in algebra and geometry at the matriculation examination caused him to take a more serious view of things; while a summer up north, fire-ranging, cooled his ardour for "wild life". The majority of men in Canada are engaged in vocations of a more of less scientific character. Hence it is essential that every one should be sufficiently familiar with the general aspects of science study to enable him to know himself and his possibilities in relation to these fields of activity.

"While scientific investigation is for the few and therefore special . . . nature study is for every one and therefore fundamental".* Elementary science should appear on the general course of the lower, secondary school curriculum, since it is peculiarly suited to the native interests of the child; supplies a necessary and particular training in methods of mental action which may be "carried over" to the activities of ordinary life; organises an important sphere of human experience and preconditions the wise choice of a vocation. "No boy or girl should leave school without

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*L. H. Bailey: "The Nature Study Idea", p. 140.

possessing a grasp of the general character of science and without having been disciplined more or less in the methods of all sciences; so that, when turned into the world to make their own way, they shall be prepared to face scientific problems, not by knowing at once the conditions of every problem, or by being able at once to solve it; but by being familiar with the general current of scientific thought, and by being able to apply the methods of science in the proper way, when they have acquainted themselves with the conditions of special problems."*

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*T. H. Huxley: "Lay Sermons", p. 54.

CHAPTER II.

THE SCIENTIFIC METHOD.

Method an ordered way of doing anything. Method-habit a series of more or less automatic reactions towards a definite end, initiated under certain conditions. Method-habits and teaching methods. Common elements in methods of scientific research and methods of ordinary activity; discovery of problems; solution of problems; the inference; the development of the inference through just judgment of systematically observed experience; probability of conclusions; application to practical life. Excess of research methods over ordinary methods.

WHEN a housewife bakes a new kind of cake she follows a certain method as outlined in the recipe; the ingredients are prepared, mixed and baked in a certain, definite way. The next time she tries, the plan at first pursued may be modified somewhat. When a cake is produced that exactly suits the taste of the household, she soon becomes so familiar with the recipe, or modified recipe, that she does not need to refer to the cook-book. Now whether she follows the cook-book, or her memory, or her judgment, the plan pursued may be termed the method of making the cake. Method is an ordered way of doing anything.

In making his morning toilet a man goes through a regular routine of action. He may brush his teeth before he shaves, and shave before he takes a cold shower. The relations among these actions are apparently fortuitous. There is no reason why he should not, like many men, take the cold shower before he shaves. But the sequence of actions has been repeated so frequently, that the completion of one action seems to initiate the following one, forming a series of nearly automatic reactions. In a strange house or under unusual conditions in his own home, this routine may be disturbed, but the tendency to reinstate itself under favouring circumstances remains. When a boy in the higher form tries a constructive problem in geometry he first makes a sketch of the completed figure; from this sketch he ascertains the geometrical relations that would exist among the various parts of the construction if finished; finally, he combines the newly discovered data with the data originally given him, reconstructing the required figure. No matter what the details of the problem may be, the boy has a "fixed" way of doing constructive deductions. The relations between "sketching", "data searching" and "reconstructing" are highly rational and persist for a long time as "initiating ideas". Indeed after studying and teaching geometry for twenty years, I find, when working at a constructive deduction, the initiating idea, "sketch the figure" frequently coming into consciousness in the form of a command; though I think the process of searching for data and of reconstructing the figure are automatically sequent. In solving a quadratic equation, whether the factoring, the perfect square, or the formula method be used, a certain routine of action is followed. In the beginning, each step in the sequence originated in a distinct idea; but with practice, the ideas controlling each step gradually disappear from consciousness; finally the completion of each step serves as a sufficient stimulus to initiate the following. Indeed, I frequently find pupils, while solving an equation rapidly and correctly, have completely forgotten the reason why certain steps are to be taken. After teaching the same lesson at school year after year, I find there is a serious danger that my plan of teaching may become so fixed as to form a kind of segregated habit, existing apart from and uninfluenced by any new conceptions of education I may gain.

In each of the above specimens of experience there is a succession of actions forming a more or less fixed series, a definite purpose in view, and a more or less constant set of circumstances. A series of mental reactions toward a definite end, which, when initiated in response to certain combinations of conditions, tends automatically to complete itself, I purpose calling a "method-habit".

Since the constant employment by the pupil of any general method results in the formation of a method-habit, and since formal education is a training for future social activity, then the way the child thinks and acts in the schoolroom should correspond closely with the way the adult ought to think and act in the outside world. The method-habits formed in the school should be the method-habits that can be and are used in everyday life. In Chapter I it was pointed out that method-habits acquired in the schoolroom could be "carried-over" to the affairs of ordinary life, if (1) the material conditions were the same in each case, (2) the individual recognises the applicability of the method-habit to new conditions, (3) ideals of action developed in one sphere of activity are recognised as true and valuable ideals of action in a different sphere. Teaching method, then, has three functions. It must develop in the child's mind those method-habits which he will find useful and necessary in ordinary life. Since method-habits are developed specifically, as special reaction series responsive to particular combinations of conditions, the second function of teaching method will be the relation of each specific method-habit to other important spheres of activity in which it may be used with advantage. And the third function of teaching method will be to render clear and explicit the value of those ideals of action strikingly exemplified in the study of any subject, and to give the pupil a conception of their value relative to other phases of conduct.

Since we are here treating scientific method in relation to the teaching of elementary science, which is a general course, secondary school subject, we must first discover the method-habits common to the study of science and to the activities of ordinary life. When the material conditions of each are the same, the methods of scientific research are directly transferable to the activities of practical life. For instance, I am trying to make some window boxes in such a fashion that the plants may receive moisture from water rising through the soil, instead of being watered from above, and I find myself adopting much the same line of experimental study that I pursue in the school laboratory. But when we come to consider cases in which the material conditions of practical activity are quite different from the material conditions of research work, those method-habits which may be transferred through the "recognition idea" are much more difficult to discover. Yet when we consider that research methods are just refined forms of common sense from which they were developed, we cannot doubt the presence of common elements in each. "There is no difference of kind between the methods of science and those of the plain man. The difference is the greater control in science of the statement of the problem, and of the selection and use of relevant material, both sensible and ideational. The two are related to each other, just as the hit-or-miss, trial-and-error inventions of uncivilised man stand to the deliberately and consecutively persistent efforts of a modern inventor to produce a certain complicated device for doing a comprehensive piece of work."* There are many general modes of mental action constantly, though imperfectly, used in the activities of ordinary life, which find their highest perfection in the work of scientific research. "As to the sciences which are not to be investigated deductively, but depend on experience, observation and a generalisation from a multitude of phenomena . . . the mode of attaining truth in these matters corresponds more nearly than any other to the mode by which right general opinions are formed about all the principal subjects which for the purpose of practical life it behooves us to know."†

But complete preparation for ordinary life cannot be attained through the study of science alone, and it is equally evident that many methods used in scientific research reach beyond the requirements of ordinary life. Research work is a special study preparatory to a special vocation; elementary science is a fundamental study preparatory to general life. To arrive at those method-habits common to each, we may superimpose the methods of research on modes of mental action found in ordinary life, retaining what is common to both and neglecting the excess in each.

Many comparisons should be made. A brief one is here given to illustrate the process. Two actual events are cited, though two ideal occurrences might have served the mere purpose of illustration better. The first is a statement of the manner in which a simple scientific discovery was made, through methods of research. The second gives a brief account of an ordinary commercial transaction. The latter was chosen for the reason that twenty-three per cent. of our secondary school pupils leave school to enter business, and many of the others enter a commercial career later in life; at some time or other during their adult life, all high school pupils will engage in some business transactions. While modern business life is not a realm of economic ideals, it is a field of activity in which every high school pupil will to a greater or less extent engage. If "the school must fit the individual . . . not for a remote Utopian future, but for the immediate future, the requirements of which can be predicted with reasonable certainty",‡ it would appear that an investigation into the method-habits found in this wide field of

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*J. Dewey: "Studies in Logical Theory", p. 9.

†J. G. Fitch: "Lectures on Teaching", p. 49.

‡W. C. Bagley: "The Educative Process", p. 65.

ordinary activity, in order to discover the extent of their identity with the methods pursued in research work, would be well worth our time.

"Brewster accidentally took an impression from a piece of mother-of-pearl in a cement of resin and bees-wax, and finding the colours repeated upon the surface of the wax, he proceeded to take other impressions in balsam, fusible metal, lead, gum arabic, isinglass, etc., and always found the iridescent colours the same. He thus proved that the chemical nature of the substance is a matter of indifference, and that the form of the surface is the real condition of such colours."*

This afternoon, my landlord, a shrewd merchant, explained to me how he acquired the house in which I live. "W - - - and I were walking past the site for the new post-office recently purchased from C - - - at a good figure by the government. W - - - said: "I wonder what C - - - is going to do with the house on it?" That set me thinking. My lot at home ran across the block to the other street, and the back half was of no value to me. I knew C - - - would sell "cheap" because he got his "price" from the government and had to remove the building immediately. M - - -, X - - -, Y - - -, and Z - - - (lumber dealer, mason, carpenter, and teamster), owed me big store bills. I looked over the house and found it in good shape. C - - - was glad to get it off his hands at any price. I made the deal, cleaned up those bills, and am making mighty good interest on my money, renting it to you."

What common method-habits or method ideals are disclosed in the comparison?

W - - - overlooked and my landlord, J - - -, discovered a business opportunity. And this ability to see business chances is characteristic of J - - -. As a member of the town council, of the school board, and of the water commission, he has been responsible for many departures from the old routine methods of conducting affairs. Dozens of people before Brewster must have noticed impressions from mother-of-pearl, but failed to see the scientific problem involved. Brewster found and solved many other problems in physics. Biographical history proves that the great men of science were all problem-finders; and ability to see opportunities is the striking characteristic of men of affairs. On the other hand it will

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*W. S. Jevons: "Principles of Science", p. 419. See ' Treatise on Optics" (Brewster), p. 117.

be a long time before J - - - is confronted with the problem of extending foreign missions in China; and I expect the question of next year's fashions did not seriously disturb Brewster. Neither the research worker nor the business man is possessed of a general problem-finding faculty; but each has the habit of looking into and discovering problems in relation to those things in which each is interested. The first common characteristic disclosed by this comparison is the problem-finding tendency in connection with attention absorbing activities, possessed alike by the scientist and the successful man of affairs. In ancient philosophy it was called " wonder "; in modern psychology we speak of it as "curiosity"; in the business world it is termed "wide-awakeness".

Both J - - - and Brewster solved the problem they had found, and the general method pursued in solving it was much the same in both cases. When J - - - first looked over the house, he formed a hasty idea of its value as an investment. When Brewster first noticed the impression accidently taken, he formed the hypothesis that the iridescence was due to physical rather than chemical causes. Each proceeded to test the probability of his inference by referring it to other experiences, confirming, denying, or modifying his hypothesis as he proceeded. The work in which J - - - was engaged was complex, demanded an immediate decision, and required only an approximately correct conclusion. Time was not an element to be considered in the research work in which Brewster was engaged, which, though simple in character, was of fundamental primary importance, since many other actions would be based upon the results obtained. The conclusion of Brewster had to be so probable that it would be practically a certainty. Hence his tests were more accurately applied, were more technical in character, and approached the question from every point of view. Both the scientist and the business man solve problems by the same general method-habit of subjecting inferences to the test of experience, modifying them in accordance with the results obtained until a conclusion is reached sufficiently probable to receive the credence necessary to its importance in relation to human action.

This general method-habit embodies special method-habits and method-ideals. J - - - tested his inference through investigation of actual conditions. An inefficient business man would have acted on partial evidence, hearsay evidence, or no evidence at all. Brewster also appeals to real experience for data. Here we find a common method-ideal, that truth must be tested by the touchstone of real experience.

But the virtue of this touchstone lies not altogether in itself, but depends a great deal upon the way it is handled. Not only did J - - - refer to real evidence, but considerable skill was required to obtain and investigate that evidence. A certain methodical procedure was necessary in evaluating all the parts of the house and in estimating the cost of moving, locating, and renovating it. He had to know how and where to get evidence on each of these points; had to follow a systematic scheme in checking that evidence; had to discriminate among conflicting testimonies and to sum up the relative importance of each bit of evidence in relation to the whole plan. Brewster selected his evidence more cautiously and sifted it more skilfully. He subpœnæd witnesses from all departments of experience. Had he tested resins alone, the colour might have been due to some peculiar chemical property of hydro-carbons. He pursued technical methods of testing the evidence offered in order systematically to eliminate all possible sources of error. Both the scientist and the man of affairs possess method-habits in the way of collecting and investigating real evidence; both are trained observers, though the scientist exhibits a higher type of training. This does not mean that in either a general faculty of observation has been developed. The other day I was walking with J - - - through the woods, and I do not think he so much as even noticed the spring flowers. A trained observer is one who has acquired definite ways of making inquiry in certain departments of thought and action in which he is interested.

Though he does not habitually use these methods in other departments, yet in case of need he can use them. For instance, I have no direct interest in millinery, while my wife is somewhat of an expert. We both undertook to write out a description of a certain hat. I was unable to appreciate and distinguish colours as well as my wife, and my vocabulary was lacking in technical terms; but in all else she agreed that the description I wrote was fuller and more accurate than her own. From teaching science a number of years I had acquired a method-habit of proceeding from whole to parts, of searching for relations between part and whole and between part and part. On the other hand, my wife's description of the hat was a collection of more or less unrelated statements of facts. The first might be called a subordinating process of observing, the second a co-ordinating process. Partly as a result of systematic method and partly from the idea I had learned in the laboratory of the importance of small things, my description contained a greater wealth of detail. Finally I was able to introduce and use mathematical conceptions in making my description more accurate. Now the next time my wife asks me to tell her about a hat some lady was wearing, I do not suppose I shall be able to remember whether the lady wore a hat or not. Nevertheless, I can "carry over" certain method-habits of observation from the laboratory to other fields in which for the time I am interested.

In the observing process there are several method-ideals such as accuracy, neatness, etc., whose value can and should be made explicit in the mind of the pupil. But among these there is one method-ideal pre-eminently distinctive of science study. When Brewster took an impression with lead, he did not say: "A metal cast reproduces the iridescence", but "a lead cast reproduces the iridescence". In the same way, when J - - - estimated the cost of repapering a room, he did not say: "This room can be done for ten dollars". He thought: "This room will require so many double rolls at such a price, and the cost of putting it on will be so much". In both cases each portion of evidence was justly judged. The judgments neither exceeded nor fell short of the facts submitted nor were they influenced by personal bias.

Now if Brewster, like J - - -, had put his conclusion to some practical use, say manufactured artificial mother-of-pearl, the comparison would have been complete. In this age of specialists, we have students of pure science whose business it is to discover and establish the laws of nature, and students of applied science who discover some way of using these principles in practical life. I do not mean to say that one who practises an art based upon scientific principles is a scientist. One would scarcely call a civil engineer a scientist, just because he graduates from a school of applied science where he learns to practise certain arts resting upon a scientific foundation. But one would call that civil engineer a scientist who introduced the parabolic curve to do away with the "grind and shock" of the circular curve in railway construction. Sir Humphry Davy was as much a research worker when he invented the safety-lamp as when he announced his discovery of the complex composition of potash. Edison is essentially a worker in scientific research. "The 'pure' scientist is prone to regard industry and 'applied' science after the manner of the Greeks—namely, as unfit occupations for a gentleman and a scholar. According to the academic creed, research which has no immediate practical application is the 'academic ideal' of pure science while the 'mighty dollar'—the manifest goal of industry and applied science—is but a degraded ideal of the market place. If industry meets human physical and mental needs by physical means only, while science forms theories and laws to satisfy the intellectual feelings of wonder, is not this again a difference of degree rather than of kind, since both are engaged in manipulating material things and creating forms to satisfy human needs?"* The representative scientist would be he who in one continuous process first abstracted the general conception from the concrete manifestations and then re-embodied it in new concrete forms.

Both the business man and the scientist apply general principles to the solution of practical problems. The method-habit used in doing this is almost the reverse of that used in the discovery of the principle. A study of the data supplied by the problem must suggest some known general conception which may be used in solving it. Then comes the process of adjusting the principle in relation to details of concrete experience. In the various discoveries connected with electric lighting, the general conception suggested by the nature of the problem was that the heating power of an electric current varies directly with the resistance of the conductor. This principle had to be adjusted to conditions of cost, safety, simplicity of operation, etc. The general conception arising from the nature of J - - -'s problem was that the cost of renovating the house must be proportionate to the rental value. Thus, the plumbing must be installed in such a way that it would be satisfactory to a tenant, and yet the cost must be so limited that its proportion to the increased rental value resulting from plumbing the house, did not exceed the standard ratio.

By this process of superposition we find that there are certain method-habits and method-ideals common to research work and business activity. In each case there is a problem-finding ideal. Then there are general method-habits of solving problems both abstract and concrete, theoretical and practical. There are the more specific method-ideals of appealing to real experience and of

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*C. R. Mann: "The Teaching of Physics", p. 123-125.

passing just judgments, and the more specific method-habits of making observations and of testing inferences. On the other hand this process of superposition reveals the fact that in many respects the methods of research exceed the methods of ordinary life.

"In the ordinary affairs of life we are contented with hypotheses which fairly cover the facts, without demanding proof that they do so exactly."* The extreme caution, so commendable in the scientist, would frequently prove ruinous to the man of affairs who, forced to decision and action within a time limit, must be satisfied with approximate results and conclusions that are reasonably probable. If a man starts out to walk a mile before he breakfasts, a few rods more or less than a mile is a matter of no importance; if a man builds a racecourse, he will have to measure the mile much more exactly; while an engineer laying out an astronomical base line will have to determine the distance with all the accuracy that human ingenuity, with the assistance of delicately constructed apparatus, will permit. Since the results obtained by the research worker are accepted as true and acted upon by a great many other workers in various fields of action, these conclusions must be made so probable that our intelligence may regard them as certain. Consequently the research worker is forced to use special methods. In the first place, he consciously employs general, technical methods of testing inferences—method of agreement, method of difference, method of concomitant variation, etc. In the second place, he must select and test data from all classes of phenomena relative to the subject in hand. In the third place, when making each test he must use the greatest caution and skill in eliminating all possible sources of error.

Now it is a very difficult matter to decide just where the line between general and special method-habits is to be drawn. In the office of a large store, the sales manager, the chief buyer, the head of the mail order department use methods in the study of their particular work which much more nearly approximate the methods of scientific research than the ways used by the country merchant in conducting his business. In fact we frequently hear the expression: "Big business is run along scientific lines now-a-days". Modern competition is forcing men in all departments of life either to adopt scientific methods of "getting and keeping their affairs

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*J. Welton: "The Logical Bases of Education", p. 206.

in hand" or to go out of business. It would appear that no strict line of demarcation can be drawn between the special methods of scientific research and the general methods of ordinary activity; and this is just what one would expect from our previously drawn conclusion that the scientist is but a specialised social worker. Just as a rudimentary knowledge of mathematics will be sufficient for the man of small affairs, so an ability to use in a general way the method-habits and method-ideals of research will suffice the ordinary citizens. But just as big business requires the use of more special mathematical knowledge in the direction of its affairs, it likewise demands the application of the more special methods of scientific research.

CHAPTER III.

METHODS USED IN TEACHING SCIENCE.

Purpose of the chapter. Problem finding conditioned by primary interests, novel conditions, and self activity derived from confidence. School must solve the pupils' problems; direct transference in scientific matters. Problems of abstraction and application. Probable reasoning; the hypothesis; the preliminary list; direct transference; indirect transference through the study of the method abstracted as an idea. Criterion of real experience; the laboratory—how it may be overworked and overestimated. Descriptive observation; perceptual development; systematic forms; end in view; transference. Experimental observation; qualitative and quantitative; methods of agreement, difference, concomitant variation averages, self activity of the experimenter; transference. Just judgment; the use of errors. Solving problems of application.

IN Chapter II certain characteristic method-habits and method-ideals were found common to the work of scientific research and the activities of everyday life. It will be the business of this chapter to discover how these may best be developed in the mind of the pupil. In the same chapter it was shown that methods used in certain activities of ordinary life more nearly approach the methods of scientific research than those used in other activities. It will be our endeavour to decide to what extent the methods of scientific research should be developed in the elementary science class. In Chapter I it was concluded that method-ideals and method-habits developed in the study of science could be "carried over" to the affairs of practical life through "recognition ideas". It will be our concern to determine in what way "recognition ideas" may be established in each case so that school work methods may be related to life work. Possibly the most satisfactory way of attacking these three problems will be to examine each common method-ideal and method-habit in turn from each of these three standpoints.

In dealing with problem-finding ability we are concerned with problems of new adjustment. A merchant finds many problems in connection with his business, or a woman in connection with housework; but the merchant finds very few in connection with housework, or his wife in connection with business. Problem-finding arises from interest—not interest that is slight or transient, but interest that forms a large continuous body. Such I propose calling primary interests. In the case of the child, they will refer largely to his out-of-school interests. Life has been defined as a continuous process of adjustment; since finding problems is simply finding new ways of adjusting oneself, the problem-finding tendency is a natural characteristic of conscious life. But life also tends towards a state of moving equilibrium wherein a man becomes adjusted to an environment which remains comparatively constant from day to day. The child is an incessant problem-finder, because each day he is confronted by new conditions; the average elderly man finds few problems, because he is already adapted to the conditions that each day brings forth. Problem-finding, then, depends upon primary interests being brought in contact with new conditions. On the other hand, many wonderful discoveries in science have been made by comparatively old men; some business men are branching out in new directions, while others jog along the same old way. Why do some retain their ambition, their powers of initiative, their youthful tendencies towards continuous readjustment which others rapidly lose? Various accessory causes might be noted, but the primary cause in nearly every case is this—that, urged by necessity or prompted by favourable opportunity, they have attempted and successfully solved problems, thus creating an appetite for new ventures. This spirit of aggressive confidence resulting from successful effort, causes the native interests, on being confronted by novel conditions, to reach out and adjust themselves to those conditions. To develop the boy's problem-finding ability in the elementary science classes, these three conditions must be maintained. In every lesson the boy's native interest must be brought in contact with new conditions in such a way that the natural tendencies towards self adjustment to those conditions may be given free scope.

Every science lesson must be founded on interests already in the child's mind. Teaching in a northern lumbering town, I found the lessons dealing with insects injurious to orchards very dry affairs; but my present class, the parents of whom are engaged for the most part in fruit growing, bring up so many problems that I can scarcely get away from these lessons. To stimulate self-activity among the child's interests and at the same time to maintain and develop the continuity of these interests, each lesson should provide means of solving problems already in the mind of the student. The pupil must bring problems to the class, instead of the class or teacher giving problems to the student. The best way of encouraging him to find problems is to give him a chance of solving them. The student who finds the laboratory a place in which he can settle questions that have been "bothering" him will not be slow in bringing grist to the mill. But if he has to spend all his time grinding at someone else's wheat, he will soon learn to leave his own waggon at home.

In an ideal school a boy might be allowed to solve problems as they came to him. But under our present class system of teaching it would be impossible to have each member of the laboratory class working along distinct and separate lines, each solving his own special problems. Moreover, the socialising influence of school life would then be lost, and though the boy might become a scientific genius, he would scarcely become a good citizen. The pupil soon learns that the laboratory is a community in which, if he aid others in solving their problems, they in turn will aid him. Nothing will "key up" a boy's aggressive confidence in his ability to discover real problems so much as having an entire class working at some question which he himself has propounded. At the same time nothing outside the play-ground will so tend to develop within him the social community spirit.

But if the class is to work as a class they must move along some definite direction. Their work must be continuous. They cannot first solve some pupil's problem in botany and then another's in electricity. There must be a clearly defined programme of work, so closely articulated that the class can move from point to point through their own efforts. But the programme will be for the teacher, not for the pupil, and must be merely a programme in outline, not in detail. It will be the duty of the teacher, keeping this programme of general progress clearly in view, to herd the interests of his pupils, tactfully to keep the wanderers from straying off; but to do so in such a way that the pupils appear to travel forward of their own volition. This he can readily do through his right of selecting problems for class solution. Irrelevant questions he can quietly shelve for future reference, or better still, refer them back to their originator for outside solution. And this is just the method used in ordinary social life. In the church, the council, or the factory there is an executive head who determines the general policy of development. Problems arising out of the pursuit of this policy, while generally propounded by individuals associated with the business, are discussed and solved by the whole body or its representatives.

This problem-finding tendency may be directly transferred from the laboratory to the affairs of ordinary life in so far as the latter are concerned with scientific matters. Bodies of primary interest relative to the pupil's future physical environment have been developed in the school. The activities of everyday life will bring these bodies in contact with new conditions. And a training in problem-solving as suggested above will give the pupil such confidence in his ability to solve problems that he will seek rather than avoid them. If the school all along has been encouraging the pupil to find and study problems from real life, since the conditions for discovery remain the same, the child will, on graduation, merely continue his school habit in this direction. But when the high school graduate comes to cast his first vote, it is very doubtful whether his training in science will prompt his political interests to original investigation. He will probably accept the political problems as propounded by the newspapers, though these may not be the real issues at all. The habit of finding problems is so closely bound up with special interests that it would seem very difficult to abstract it from these interests to form a method-ideal that will react on other interests. It would seem that the habit must be developed specifically in relation to each special interest.

The pupil must be trained in method-ideals and method-habits of solving problems. As seen in Chapter II, problems in science may be of two types, those concerned with the abstraction of general ideas, and those dealing with the application of general ideas to the practical affairs of life. First we will consider methods of solving problems of abstraction. "The reasoning we have to depend on in the natural sciences and in the daily conduct of life is almost all probable and not demonstrative reasoning."* In probable reasoning, as the result of some experience, a hypothesis is first formed; this is then tested by relating it to various other experiences along the same line, until either unaltered or in a modified form its credibility is sufficiently established for the

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*Eliot: "The Concrete and Practical", p. 26.

purpose at hand. If that purpose is of great importance the tests applied will be severe, if of less importance less severe.

It is evident that this process will proceed much more satisfactorily if the first guess comes near the mark, or at least contains the truth. Hence it should be something more than a mere guess. In fact what we might call the preliminary hypothesis should be made only after the conditions of the problem have been subjected to careful scrutiny and should be little more than a summary of possible explanations. Suppose a student is beginning the study of "pitch". He would first draw up a list of all the possible causes of pitch. Pitch might depend upon the size of the vibrating object, the force with which it is struck, the vibration frequency, the nature of the conducting medium, etc. By thus "rounding up" all possible causal factors, the true one is certain to be included, and may be arrived at by eliminating the false ones. The value of this method would be still more apparent in a case where several causal factors were at work, one or more of which might otherwise escape notice. And here we are only systematising the more or less loose methods of ordinary thinking. When the engine in the motor-boat "dies", the boatman thinks: "It may be the batteries or the gasoline flow that has gone wrong". Only, if new at the business, he is likely to think of and test each possible cause at a time, doing a lot of fooling with the induction coil, when the real difficulty may be due to a bit of dirt in the feed. A trained engineer, having all likely causes in mind, would rapidly test each in turn, quickly and surely "running-down" the real one.

In the practical teaching of elementary science this preliminary list can be rapidly drawn up as a class exercise. From three to five minutes will suffice, if the majority of the class are interested in the problem. However, in the study of some topics, such as Pascal's Principle, I have found it almost impossible to get the class to compile a preliminary list. The pupils brought no problems dealing with this topic to school, and had no body of primary interest relative to it. If such topics are to be taught in the elementary science class, some other method than the scientific method must be employed.

If the school science course deals with problems springing from the pupil's real experiences in out-of-school life, that is if school life is not divorced from real life, then, as in the case of transferring the problem-finding tendency, this method-habit of drawing up a preliminary list of possible causal factors will directly "carry-over" from the laboratory to those activities of life dealing with scientific matters. But, that this method-habit should be more readily attained in school and more readily practised out of school, it should be made an explicit object of study in itself. At present we are much concerned with giving the student clear cut ideas of the facts and laws of science, but trust very much to luck that the pupil will "catch-on" to the methods used in finding these laws. When I first began teaching geometry, my pupils followed a hit-or-miss method of solving constructive deductions. A regular general method of solution as outlined in Chapter II was not explicitly taught them; a regular way of discovering the key to the solution was not made an object of study in itself. Though I frequently used the method in working out deductions on the board, yet, since the method itself was not emphasised, very few of the pupils (less than ten per cent. I should say) adopted it as a fixed certain way of solving this type of problem. Now, I take several periods in explaining the advantage and the way of using this method. As a result, when the senior students meet a consecutive deduction, they do not fumble around for a start, but attack it directly in a known definite way. In the same way this general method of framing an hypothesis should, after several weeks' work, be abstracted and made an object of study in itself. The student will thus be led to see that it is a real form of thought, not a mere school form, such as some of the "solutions" he is compelled to write out in the arithmetic class but never uses in real life.

But the applicability of this method-habit of framing hypotheses is not confined to those spheres of activity relative to the physical world. It may be used by the lawyer, the merchant, or the politician. Since this method reaches its highest development in the study of science, and since scientific methods are as yet but slightly used in other training departments, it would seem that considerable benefit might be derived if this method could be "carried over" to other activities than those of a scientific nature. A workman understanding the true nature of the tool with which he labours will be able to see its applicability to other uses than that for which it was specially manufactured. Since the form of this method-habit may be abstracted and studied as an idea, the pupil who has a clear conception of this idea may apply this method-habit to new departments, provided that he recognises the possibility of its use.

In the secondary school we have no subject treating of general knowledge or philosophy in the modern sense of the term. It is the duty of each teacher to co-ordinate the subjects of his department with those of other departments where possible. There is no good reason why this co-ordination should, as heretofore, be limited to details of subject matter and not be made to include common methods as well as common topics. If the teacher in geography or history has occasion to discuss topics usually considered of a scientific nature, the science teacher should not only feel at liberty but should regard it as a duty to show his class how the methods of science study can be used advantageously in the study of history and geography. Since the method-habit would not be inculcated by practice no very striking results might be expected. But until scientific methods are more fully utilised in the teaching of history, geography and other subjects, no other avenue of transference is open.

Having made up the list of possible causal factors, the pupil must first narrow it down to a working hypothesis, and then proceed to establish the probability of that hypothesis either in its entirety or in a modified form. He may attempt this by appeal to authority or opinion, by dialectical reasoning, or by referring the matter to the test of actual experience. However excellent criteria the two former may prove in other branches, no one will in this day deny that the ultimate criterion of all scientific truth, considered as scientific truth, is the test of real experience. And just as the touchstone of real experience is the acknowledged criterion in scientific research, so the laboratory is an acknowledged institution in the modern teaching of science. It would be a waste of time to advance supporting arguments for that which is universally accepted. There is even a danger that the laboratory may be overworked and its function overestimated.

The primary purpose of the laboratory is not the impartation of scientific information, though that indeed is an important secondary function. But the first use of the laboratory is to provide a training ground where the student may exercise the methods of science study, so that he may become proficient in its method-habits and familiar with its method-ideals. If the student receives such a good grounding in these methods that he will be able efficiently to put them into practice, it is needless (even if it were possible) for him to *discover* all scientific truths which for the purposes of ordinary life it is fitting that he should know. "It is clear that although it is infinitely easier and shorter to learn than to discover, it would certainly be impossible to attain the end proposed if we were to require each individual mind to pass successively through the same stages that the collective genius of the human race has been obliged to follow."* By far the greater portion of each individual's knowledge has been learned, not discovered, and it is not only fitting but imperative that students become familiar with our ordinary sources of information, books, magazines, lectures, etc. He must be taught to use the brains of others as well as his own. The farmer who reads agricultural papers, attends agricultural conventions, and keeps in touch with the Government Department of Agriculture will make more progress than one who depends entirely on his own experience and experiments for better methods of farming. The former has a dozen good heads thinking for him, the latter only one. But if the man is to use the more direct sources of information, he should form the habit of consulting them while a boy at school. And he should also possess some standard of criticism which will enable him to discriminate between statements that are authoritative and those that are not. "To be accepted by the expert is a sort of verification (well-known and not despised) by science",† but the boy must learn how to tell the expert from the charlatan. He must learn to subject the testimony of others to the same test that he applies to his own opinions, the criterion of real experience, and to accept as authoritative only such statements and conclusions as have evidently been founded on real evidence. The laboratory has its own function to perform, that of training the student in the use of scientific methods of investigation, and should not supplant the library or lecture room, whose chief function is to impart scientific information.

There is also a possibility of overemphasising the laboratory as a source of real experience. We cannot in the ordinary affairs of life, as in the laboratory, always control the phenomena to be investigated. Each piece of evidence is not pure and absolute but mixed and circumstantial. There is grave danger that when the boy leaves the region of pure science, with its test tubes, balances,

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*Comte: "Philosophic Positive", Vol. I, p. 62. Quoted L. F. Ward: "Applied Sociology", p. 102.

†Thorndike: "Principles of Teaching", p. 157.

and graduates, he may fail to recognise in the fields and factories about him the real material of experience. The laboratory is just a place where we purify evidence and is not in any sense of the word a warehouse or a manufactory of experience. Real experience is out of doors, and the laboratory is just a place where the student may bring his knotty problems, because he finds a better equipment there for solving them. The boy who notices that a waggon tire expands when heated in the smith's shop is appealing to experience much more real from the viewpoint of the ordinary citizen than the student in the laboratory who heats an iron ball and tries to pass it through an unheated ring of the same diameter as the ball when cool. The pupil should find his data where he finds his problems. He must become accustomed to appealing to the experience of ordinary life, and must not be given the idea that all real experience from a scientific point of view is enclosed within the walls of the laboratory. He must get into the habit of looking for evidence where he will have to find it in after years. For this reason the laboratory course dealing with pure evidence should be largely supplemented by out-door work and the boy brought in contact with the confused but no less real experience of everyday life. I would go still further and say that the laboratory should rather supplement the out-door work. It should form a sort of high court in which cases that cannot be decided in the lower courts of everyday experience may be carried and finally settled.

How can this method-ideal of making appeal to real experience be transferred to the ordinary activities of life? If the suggestion in the preceding paragraph be followed, the pupil will already have formed the habit of appealing to the real experience of life in affairs of a scientific nature. He will be cautious in advancing an opinion unless he can back it up with real evidence. The class criticism which taught him caution in this respect will also teach him to accept with hesitancy the unsupported assertions of others. He will even doubt such assertions if made in print. The topics of science shade so gradually into the topics of geography, and are so intermingled with the topics of history and literature, that the critical spirit of science-study will spread out among neighbouring topics belonging more strictly to other departments. Scientists as a body are proverbially sceptical. When one begins to doubt mere opinions concerning some subject, it will not be long before he doubts mere opinion altogether and demands to see the evidence back of the assertion.

But it is not enough that the student learn to appeal to real evidence. He must learn how to make this appeal; how to apply the test methodically and systematically. Methods of making observations, that is of appealing to real experience, fall into three groups according to the purpose in view. When the student aims to discover and properly classify the qualities and characteristics of an object or phenomenon he will employ methods of descriptive observation. If the purpose is to ascertain relations between phenomena, that is to discover causal factors, he will use the qualitative experiment. And if he then wishes to measure these ascertained relations, he will utilise the quantitative experiment for that purpose. Thus, when the pupil examines the structure of a bean seed, he makes a descriptive observation. When he plants seeds under different conditions of warmth, moisture, light, soil, etc., for the purpose of ascertaining the causal factors of germination, he performs a qualitative experiment. If, having discovered that heat is a causal factor, he proceeds to find out the minimum temperature at which certain seeds will germinate, or the optimum temperatures of germination, he performs quantitative experiments.

Descriptive observation dealing with the proper classification of facts is foundational to all higher forms of observation used in the study of science. It is dependent upon trained sense perception. The boy who cannot discriminate among colour shades and correctly name them can never be a good observer when occasion demands a colour description. Training in sense perception should form an essential part of primary education. By the time the boy enters the secondary school the best training period is past. My own experience in the laboratory, in this matter, has been confirmed by several art teachers, who tell me that if a boy does not bring to the high school a fair ability in distinguishing colour, size, shape, distance, etc., it is very difficult for him afterwards to acquire this ability. I have students in the Middle School who cannot distinguish an acid from an alkaline substance by taste. There are even one or two who cannot tell which of two notes has the higher pitch. If throughout his primary education the boy has not been led to package and label his sense perceptions in sight, sound, smell and taste, these impressions will have become so confused and muddled that to make the boy a good descriptive observer would seem a hopeless task.

Accuracy in descriptive observation also depends upon the observer following some plan or scheme in making note of different points. A horse dealer rapidly notices a great many details about the animal he is judging, because he is looking for those points—size, weight, proportion, hair, skin, teeth, joints, etc. The ordinary man sees just plain horse, because he has no scheme to guide him in concentrating his attention upon each point in turn. When the pupil in the botany class is first given a leaf to examine, he notices very few things, because he does not know what to look for. But when he gets the conception of a descriptive scheme—size, shape, edge, point, base, surface, etc., the results of his observation are much more complete. Hence it is necessary that pupils learn to adopt systematic ways of making observations along various lines.

Descriptive observation also depends upon the end in view. An artist would view a horse from a standpoint different from that of a horse dealer, and a veterinary would adopt still a different viewpoint. In classifying a new variety of clover the attention of the botanist will be directed towards quite different things from those which a farmer, who is testing its value as a fodder, would examine. I doubt whether there is anything to be gained in describing a plant for the mere sake of the description. The pupil should always have an end in view, so that the scheme of observation which he adopts may be so associated with that end that when a similar purpose demands his attention at some future time the scheme used in making the necessary observations may be instantly recalled.

The transference of these method-habits in descriptive observation to the activities of ordinary life presents unusual difficulties. It is evident that the various schemes used in making observations are not only limited to scientific affairs, but to particular aspects of the various branches of scientific study. Thus the scheme of leaf observation would be of no use in examining a horse and of little use in examining a flower. Each separate method-habit must be taught specifically and associated with the purpose in view. Still, as shown in Chapter II, one may gain the idea that some scheme of making observations is necessary before one can conduct a successful examination along any particular line, and this idea may lead one to formulate plans beforehand. On the other hand the training along lines of sense perception, begun in the primary school and carried along in the secondary school, will be directly applicable to the ordinary affairs of life.

That higher form of observation more strictly scientific in character, whose function it is to determine relations among phenomena, may, as we have seen, be divided into qualitative and quantitative experimental work. The function of the qualitative experiment is to choose among the possible causal factors listed in the preliminary hypothesis, the one or ones that are most probable and then to substantiate further their probability. Four method-habits should be explicitly taught the secondary school pupil. First there is the method, as used by Brewster in the experiment series mentioned in Chapter II, in which a number of experiences containing a constant factor amid a variety of conditions are examined. This we may call the *method of agreement.* It is commonly used in substantiating the probability of some selected factor, rather than discriminating among a number of possible factors. The next is to compare two experiences identical in all respects save that one contains a possible causal factor and the other does not; as when two boxes of seeds are placed in a south window, the earth in one being kept moist, in the other dry. The absence of result in the latter case renders probable the supposition that moisture is a causal factor in germination. This method we may call the *method of difference.* It is the one most frequently used in purging the preliminary list of possible factors. Sometimes the possible causal factor cannot be entirely eliminated. When the student wishes to find out whether a material medium is necessary for the conduction of sound, he cannot experiment with an absolute vacuum, but he can make the air in a bell jar more or less rarefied. And when he finds the intensity of the sound of an electric bell, suspended in the jar, decreasing with the increasing rarefaction, he may conclude that very probably sound would not travel in a vacuum. This method of varying one possible causal factor while the others remain constant we may call the *method of concomitant variation.* This method is used in the quantitative experiment, whose function it is to determine exactly, that is in mathematical terms, the causal relation between two phenomena. Known quantitative variations are made in one of the previously discovered factors, the others remaining constant, and the resulting quantitative variation in the phenomenon is measured. By repeating this process and averaging results, a mathematical relation is established. The latter process may be called the *method of average.*

It is at once evident that quantitative experiments must always follow qualitative, since it is absurd to think of measuring a causal relation before it has been established. It is equally evident that these method-habits may be acquired only through the mental self-activity of the pupil. When he works a question in algebra, the answer he may obtain is important only as a test of the accuracy and correctness of his work. The aim in the teaching of mathematics is to develop the pupils' method-habits of solving various kinds of problems, not to obtain the answer of any particular problem or problems. But in the teaching of science the answer obtained from the experiment is important in itself. While the pupil in algebra directs his attention for the most part on the method he is pursuing, the pupil in science may so centre his mind on the answer to be obtained that he does not become explicitly conscious of the method at all. Such a result must almost of necessity follow if the boy merely *performs* an experiment which has been *devised* and *given* him by the teacher. The boy's mind will be entirely concerned with mechanical manipulations and the results following such manipulations. He will have little concern in the question of why such manipulations were undertaken in such a way. But if the pupil is to learn the methods of science as well as the knowledge of science, he must dissociate the process and make it a study in itself. The result of an experiment is one thing and the process of obtaining that result is quite a different thing. The devising of an experiment is a way of thinking, and the only means whereby the boy can recognise the existence of these modes of thought, learn what the various forms are, and develop habits of consciously and definitely following these forms, is to do that thinking for himself. If he is to learn the methods of science, as distinguished from the knowledge of science, he must plan his own experiments.

Suppose the pupil has listed as the possible causal factors of germination, warmth, light, moisture, soil, air, etc. If he has been trained in the scientific method, he will then proceed something like the following:—

"The chances are that some of the things mentioned on this list are not causal factors at all. I am going to test each in turn and eliminate those that do not stand the test. I can 'mark out' soil immediately, because I have seen wheat sprouting in the shock after a week of rain. To test the others I intend using the 'method of difference'. To test the first factor, I am going to plant bean seeds in two boxes of moist soil. One box I shall put in the refrigerator and the other I will put in a closed box in a warm room. Since the seeds in the latter germinate while those in the former do not, I am quite sure that warmth is a causal factor, but to be still more certain, I am going to try the method of agreement. When the cellar gets warm, the potatoes begin to sprout. These are not exactly seeds, but they are somewhat the same. The cucumber seeds planted on the twenty-first of April did not come up for two weeks, while those I planted on the tenth of May came up in five days. It was cold during the latter part of April and warm during the middle of May, while other conditions were about the same. I have often heard father say that the corn was slow in coming up, because the weather was too cold. I am pretty certain that warmth must be one causal factor in germination."

If on the other hand the teacher always tells the boy what to do, he will never learn to plan his own experiments; that is he will never become consciously acquainted with the scientific methods mentioned above. It is not necessary that he always use the scientific method in obtaining scientific information. Information may be obtained more readily in other ways. But it is necessary that he practise these methods a sufficient number of times under sufficiently varying circumstances, that he may obtain an intelligent comprehension of their modes of operation, and that he can and will habitually use them when thrown on his own resources.

There are two great difficulties in the way of transferring these methods from the schoolroom to the realm of actual life. In the first case the pupil may not grasp these methods as ideas. He may practise them under a teacher's direction without becoming clearly and intelligently conscious of them as modes of thought. Hence he will be unable to recognise conditions where they may be applicable, or if he does recognise their applicability, he will be unable to plan ahead so as to use them. In the second case these methods may have been associated altogether with laboratory surroundings and not at all with the environment of everyday life. The novel conditions of everyday life will not provide the necessary stimuli to set off the reaction series. But if the school boy finds his scientific experience in the home, the factory, or the fields, using the laboratory as a court of appeal, as has been suggested, by the time he leaves school this method-habit will have become so associated with the things of real life that he will merely *continue* to practise a way of examining into the facts of his physical environment. There will be a continuity, not a transference. On the other hand, I scarcely see how the scientific method of testing hypotheses may be carried over to other departments than those of a scientific nature. The reason of this is quite clear. At present the average man does not recognise the fact that politics, business, journalism, etc., are sciences. Hence the idea that scientific methods may be applicable to these departments does not even strike him. A growing appreciation of the scientific aspect of many things heretofore regarded as non-scientific is noticeable, but until this appreciation becomes common, the science master can only suggest and illustrate the possibility of applying these methods to things beyond the strictly physical world. Even then he will likely meet the usual fate of the missionary.

The most prominent method-ideal in science study is just judging. Judgments in research work fall under two heads, absolute judgments and probable judgments. When a boy notices that the rails on a track elongate when heated, the ideal of just judgment compels him to conclude that steel expands when heated between certain temperatures; but he cannot with justice conclude that metals expand when heated. Absolute judgments merely state relationships observed among facts. The result of each experiment must be stated in the form of an absolute judgment; hence an abstract truth cannot be proven by any single experiment, but must be a generalisation from a number of experiences. Probable judgments deal with inferences based on absolute judgments from a number of separate experiences. The general truths of science are not absolute, but probable. The student must recognise this and learn to estimate the degree of probability. He must eliminate personal bias whether due to his own opinion or that of another, and base his conclusions entirely on the evidence submitted.

Now the natural and indeed the only effective way of inculcating that habit of judicial caution which avoids rashness, hastiness and personal bias, is to allow the student to experience actually the evils of these defects in judgment. Not only let him make mistakes but let him discover his own errors. If the student after a single experiment wishes to conclude that solids expand when heated, the teacher should accept the conclusion, but should see to it that in the near future the boy either experiments with or at least discusses the expansion of type metal. After several experiences of this kind, the pupil will see the need of caution, and he must be brought to recognise the necessity of being cautious before he can be expected to practise that virtue. Now it is evident that if the boy is to gain a clear conception of the necessity of guarding against rash conclusions, he must devise and perform his experiments. If the teacher outlines the experiment to be performed, either the boy is never brought into contact with error and when he leaves school is not cautious in guarding against it, or, as is more likely the case, the boy either does not notice or does not care to criticise the wrong method adopted by the teacher. The boy accepts the teacher's authority, and thus in reality substitutes opinion for real evidence, quite contrary to the very spirit of science teaching. When the science course is heavy, too frequently we find pupils performing a single dictated experiment and drawing from it some general conclusion. "And too often the teacher accepts such a generalisation as . . . . a valid inference. To do this may be to teach science, but it most certainly is not to teach scientifically. It is, indeed, to cultivate that habit of rashness in drawing conclusions, and that inability to estimate the force of evidence which it is the special task of education to replace by the opposite qualities."*

If the data used in his scientific investigations has been gathered from the experience of his everyday life, and if the pupil has devised and performed his own observations and experiments and learned from experience "the difficulty of arriving at truth and the need of caution in making inferences from insufficient evidence",† the transference of the habit of judging justly will be direct from the laboratory to the affairs of practical life in so far as these are of a scientific nature. But until it is recognised that practically all activities of life have a scientific aspect, we shall still find the cautious professor in science buying "wild cat" mining shares and the science student voting in accordance with the paternal traditions or the cry of his favourite newspaper. The method-ideal of just judging will not "carry over" to departments where an idea of its applicability is wanting.

The mode of thought employed in making use of general conceptions differs from that employed in discovering them, and so requires a special training. In the process of discovery the general

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*Welton: "Logical Bases of Education", p. 259.

†Welton: "Logical Bases of Education", p. 260.

conception is the end; in the process of application it is the means. The process of discovery is the focussing of a number of experiences, the abstracting of a common constant relation to form a general conception. The process of application is the passing from an incomplete concrete experience through a general conception to another concrete experience which serves to perfect the first. A housewife wishes to prevent the milk from running down the side of the jug after it has been used. The circumstances call to mind certain general conceptions of adhesion and cohesion. This conception in turn suggests some previous experience in which it was found that water would not stick to a greased surface. On slightly touching the spout with butter, she finds that the milk no longer dribbles down the side after use. Frequently, of course, this process is abridged. The incomplete experience may immediately call up some concrete experience of the same kind without the general conception coming into consciousness. The housewife might have greased the spout of the jug, because she recalled the fact that water ran off greased paper. Such empiric methods, however, do not always result successfully. The fruit grower across the way having no general conception of the actions of insecticides, sprayed his trees for aphides with paris green, because in the spring paris green had proved an effective remedy for codling moth. Just as one can find theatre seat fifty more readily if row G, centre aisle is marked on the ticket, so the clue to the solution of a practical problem is more quickly discovered by passing through organised conceptions than by searching at random.

Just as a pupil in solving deductions in geometry is trained to recall propositions associated with the data given, and so find the key to the solution, so the science student in working out problems in practical science should be trained to recollect general conceptions suggested by the conditions, which, when found, will direct him to the needed concrete material. In the learning process the main classes of concrete experience relative to any principle must be related to it, so that in working practical problems, a recognition of the abstract idea involved may readily follow an investigation of existing conditions, and bring with it such a wealth of concrete ideas that the wanted material may be quickly secured. Too frequently the science teacher is content when the student formulates and understands the principle being taught. But to know a scientific law and to be able to make use of it are two quite different things. A man may make a canoe and yet be unable to paddle it. The science lesson should never stop short with the discovery of a scientific principle, but should always provide exercises in which the student may become skilful in making practical use of the law.

CHAPTER IV.

THE SUBJECT MATTER.

Selection of material conditioned by the needs of method training, the needs of citizenship, the needs of child nature. The material must form part of the pupil's ordinary experience. The call for a uniform curriculum, the need of method training, the requirements of citizenshp and of child nature, all demand that the syllabus specify general conceptions to be taught, but that the choice of concrete material be left to individual schools. Applied science and the curriculum; the "transference" of knowledge; general conceptions must be associated with the main classes of relevant phenomena. The scientist, the citizen and the educator must take part in the selection of material. The science course should not be differentiated into special sciences; definition and correlation; abstraction and application of general conceptions, school efficiency. Topic arrangement; seasons; complexity of methods; concentration periods.

"THE child initiates new processes of thought and establishes new mental habits much more easily than the adult, but the adult, with trained powers, has an immense advantage over the child in the acquisition of information. The important thing in childhood is, therefore, to train the child in as large a variety of mental processes as possible, and to establish as many useful mental habits as possible."* In the teaching of elementary science the chief aim should be to give the pupil a working command of the methods of science. A fund of useful and necessary scientific information may be gathered by the student in after years, but the method-habits and method-ideals of science study can scarcely be acquired by the ordinary adult. A certain amount of scientific knowledge is, in a sense, forced upon his attention by the affairs of his daily life, but these same activities tend to distract his attention from a study of method. Habits require time and practice. But the adult who has not been trained in scientific methods during his student days has not the time to devote to their study, is not compelled to practise them, and has likely formed habits of a contrary nature. If the essential thing in primary and secondary education is the initiation of thought processes, then the selection

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*Eliot: "Education for Efficiency", p. 3.

and organisation of the material for study must, to a great extent, be subordinated to the needs of method training. The first test of a curriculum should be, does it make for good mental habits?

But a wide choice of equally valuable material for method training is open to the curriculum maker. The field must be more narrowly limited. Since the aim of the state school is to prepare the pupil for future social activity, the school environment to which the pupil's present activity is adjusted must be such as will make him a good citizen. The study of plants makes one man a botanist, the study of animals makes a second a zoologist, though both pursue much the same methods. While scientific method is concerned with the way mind acts upon environment, the problem of subject matter is concerned with the way environment acts upon mind. Hence to make the student a good citizen, he should study the things of citizenship. But scientific knowledge has relative degrees of value considered from the standpoint of good citizenship. A knowledge of domestic sanitation is of much more importance to the average man than a knowledge of Avogadro's Hypothesis, though a knowledge of the latter might be of greater value to a student who intended to be a professional chemist. Since the function of elementary science is to prepare for the general rather than the special activities of citizenship, it is clear that the syllabus should be compiled from topics of use or interest in ordinary life.

But many things with which the ordinary citizen should be familiar, the child of fourteen is not sufficiently mature to comprehend. Many of these things do not appeal to him—he is not interested in them. And the school environment must harmonise with the nature of the child as well as with the needs of the citizen. "As parents and teachers it is our business to take a sort of composite photograph of a child's present impulses and future needs . . . . satisfy a child's present growing needs for food and nourishment, and at the same time fit him for his future life in the midst of nature and society."* The third criterion of a curriculum should be, how far does it correspond with the native interests and abilities of the average child?

Hence the programme of subject matter in elementary science must satisfy the needs of method-training, the needs of citizenship in the matter of scientific information, and the needs of child nature.

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*McMurry: "Special Methods in Elementary Science", p. 17.

What material will best satisfy the needs of method-training? In Chapter III it was shown that the development of the boy's problem-finding ability resulted from the activity of his primary interests. But his primary interests centre about his past and present experiences in everyday life. In solving problems he is taught to appeal to real experience; not the experience of the laboratory only, but experiences arising out of his life at home and its surroundings. The transference of method-habits and method-ideals of science from the schoolroom to the activities of mature life also depends, to a large extent, upon these methods having been associated in the acquiring process with those things in relation to which they will afterward function. "The child who draws his knowledge of science directly from life under usual conditions will not have much difficulty in finding it again in life. It is not difficult so to isolate the study of physics and chemistry, or even botany and zoology, from the usual conditions of life that the student in after years will have more difficulty in rediscovering his knowledge than he had in first acquiring it."* Since the pupil must find his problems in his daily experiences in the out-of-school physical world, since he must appeal to the same sphere of experience to provide him with the necessary data for solving these problems, and since the transference of methods learned at school is only possible when these methods have been developed in an atmosphere similar to that into which they are to be transferred, it follows that the material to be used in method-training must be largely if not entirely selected from those experiences common to the average secondary school boy or girl.

What knowledge is essential to good citizenship? The man who studies plant life becomes interested in botany. To become a good citizen a man must study and thus grow interested in those things with which good citizenship is concerned. The subject matter selected must "form or help to form an important life-long interest —an interest not technical or superficial, touching life only on the surface here and there, and at long intervals, but one that lies close to the heart, to the home and to all that makes life worth living."† Now where is one to look for this material? Wherever else it may be found, one cannot fail to find it in the daily lives of actual citizens. We cannot find it in theories, unless these

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*McMurry: "Special Methods in Elementary Science", p. 31.

†Hodge: "Nature Study and Life", p. 24.

theories are broadly based upon the actual experiences of citizenship. No greater crime against the race was ever committed than when the German bureau of education undertook to instil into the minds of German students ideas of citizenship evolved apart from national and historical experiences. To burden the child mind with useless knowledge, which bears no relation to the needs of his adult life, is only less criminal than to misdirect his aims and activities. The school environment to which the child's present activity is to be adjusted should correspond to that sphere of social activity in which he, as an adult, will take a part. The science curriculum should epitomise the physical world in which he will afterwards live. But the elements of the physical world in which the man will live differ only in details from the elements of the physical world in which the boy now lives. So the second criterion of subject matter selection requires that the topics comprised in the curriculum be selected from experiences of the boy's out-of-school life. But these experiences are just the stuff out of which the boy's primary interests have been developed. The three criteria of subject matter selection all point to the same conclusion that the materials out of which the science curriculum is constructed are to be gathered from the world of the boy's actual experiences. The school science course must deal with the boy's out-of-school life. To "develop only such principles as grow out of and interpret life's experience would be not only ideal, but in the nature of the case the only method which can be successful."*

Though this idea of selection cuts off a huge mass of material of interest only to the special student in science, and another mass of interest to the few but not to the many, an enormous field is still left to be covered. It would seem an impossible task to prepare a uniform curriculum for the schools of one province, or even for the pupils of one school. The experiences of a country and a city lad differ widely; the physical environment of a lake port town, of an agricultural community, and of a mining district are far from being the same; a boy and a girl in the same school, or even from the same home are not in contact with the same physical world. Yet some uniform curriculum must be devised which will comprehend the greater part of such varied and diversified experiences. An attempt may be made to compile a composite curriculum representing

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*McMurry: "Special Methods in Elementary Science", p. 31.

aspects chosen from the life of the town boy, of the farmer's son, of the lumberman, of the fisherman, etc., but such an attempt to satisfy all classes will end by satisfying none. The miner's son in Sudbury will not be interested in the weeds found in agricultural districts; neither will the farmer's boy from the level stoneless plains of Lambton county be much concerned with granite and feldspar. It will be impossible to teach such lessons by the scientific method, since they will afford no material for method training; they do not form part of the boy's primary interests, and only rarely will they be related to the activities of adult life. Neither will it be possible, unless we revolutionise our entire school system, to adopt different curricula for different schools.

Since the concrete forms of experience of different students under different conditions of life cannot be expressed fully and freely in detail on a composite curriculum, and since special curricula are impossible under present methods of school administration, we must go back of particular concrete experience to find common ground on which to build our syllabus. Though the Sudbury boy is not interested in weeds, both he and the Lambton boy are interested in plant growth; though the Lambton boy is not concerned with granites and feldspars, both he and the Sudbury boy are interested in geological formations. Both the fisherman's son and the farmer's son are interested in animal life, but the one knows it best as seen in the study of fish, while the other is more familiar with it as seen in the study of domestic animals. To satisfy the demand for a uniform course of study throughout the Province, the programme must specify only the general scientific conceptions relative to common experience. These must, in each case, be developed from the concrete material afforded by the particular experiences of pupils in each school. The city boy will bring his experiences of street cars, automobiles, elevators, etc., the country boy will bring experiences of threshing machines, hay forks, wind-mills, etc., to the study of the same mechanical principles outlined on the common school programme.

In method-training an abundance of suitable material presents itself in any school for the establishment of scientific conceptions through scientific methods. But we have seen that the requirements of method-training demand that the pupil make use of his own individual experience. In one school certain material which can be used to establish a general scientific conception will be closely associated with the pupil's primary interest in that direction; in another school equally suitable but quite different material will be bound up with his primary interests. Now a programme that specified the concrete material to be studied, rather than the general conceptions of science which they embody, would, under the most favourable circumstances, seriously interfere with method-training since no general programme could be devised which would correspond with the experience of an ordinary boy. Under less favourable circumstances, where the material specified was either of little interest to the boy or quite unknown to him, the process of method-training would be brought to a standstill. The boy, being unacquainted with the specified material, could bring no problems to school concerning it, he could not use it as real evidence in solving problems, and since this material from which his general conceptions and his method-habits would have to be evolved has little relation to the ordinary activities of his life, he could not transfer these ideas and habits directly from the schoolroom to the affairs of everyday life. Method-training, therefore, likewise demands that the programme specify the general conceptions to be taught, leaving the choice of concrete material to the teacher and the pupil.

The needs of citizenship make similar demands. The pupil cannot be adjusted in detail to his future physical environment. The details of adjustment are innumerable, impossible to foretell and peculiar to the individual. The engineer, the lawyer and the physician learn the fundamental conceptions of their respective professions and when the need arises are enabled to grasp the particular details of the bridge to be built, of the case to be undertaken, or of the patient to be treated, and then to apply these principles to the solution of the problems that arise. If the professional schools cannot hope to pre-adjust their students to the details of a comparatively restricted sphere of activity, the secondary schools of general education have much less chance of pre-adjusting their students to the details of a much wider range of activity. They will do well to familiarise them with the general scientific principles involved in social life.

Moreover the chief functions of the school in the matter of instruction is not to teach the child, but to put him in the way of teaching himself. The greater part of the useful and necessary information required of him in the active duties of life will be acquired during his adult life. But the school must develop mental centres about which this information may be organised. In the study of the physical world, conceptions of scientific laws and principles form such gravitation centres. The pupil in whose mind these conceptions have been developed will not only more readily comprehend the concrete details of life about him, but his knowledge will be so organised that he can make the best use of it. While the needs of citizenship along the lines of scientific knowledge cannot be satisfied in detail by the school, pupils can be given the power and tools wherewith to work out their own salvation. If centres of organisation have been rightly established in the mind of the pupil, he will be able to adjust himself to the details of his physical surroundings as need arises. Hence from the standpoint of the citizen the science curriculum should emphasise the teaching of general conceptions rather than the teaching of concrete information.

"An elementary presentation of physics should begin by resuming what might be called the experience of the average youth of sixteen years. The number of physical facts which a student of this age has accumulated is astounding . . . . The demand therefore is not so much for new facts, or for sheer facts of any kind, as for an orderly arrangement and an ability to use these facts."* As the mind becomes saturated with facts, these tend to crystallise. And if true centres of organisation are not present, these facts will crystallise about false conceptions. The boy "sucks up" water through a straw, the pump "sucks up" water from the well, the tree "sucks up" nourishment from the ground, the sun "sucks up" moisture from the sea. Just at that period of life when the boy enters the secondary school, these centres of organisation tend to become fixed and permanent, so one of the chief functions of science teaching at this period will be to clear his mind of wrong general conceptions and to establish right ones.

Thus we see that the demand for a uniform curriculum, the need of method-training, the needs of citizenship and the needs of child nature all point to the same conclusion—that the curriculum shall specify the general scientific conceptions to be taught, but shall leave the choice of concrete material used in teaching to the teacher and more especially to the student.

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*Crew and Jones: "Elements of Physics", p. vi.

But when we look at science from the viewpoint of its applicability and use in the practical affairs of real life, the above conclusion must be somewhat modified. Since in applied science the general conception is used to relate an incomplete experience to some similar complete experience, it is apparent that general conceptions must be associated with the necessary concrete experiences to make the relation possible. If in the illustration given in Chapter II the housewife had merely a general conception of cohesion and adhesion, unrelated to concrete experiences, then the conditions surrounding the problem of preventing the milk from running down the jug could not have called to mind this general conception. Even had the general conception been aroused, it would have been unable to recall such associated concrete experiences as would have served to solve the problem. While general conceptions, rightly taught, must have been evolved from a number of concrete experiences and therefore related to them, such relationships may not be sufficiently extensive to satisfy the needs of applied science. Some systematic scheme of establishing relations must be followed. A general conception of convection might be induced from the study of water currents alone. In later years, the student trying to solve some problem in connection with the ventilation of his house would be unable to use his knowledge of convection, since this conception has been associated only with water currents and not at all with air currents.

It is apparent that a problem of "transference" exists in connection with knowledge as well as with method-habits. Knowledge will only "carry over" along lines of association. Hence general conceptions to be available for practical use in the solution of problems of everyday life must have been associated in some way with the concrete conditions present, and must be related to other concrete ideas which will serve to complete the incomplete experience. But we have seen that it is impossible to relate specifically each general idea with all the special concrete phenomena in which it may be involved. Nor is it necessary for our purpose. The boy who understands the relation of convection to air currents can readily apply it to questions concerning winds, ventilation, hot air heating, etc. What is necessary is that each general conception taught should be related to the main classes of common phenomena in which it is exhibited. The idea of convection should be associated with currents in liquids and currents in gases. The principle of buoyancy should be associated with vessels, air craft, sedimentation, etc. If each class of relevant phenomena is represented in the association process by one or more examples, and especially if in this representation the class idea is emphasised, then in future use the relation of the general conception to other members of the same class can readily be effected.

We may draw this final conclusion—that the curriculum in elementary science should specify those general conceptions of science about which the common physical experiences of life are organised, associated with the chief *classes* of common phenomena in which they are exhibited.

The question of how such a selection is to be made really resolves itself into the question of who is to make the selection. In vocational schools the programme is outlined by a body of active practitioners who, besides being well versed in the academic knowledge of their respective professions, are familiar with the practical needs of those professions. The medical programme is not arranged by physiologists and anatomists, but by physicians and surgeons who are most familiar with the applications of medical science to the conditions of ordinary practice. The course in engineering is not compiled by mathematicians, but by bridge-builders and railroad constructors. Even the university course in Latin is drawn up by Latin scholars who possess that culture and refinement which is the end of classic study. A boor could not be entrusted with the task of arranging a Latin course, however well he might know his Virgil. In devising an elementary science course it is not sufficient that a man should be a specialist in physics, chemistry and biology; he must also be familiar with the bearing of these sciences on ordinary life. It cannot be too strongly emphasised that the end of elementary science study in the secondary school is not to give the students a knowledge of physics or botany, but a knowledge of life; not to make them specialists in any of the departments of science, but to make them good citizens. Three factors enter into the preparation of an elementary science curriculum, a knowledge of the sciences themselves, a familiarity with the needs of ordinary life, a comprehension of the principles and practices of pedagogy.

Now as a rule the scientist and the educator do not largely participate in the ordinary activities of real life. Standing somewhat apart they are in an excellent position to sum up the needs of education from a theoretical and ideal standpoint; but having had a limited experience with the common realities of life, they cannot very well choose the elements of knowledge essential to good living. The botanist is eminently fitted to specify what knowledge a student should possess in order to become a botanist. The educator can map out the course of training that a teacher should pursue. But neither is well fitted to outline a programme of studies leading to good citizenship. The needs of the citizen are apparent only to the citizen. No man, however, is sufficiently cosmopolitan to represent in himself all sides and aspects of good citizenship. No man therefore (or for that matter no small group of men, unless they are widely representative of the various classes and conditions of society) will be in a position to select the material for an elementary science course. The course should represent the opinions of the great body of citizens. It is one of the peculiar features of democratic governments in this country that successful parents who know what makes for success in life, and who are able to express their opinions in a clear, intelligent manner, are not only never consulted about this matter, but are forced to send their sons to schools to be taught that which the parents do not particularly desire them to know, and to be taught little about the things their parents wish them to understand thoroughly.

But while those actually participating in the activities of ordinary life should be consulted as to the elements of knowledge there needed, they are not in a position to organise the chosen material. A great deal of the valuable knowledge possessed by successful men of affairs has been learned empirically. Their conceptions are partial and unsystematised. They need to be ordered into a complete, compact form, so that the student may more readily attain them and more efficiently use them. This is the duty of the scientist. He must take the mass of crude material gathered from the common experiences of life and put it into a teachable scientific form. And in so far as the preparation of the programme is concerned, the function of the educator is to elaborate this organised material and specially adjust it to the needs of the growing child.

Finally, how are the parts and topics of the programme itself to be organised? "Nature is not consecutive except in her periods. She puts things together in a mosaic. She has a brook and plants and toads and bugs and weather all together. Because we have put the plants in one book, the brook in another, we have come to think that this divorce is the logical and necessary order."* This differentiation of science study into special sciences is subjective rather than objective. Utilitarian interests together with the rapid increase of knowledge have compelled the student more and more to concentrate his attention, giving us at first the special sciences and next the special departments in each science. But to the lower school student this specialisation has no meaning. No economic reasons compel him to centre his attention on any one or two branches of science. His horizon of knowledge is not so extended nor his time so limited that he must pick out some particular path to travel. His it is, for a time, to roam at will.

What advantages would arise from the fusion of physics, chemistry, biology and physical geography into one general elementary science course?

The student would get a true conception of the provinces of the special sciences. He would begin with an undifferentiated course and mark in the divisions, as he found topics naturally segregating about different interest centres. We should no longer have the student look up from his note book and ask: "Is this physics or chemistry?" "Is this botany or zoology?" When he does come to study the special sciences as sciences, in the higher forms, he will have clear, definite conceptions of the nature of the subjects which he studies.

Not only would the provinces of the special sciences be defined, but they would also be related. The problem of correlating the various science studies would be solved by the simple process of banishing the problem itself. The present need for correlation arises from the fact that in the objective world we find nothing to correspond with the hard and fixed divisions of the special sciences. Hence as soon as we begin to study any special science at all from a practical standpoint we must revert to this oneness of the objective world. We cannot study botany from the standpoint of real life without studying physics, chemistry, physical geography, etc., at the same time. But the study of science as a number of distinct separate subjects, results in the content of each subject being bound up in itself and divorced from the content clusters of other subjects. Chemical explanations of vital phenomena do not

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*Bailey: "The Nature Study Idea", p. 132.

readily come to the mind of the student in botany, because his knowledge of chemistry is bound up with ideas of test tubes and reagents rather than with leaves and plant food. Having broken up the unity of nature and boxed its content in distinct, separate compartments in the mind of the student, the next problem of the educator is to redintegrate this content. This he attempts to do by various devices of correlation. But besides the psychological difficulty of association just mentioned, there is the pedagogical difficulty that the different sciences do not develop abreast each with the other, and with the growing mind of the child. The pupil in elementary botany cannot get a chemical explanation of plant food and plant growth, because he is not sufficiently advanced in the study of chemistry. The student in physical geography cannot follow many of the explanations given him because he has not yet discovered and mentally grasped the physical science laws upon which these explanations depend. This pedagogical difficulty might be overcome if it were possible so to arrange the science course that while each special science was logically developed within itself, a co-ordinate development could be established throughout the series and in correspondence with the growth of the child's mind. Even if the enormous difficulty of arranging such a three-way organised course were surmounted, the psychological problem of association could never be solved by artificially bridging over the gaps between the special sciences.

This difficult problem of correlation would not appear in an undifferentiated elementary science course. The causes leading up to it would disappear with the disappearance of the special science studies. When the pupil had experimentally established the general conception of osmosis he would immediately use it to explain the absorption of nourishment by root hairs, the transference of tissue fluids in the animal body, animal respiration, etc. Physics, botany and zoology would not need to be correlated because there would be no division walls among them. To the student they would all be one. When he found the principles of physics in operation throughout the entire physical world, he would gain a far truer conception of the meaning of "law", the influence of which would extend even to his moral life. Most people "go wrong" because they imagine they can dodge the consequences, that law is not universal.

A general conception is the abstract from many and varied experiences. The inductive process whereby it is established would be greatly hindered if these experiences were scattered over a two-year period and throughout several study courses. To get a true conception of an abstract principle, both just before and just after it has been formulated, the student's attention should be concentrated on relative data. The more varied the data and conditions studied, the more abstract and general is the resulting conception. It becomes more than a mere formula, it becomes a true centre of mental organisation widely rooted and widely active. Not only does such an undifferentiated course promote the generalising process, but as a result it enables students more readily to apply principles. In a previous paragraph, it was pointed out that to apply general conceptions to the practical affairs of life, they should be related to the chief classes of phenomena in which they are exhibited. In an undifferentiated course these relations could be widely and strongly established; but when the course is divided into special sciences, many of these classes of phenomena would be separated from the first establishment of the general conception by breaks in time and interest. Association processes are best formed during the genesis of an idea, when the whole energy and activity of the mind are being centred upon the one subject, and vitally establish any relations made therewith.

In the preparation of the syllabus such an undifferentiated course would result in topics being stressed in proportion to their importance in life, as they should be in a general course; and not in proportion to their importance in the study of some special science. The elementary principles of a science are not by any means the first principles of real life. For instance, at present some two or three weeks are spent in teaching the pupil the tables of metric measure. If the aim of the elementary science course is to give the pupil a grounding in science study, well and good. It is time well spent. If the aim is to prepare him for the activities of everyday life, the time is utterly wasted. I do not think that in this province one man in a hundred knows that a litre contains one thousand cubic centimetres, or that one man in two or three hundred makes use of this knowledge. At least in a town of some two thousand inhabitants I recently had occasion to make inquiry, and found only three men who knew it and only two who made use of it, though quite a number had at one time in life known this table but had completely forgotten it. Moreover, time spent on lessons partly duplicated in the different divisions would be saved, the whole programme of science studies would be simplified, and the training in method would receive more attention and become more uniform.

If we cannot start with the first principles of a science and work up, the arrangement of topics is apparently a difficult matter. But no programme, however well devised, can be rigidly followed alike by all teachers and all schools. So long as the work laid down is covered, the teacher must be allowed more or less freedom in the order followed. Each teacher has his own methods and each school its own peculiar conditions, and the work will be done in a more satisfactory manner if the teacher can express his own individuality to a certain extent in the classroom, and if allowance is made for the peculiar conditions of each school. But three rules can be laid down governing the arrangement of topics. The problems the boy discovers, the experience he brings to school to be organised, and the real data upon which he builds his inferences are things of present moment. Hence the topics must be arranged in relation to the seasons. Topics requiring difficult and complex methods of investigation should succeed topics in which the investigating methods used are comparatively simple. The child's mind naturally works in short periods of concentrated interest. One aim of education is to lengthen these concentration periods. But if the child studies one thing too long he becomes weary of it and cannot work efficiently. At first related topics should be grouped to cover a period of not more than three to five lessons. Later on these groups and periods should be enlarged.

CHAPTER V.

THE SCHOOL AND THE COURSE.

Elementary science not obligatory on all secondary school pupils; twenty-five per cent. do not take it; tendency to make it compulsory. Present course academic and preparatory to higher education; illustrations from botany and zoology courses; tendency to readjust the course; consequent confusion. Changes should be tried out previous to adoption; Department is executive, not formative and creative; universities should do the research work in education. University not executive in state education; increased necessity and growth of general education; secondary schools no longer mere feeders to the university; matriculation requirements and university ideals should not dominate the secondary schools.

IF elementary science is an essential feature of general education, every one taking a secondary school course should study it. But in the secondary schools of Ontario it is not obligatory. The regulations read: "When the content of a subject differs from that of the corresponding subject for University Matriculation, the Principal shall make the modifications necessary for the latter."* Since the only part of the present elementary science course required for matriculation purposes is a review of the second year's work in physics, no matriculation student need take either the biology of the two-year lower school course or the physics of the first-year course.

Students preparing for matriculation may take either a language option or a science option comprising physics and chemistry. Students taking the science option will receive only a five months' course in elementary physics. Even though these students take the special sciences, biology, physics and chemistry, in the higher forms of the secondary school or in the university, they will lose the benefit of a science course, which being undifferentiated (Chapter IV), forms the natural source of study from which the special sciences outbranch and through which they are correlated. While the special sciences prepare for the special activities of life, the elementary course prepares for the general activities of life. The

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*1913: "Report of the Minister of Education, Ontario", p. 357.

special sciences are one step removed from ordinary life, the elementary course is in direct contact with it. A student who studies the differentiated sciences only, while skilled in special methods of scientific research, will not necessarily be proficient in those practical methods which are derived from a science course not far removed from the activities of real life. He might be able to find the coefficient of expansion of copper, but might not be able "to thaw out a frozen water-pipe" without breaking it. Special knowledge, special method-habits and special method-ideals will not necessarily "carry over" from the special material and conditions from which they were derived, to the common phenomena found in the house, the garden, the flower-bed, the stable, the town in which one resides, or the country surrounding it.

But the loss of students taking the science option is slight compared with the loss of those students who take the language option. The latter study neither elementary nor advanced science, and enter life with no clear knowledge of the physical world about them, and with little or no training in those scientific methods of thought and action so widely used in the affairs of real life. The lettered scholar, who is ignorant of science, and as a result lives in a badly ventilated house, takes no exercise and is poorly nourished, who finds little interest in the flower or vegetable garden and less in the surrounding fields and forests, who stands helpless when the water-pipes freeze or when the automobile breaks down, who cannot intelligently discuss the town's water supply or sewage system, is not well fitted for real life, however learned he may be.

In 1912 there were 19,829 lower school pupils in the collegiates and high schools of Ontario. Some 15,000 of these took biology, so the remaining 4,800, or over twenty per cent. of the pupils attending, did not take the biology of the elementary science course. Experience shows that many of the matriculation students who voluntarily take the non-compulsory part of the lower school science course either drop it during the term or partly neglect it. We are safe in saying that one-fourth of our secondary school students are not in any way adjusted to the physical world about them.

Since elementary science is not obligatory on all secondary school pupils, we must conclude that, at present, it is not regarded in the light of a fundamental general course subject.

On the other hand, many matriculation students, either voluntarily or urged by the teacher, take the entire course. Recently it has been made a compulsory subject on the general as well as the teacher's course. This shows that there is a strong and growing tendency to accord it full recognition as a general course subject. The chief difficulty in the way of full recognition is the fact that, at present, elementary science is treated more or less as a special subject, forming part of a special science course. Many who do not wish to study the special sciences would gladly pursue a course dealing in a scientific way with the things of practical life.

The tyranny of the classics has been succeeded by the tyranny of the sciences. The subject matter outlined in the present elementary science programme has not been derived from the common experiences of life, but from a study of the first principles of the special sciences. The biology course is based upon an academic scheme of classification. In the regulations issued by the Department of Education, we read: "The teacher's immediate responsibility lies in the laboratory work which embodies simple morphological studies of common forms, representing the chief animal types."* Now the normal interest of the present boy or the future man is not divided almost equally among a dozen types of animal life. He is not interested in the study of types at all. With some of those chosen, such as the wood louse, he has little or no acquaintance. The present course in zoology does not correspond with the normal interest of the boy. Morphological study of types may form an excellent basis for the special course in zoology taken in the higher forms, but it has little relation to the biological knowledge required by the ordinary man or woman.

The first-year pupil is required to identify spring flowering plants "by means of a flora".† Apart from the fact that the technical name of a plant is rarely heard outside the walls of a university, a vast store of technical terminology which is of little use in ordinary life must be accumulated before the pupil can make intelligent use of a flora. To make use of "Spotton's Key", the flora generally used in Ontario high schools, he must become familiar with from two to three hundred technical terms. This represents a vocabulary from one-third to one-half as large as that required from a first form student in Latin. Such a task is impossible to accomplish within the limited time. But the attempt to do so determines to a great extent the way in which descriptive

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**Ibid.*: p. 393.

†Ibid.: p. 395.

botany is at present taught. Part of the aim in almost every lesson is to familiarise the pupil with the use and meaning of technical terms, so that the entire course in botany is technical rather than practical in outlook. Moreover the botany course like the course in zoology is cast about the idea of type study. This defect is of a similar nature to that noted in connection with the latter course.

This insistence on the academic aspect of science study shows that elementary science is at present regarded in the light of an introduction to special science study rather than a general course subject. In fact the "Regulations" definitely state that one aim of the course is "to lay foundations for the more detailed study of each subject in the case of those who will continue the work in the higher forms".* The other aim is to give "a fair knowledge of the world around them to those who will not remain at school more than a few years".† Why the distinction? Why should the boy who is leaving school in a few years be the one singled out as requiring a knowledge of the physical world of ordinary life. Surely the student who continues his course through the university, and enters a wide sphere of general activity, is the one who particularly requires an education along general lines. This dual aim would be like teaching arithmetic for the purpose of giving one boy a conception of elementary mathematical operations, so that he would be able to pursue the studies of algebra, geometry, and trigonometry, and teaching the same subject in the same class to another boy, so that he would be able to perform the ordinary commercial transactions of life. Not only would these aims conflict when one tried to compile a programme, but it would be absurd to suppose that the boy who studies trigonometry and becomes perhaps a civil engineer requires less education and training in the mathematics of business affairs than the boy who remains at school but a short time and becomes perhaps a railroad engineer. A general course subject cannot have dual aims. Its one and only function is to prepare for the activities of general life. Since, however, the special activities of life sprang from the general, and special branches of knowledge grew out of general knowledge, any training in general knowledge will prove the best and most natural foundation for future study along special lines. The general course in elementary science is to

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*Ibid.: p. 394.

†Ibid.: p. 362.

enable the more highly trained man to adapt himself to the broader sphere of general activity in which he will be placed.

Still this expressed aim to relate the subject matter of the course to the activities of real life shows that the Department of Education is tending to recognise this subject as a phase of general education. Twenty years ago the science programme, in what corresponded to the present lower school, was exclusively concerned with the technical aspects of botany and physics. The present programme embodies a great deal of material relevant to the practical activities of everyday life. The chief difficulty in the way of full recognition of this subject as an essential feature of general education is that educationists still view the common world through the spectacles of the specialist.

This gradual readjustment causes some necessary and much unnecessary confusion and disturbance. There are frequent and violent changes in the elementary science curriculum. The present course in that subject has little in common with the course of six years ago. As a result of these changes the classes become disorganised, the equipment soon grows obsolete, and the teacher is unable to perfect his practice or to make those extensive preparations so essential to good teaching in this subject. These readjustments must be made, and if the present method is pursued, the wheat will no doubt eventually be separated from the chaff. But in the meantime our schools, which should be seed beds, are turned into threshing floors. The schools should not be placed at the mercy of pedagogical vivisectionists. The changes in the course should be tested and thoroughly tried out before being applied to the schools.

This is especially true, since in Ontario the control of educational affairs is in the hands of a bureaucracy of professional educationists. Conversant as these men may be with the psychological theory and schoolroom practice of education, learned as they may be in the academic knowledge of their respective departments, they are less familiar with the social aspects of the question. Graduates in other professions are compelled by their vocational duties to mingle with the world and to adjust their university experience to real life. But, as a rule, the educationist has little opportunity and less necessity for doing this. As a result the specifications in the curriculum devised by them do not always correspond with the training and information requisite for everyday life.

The order issued by the Department several years ago, in spite of protests made by nearly every newspaper in the Province, whereby the "our" spelling was substituted for the "or" spelling in a number of words, is an excellent example of this lack of sympathy with public conditions and demands. The child learns to spell "labour" from his spelling-book, and then reads "labor troubles in Britain" in the newspaper. The Department in this democratic country cannot remake the world in conformity with its ideals. The democratic spirit of progress along all lines must be trusted, and the means and ends of education made to conform to it.

At the same time education must be conservative. It must possess stability. It cannot change with the views of every clamouring journalist. Progressive democracy must find authoritative expression. Modifications should be made in the curriculum only after some competent body or institution has threshed out new educational ideas, separated the grain from the straw, and thoroughly tested it before passing it on to the schools. The work of the Department of Education is executive in character, not formative. Hence the need of some organised body to evolve those conceptions of education which it is the function of the Department to carry out.

"The university is . . . an integral part of the public school system . . . its ideals control the development of all that falls below it . . . an agency recognised by the people for resolving the problems of civilisation which present themselves in the development of civilisation."* Since the problems of education are among the most important problems of civilisation, and since the university furnishes ideals for the public schools, it is evidently the duty of the university to investigate not only the problem of modifying the elementary science course, but likewise the question of introducing better teaching methods in connection with it. In the previous chapter it was shown that the experiences of the citizen, the scientist and the educator were essential in the compilation of a science syllabus. The university is the only institution in which these three forces are focussed. It is evidently the function of the university to investigate these problems; but the investigation must be carried out according to modern methods.

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*Harper: "Trend in Higher Education", p. 527.

It will not do to turn from the opinions of the Department officials and accept the opinions of the university faculty. That would be jumping from the frying pan into the fire, since the officials of the Department are more in touch with and have a better conception of real conditions than the faculty of the university. But this work should not be based upon opinion at all.

To fulfil its function in this direction, the university should establish educational laboratories in which real evidence may be examined by scientific methods of investigation, and conclusions derived which are founded on facts and not on mere opinions. The needs of modern Canadian civilisation should be determined from inquiry into real conditions and real experiences. They should find out what the people do, and the conditions surrounding the doing of it; what the average man needs to know for the purposes of well being; how he needs to think and act in order to make life a success. The needs of other countries are not identical with our needs, neither can their educational programmes and methods be identical with ours. It will be the duty of these laboratories to investigate the needs of both common and special education in our own country and to devise ways and means of satisfying these needs. This data may be obtained by direct observation, or by consultation with those engaged in the ordinary activities of life. The main point is that the data shall be real and representative of the general life of the Province, and that it shall have been carefully sifted, tested and organised by men trained and skilled in such work.

The science faculty should be called upon to organise a course based upon this data. The general conceptions of science involved should be scheduled and the frequency and importance of their applications to the affairs of real life should be noted. With each should be associated the main classes of common phenomena relevant to it. In a similar way the methods of scientific research of use in the ordinary affairs of life should be noted. Their relative importance and the lines of investigation along which each can best be used should be specified.

In these laboratories the faculties of education should study the phenomena of child development. It will be their function to arrange the scheduled outline into a working curriculum. They must adapt the course to the seasons; they must group the topics in accordance with the child's attention periods at different stages of his school career; they must arrange the topics in relation to the child's increasing ability; they must likewise determine the order in which the methods of scientific research are to be taught, and to what extent they shall be used. In short, they are to make a threefold adjustment among the subject matter, the method, and the growing mind of the child.

The curriculum in elementary science devised from such research would harmonise with the needs of ordinary life, would be organised along scientific lines and would be developed according to the principles of pedagogy. The programme being comparatively permanent, violent changes, so disorganising to school work, would be avoided and the teacher would be given an opportunity to perfect his teaching methods. Teachers-in-training participating in this work would see the true relation between education and life, would gain valuable experience in educational research work, which would stand them in good stead when they came to adjust this general curriculum to the detailed and special conditions of the particular schools in which they taught. Some American and English universities have such laboratories, and in these many of our modern methods of education have been evolved. In Ontario our faculties of education are almost entirely concerned with teacher-training. Courses of study, methods of teaching and ideals of education which work well in other countries, we adopt directly. But we have our own special conditions and our own particular problems, and it is evident on the face of it that these adopted educational practices, no matter how satisfactory they may be under foreign conditions, can never be exactly suited to our needs. So, while we may greatly benefit from the experiences of foreign educational institutions and systems, it is incumbent upon us to seek our own salvation.

On the other hand, the university has no right to exercise an executive control, either directly or indirectly, over secondary education. Its function in this matter is purely in the direction of discovery and research. Its duty is formative only, to prepare leaders in the educational world, to resolve the problems of education, and to evolve and formulate the ideals of education.

Modern progress in civilisation demands a better fundamental education from all students. This is especially true in the department of science. "The applications of science to life have so transformed our surroundings that we live in a very different world from that of fifty years ago. To live properly in this new world is to understand it, to fit into it and to make the best use of it. Since the changes are due chiefly to scientific inventions and improvements, progress in education calls for a direct and more practical acquaintance with the sciences by common people".* The modern growth of democracy extends the field of common education. With the industrial, political and social uplift comes the demand that the great body of common people be better fitted for the new duties of citizenship.

Two centuries ago practically all education was special, and was confined to a knowledge and culture caste. The great mass of people, living in a narrow sphere of activity, required little formal education. The primary schools in reality served as feeders to the universities. The rising tide of democracy and the rapid, material progress brought about the establishment of free, common, primary schools in which the child was adapted to the essential features of the new social life. But for a growing democracy the bare necessities of a formal education of fifty years ago are no longer sufficient. Secondary schools are becoming free institutions; continuation classes are being established in public schools; the course in fundamental education is being extended into the secondary schools; and the age limit of compulsory attendance is being raised. All this means that the secondary school, which had taken the place of the primary school as a feeder to the universities, is in turn coming from under the shadow of the university, and is being recognised as an institution of general education. At present its function is of a dual nature. It prepares some students for entrance into higher educational institutions, and completes the general education of others. The training for those entering the university, the professional schools, or the normal schools, is as it should be of a special character in the higher forms. But for the first two years the course is more or less of a general nature.

"The state and church alike may have their own schools and colleges for the training of youthful minds and for the propagation of special kinds of intelligence, and in these it may choose what special colouring shall be given to the instruction. . . . But such schools are not universities."† So long as the university

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*McMurry: "Special Methods in Elementary Science", p. 56.

†Harper: "Trend in Higher Education", p. 8.

remains a special institution neither maintained nor controlled by the state, it has the right to dictate its own terms of admission. The professional schools and the normal schools may also demand certain qualifications from those seeking entrance. Since it is the duty of the state to prepare students for the special activities of social life, it is right that the state should fit them for the matriculation and normal entrance examinations, because these are the gateways to many special social duties and occupations. But neither the university as a body, nor the professional schools, nor the normal schools have a right to interfere in the state system of general education, whose concern it is to prepare citizens for the general activities of social life. While special courses may be evolved from, or even added to the general course of the lower school, this general course should be obligatory on all students. Its sole purpose should be to prepare students for the general activities of citizenship. The curriculum and graduation examinations connected with the general course should be entirely under state control and uninfluenced by the demands of special institutions. All secondary school pupils should satisfactorily complete this same common fundamental course before proceeding to their more special work. In brief, the lower school course which would include elementary science, should in every way be made a general course. Any subjects which a pupil may take in addition for matriculation or other purposes should be recognised as parts of a distinct, separate, special course.

CHAPTER VI.

THE SCHOOL AND METHOD TRAINING

Methods of teaching science; the teaching of science methods. Methods are not specified on the curriculum, hence not explicitly taught. The present course too extensive, specified in too great detail, and divorced from the environment of ordinary life. The results of these defects on method-ideals and method-habits. Problem-finding: the appeal to real evidence; descriptive observation; experimental observation; the abolition of dictated experiments.

ONE finds great difficulty in discussing or criticising the teaching of scientific method, for this reason: that the information to be gained from a study of science is so extensive, important, and popular with the student body that in the Ontario High Schools of to-day the imparting of scientific knowledge seems to have quite eclipsed the training in scientific method as the chief aim of science teaching. Indeed, the teaching of scientific method seems to have become almost synonymous with the method of science teaching, that is, with the plans taken by the teacher to convey information to his students. The scientific method is scarcely regarded as a specific mode of mental action, or an habitual way of thinking and doing things, in which the pupils are to receive special training, but seems to be looked upon as a way of teaching, instead of something to be taught. Since the way the child is taught is the way the child will think and act, there would seem to be but little difference between "the teaching of scientific method" and "the method of teaching science".

A comparison taken away from science teaching altogether may perhaps serve to illustrate the difference. The teaching of algebra is almost altogether a teaching of mathematical methods. A knowledge of algebraic conventions and of a few algebraic propositions is taught, but the chief aim is to train the student in methods of factoring, methods of solving equations, methods of finding the square root, etc. Now though all teachers in mathematics throughout the Province teach the same algebraic methods, different teachers adopt quite different teaching methods. When we say that one mathematical master has a good method of teaching algebra and that another has a poor method, we do not mean that they teach different things, but that they teach in different ways while training the pupil in the same mathematical methods. But no matter what teaching method the master may adopt, he can scarecly fail to teach algebraic methods, not only because there is little else to teach in a study of that subject, but also because these methods are specified on the curriculum as things to be taught. On the other hand, it is quite possible for the science master to teach the pupil a great deal of science without giving him a training in scientific methods at all. This possibility arises from the fact that in the study of science, besides a training in method, there is a great deal of scientific knowledge to be taught, and the master may unduly stress the latter aspect to the neglect of the former. And this possibility becomes almost a certainty when we consider that, unlike the curriculum in algebra, the science programme does not specify the scientific methods in which the pupil is to be trained. The syllabus says that the law of buoyancy is to be taught, but mentions nothing whatever about the method of "agreement" or the method of "concomitant variation". As a result the teacher is quite likely to adopt a teaching method which will, in his opinion, most quickly and strongly impress the designated information upon the mind of the student. And we shall see reasons for believing that under present circumstances the teaching method adopted cannot and does not coincide with the scientific method of research.

Since this failure to accord scientific method an equal place with scientific knowledge is the chief source of error in the present teaching of scientific method (or the lack of it), a second illustration may not be amiss. In the study of geometry we are partly concerned with training the students in geometric methods of proof and construction, and partly with giving them certain information having a practical value in itself. Now it is quite possible to teach geometry in a certain sense without teaching, to any appreciable extent, the geometrical methods. The information aspect may be unduly emphasised. Further, since the students use geometry text-books in which each proposition has attached to it a certain proof, it is possible and indeed it frequently happens that the student learns the proof itself as a piece of knowledge. He "learns to prove" particular propositions instead of learning methods of proving all propositions. I have distinct recollection of being able to "prove" all the propositions in the first book of Euclid, and yet unable to solve the very simplest problem or deduction. The proof given in the text was made an ultimate end of study, instead of being used as a specimen for the study of mathematical method. Even now, when the solution of problems and deductions occupies a fair part of the student's time, he may work them in a very haphazard way, and get only a confused conception of geometric method. This is due to the fact that while the curriculum specifies the theorems to be taught, it says very little about the methods of geometry in which the pupils are to be trained; and as a result the methods of geometrical reasoning are not always abstracted and taught as objects of study in themselves.

I have given this second illustration (the truth of which can scarcely be questioned when one considers how difficult a subject many students who excel in algebra, find geometry to be, and how few candidates at Departmental examinations display ability to solve geometric deductions) to show that while the student may go through the form of a certain method, he does not necessarily comprehend the method itself or become proficient in its use. This possibility must be discussed, since the science curriculum insists upon the student performing experiments and making observations in connection with the specified topics. The nature of this laboratory work will be discussed later in the chapter. At present all I wish to show is, that it is quite possible for the student to "do" the proofs of science as he does the proofs of geometry, without gaining a knowledge of or an ability to use the method-habits involved in either case. The student may perform an experiment, either outlined by the teacher or in the Manual, write in his note-book an account of it together with the principle it is supposed to have discovered to him, and then learn it as a proof of that principle, much the same as the geometry student learns the proof of a proposition as given in the text. Many students are put through the form of a method the meaning and practice of which they never acquire. Other students performing the same experiments do "catch on" to the method employed in an uncertain, confused way. But unless scientific methods are abstracted and explicitly taught, the pupil can gain no definite conception of their practice.

Since the chief aim in science teaching is a training in scientific method rather than an acquisition of scientific information, the course in method teaching should be outlined on the curriculum equally with the course in knowledge-teaching. If it cannot be left to the teacher to decide the topics of study, neither should he decide the methods of study. If it is necessary to specify on the curriculum that the students shall study the morphology of a wood-louse, surely it is equally necessary that a training in the methods of framing an hypothesis shall also be specified. There is no doubt that the present regulations issued by the Department do insistently demand that laboratory methods of instruction shall be employed. The very experiments which the student is to perform are described in detail. But we have seen previously that a student may study science in the laboratory and learn no more of the scientific method than if he had studied in the library—perhaps not as much. He may go through the form of research without having his attention directed to the modes of research. The pupil cannot learn the scientific method generally. As pointed out in Chapter II, scientific method is a complex of method-habits and method-ideals, and our discussion led us to believe that habits are special and specific, and that each must be specially taught. The teacher must devote definite time and attention to the development of each method-habit, and to impress this aspect of science-study on the teacher, as well as to guard against any neglect on his part, the curriculum should give the same place and importance to the methods of science that it now gives to the knowledge of science.

On the other hand, the teaching of methods is not to be divorced from the teaching of scientific knowledge. The abstraction of method is to be carried out only to such an extent as will give the pupil a clear, definite view of the various modes of procedure. Method must never become a mere abstract, formal study, but must always be related to specific ends, to attain which it is employed. When we consider scientific method as just refined common-sense, the teaching of method in connection with the teaching of knowledge will not prove difficult. During the lesson the child must simply be given full freedom to exercise that common-sense.

The next three criticisms of the present course deal with certain aspects which tend to limit the freedom of the child in the exercise of that fairly well-developed common-sense he brings to the school.

The present course is too extensive. If its sole aim were to impart scientific knowledge, little fault could be found with the length of the curriculum. But the student requires as much time to practise and exercise the methods of science as he would require to learn many times the information that this practice can discover to him. It takes longer to acquire a habit, than to grasp an idea. Now if the field of information mapped out to be covered by the student is so extensive that he requires practically the whole of his time to get up the details of the work prescribed, it is evident that he will not have sufficient opportunity to practise and acquire the method-habits of science.

The first two years' biology course in the Ontario High Schools covers about one hundred and seventy lesson periods of thirty minutes each. The course provides for the descriptive study of thirty-one named specimens, twelve common birds, and the wild animals and plants of the locality; the economic study of four insects and at least eight common weeds of the district; the classification of twelve wild flowering plants; the discussion of twenty-eight general topics in connection with an examination of the phenomena exhibiting them; the performance of sixteen specified experiments; and the class review of reports on outdoor work, which, while it may be in connection with the study of the above topics, must be recorded in a separate part of the student's note-book. A certain amount of review work must also be taken up in connection with the Lower School examinations. In descriptive study, the class must examine the specimen, record their observations in their note-books, make drawings of parts, describe the function of these parts, and refer to the general life history of the organism studied. A period and a half (forty-five minutes) will be the minimum time in which the details of this work can be barely covered, with the class working under high pressure. Eighty-four lessons will be required for descriptive study. Six more will be taken up with the economic study of the four insects and eight weeds. To learn how to use the flora, and to classify twelve plants can scarcely be attempted by a teacher with any conscience at all in fewer than eight lessons. The teaching of such general topics as cross-fertilisation demands at least one lesson period each, or twenty-eight in all. The mere mechanical performance of experiments on photo-synthesis, root-pressure, etc., can scarcely be accomplished in thirty minutes each. The high school inspector demands that at least five lessons each fall and spring term shall be devoted to the reports of the pupil's outdoor work. And if we take eight lessons to review for examination purposes, all of the time will have been used.

It is evident on the face of it that every moment of school-time must be given over to the imparting of information, and that no time can be specially devoted to developing the scientific method. The free activity of the boy's common-sense is rigidly limited. It may be asserted that the scientific method may be used by the student in the study of these topics. In a restricted sense this is true, especially along lines of descriptive observation. But without considering for the present the relation of this syllabus to self-active, experimental observation which is more characteristic of scientific research, let us examine how the scientific method is developed under the more favourable conditions of descriptive observation.

The boy brings a specimen grasshopper to the class, and with it a dozen questions regarding grasshoppers of his past experience. But the teacher must see that drawings and descriptions of the head, thorax and abdomen, the eyes, antennae, and mouth parts, the legs and wings, the segments and breathing pores, are entered in the student's note-book. The teacher must refer to the function of each part, the life history of the insect, and its economic relation to the agricultural community. And he must do all this in forty-five minutes. This simply means that the teacher must volley questions at a machine-gun rate, and the class must volley back some sort of answers.

"How many legs?"

"Six."

"Any difference?"

"Two large and four small."

"Use of the larger pair?"

"Hopping."

"Of the two smaller pair?"

"Crawling."

Some member of the class either observes the required answer, or guesses at it; and the remainder of the class, seeing that the answer is accepted by the teacher, note it down.

Poor teaching? Horrible! But is it the teacher's fault? He is not allowed to dictate notes, and in what other way can he get over all this work in forty-five minutes? There is no spare time, and the Lower School examiners will not accept original work from the student, but require text-book work. And what of the boy, bubbling over with questions relative to his own experience with grasshoppers, eager and anxious to fall in with and carry out any line of inquiry which will supply him with an answer. The teacher is compelled to "put him off" or to tell him directly the required information. He is given no chance to exercise and develop his common-sense activity into research methods. His attention is forced in one direction, while his real interests lie in another, and he soon learns to repress those interests while in school.

It is not necessary that all topics on the course be studied through research methods. The boy may and should use the library, and so become familiar with the sources from which the greater part of our scientific information is usually derived. But the course should be lightened so that the class shall have sufficient time and opportunity to exercise research methods, until they can and do habitually use them.

The course is specified in too great detail; too many concrete elements are introduced. This is not conducive to the teaching of scientific method. Save in descriptive observation, the scientific method is concerned with the concrete only so far as it serves as data from which general conceptions may be derived. The scientist does not care a button about the peculiar structure of the pitcher plant as a fact by itself. But it has a striking significance for him as an example of plant adaptation for the purpose of obtaining a necessary kind of food. But if the concrete elements of biology are specified as ends of study in themselves, no opportunity to practise those methods of abstracting general conceptions will be afforded for the student. And these methods are most truly characteristic of scientific research. In order to study the morphology of a grasshopper the student does not necessarily have to frame hypotheses and test them by methods of agreement, etc. The pupil in reality is not studying science at all, but merely the material from which science is developed. Such a course is not even suitable for training in methods of descriptive observation. As seen in Chapter III, descriptive study must follow certain forms of procedure which are determined by the end in view. The forms for descriptive observation are specific, both in relation to the material and the purpose. And each particular form must be related to its specific material and specific purpose. The pupil who studies a flower for the purpose of classification will adopt a quite different form of investigation from that of the student who studies the same flower in relation to cross-pollination. Descriptive study apart from purpose is barren, meaningless, and uninteresting. But the purposes in view should be general conceptions rather than particular conceptions.

To afford the pupil a training in the more characteristic methods of research, or even in the methods of descriptive observation, the course should specify the general rather than the concrete conceptions to be taught. A great part of the present biology course deals with concrete elements. This is especially true of the curriculum in zoology. As a result, this course affords the pupil small field for exercise in methods of experimental observation. And this is particularly unfortunate, as there are many biological experiments of a simple character which may be readily devised and carried out by the pupil. Since these are only slightly removed from the pupil's normal common-sense methods of investigation, they would serve as an excellent introduction to the more complex experimental methods. On the other hand, the course in physics is not specified in concrete detail. General conceptions of science, together with certain classes of phenomena in which they are exhibited, alone are mentioned. The teacher is at liberty to develop these conceptions from material supplied by the pupil's experience, either in the laboratory or out of school, and thus give the pupil a training in the more characteristic methods of scientific research. The course in biology should be recast along lines similar to the curriculum in physics. This elimination of concrete elements would do much to lighten the course, which at present is so extensive.

The present course is too far removed from primary interests of the pupil and from the experiences of his out-of-school life. Many of the concrete details referred to above are not very familiar to the average student. The general conceptions of science could be more readily developed from data supplied by the pupil than from data supplied by the Department. He would be interested in the former, and would be able to follow the true scientific method of finding a problem and then solving it. But the worst feature of the present divorce of school from home life is that scientific methods are developed from material quite unlike that which he finds in ordinary life. As a result, when scientific methods are developed in the laboratory, they will not "carry over" to the realm of practical life. The student does not see the possibility of their application in this field.

Much might have been expected from the outdoor work prescribed. However, not only is the time that can be devoted to it limited by the amount of specified class-work, but instead of forming the basis from which each lesson springs and the field of application in which each lesson ends, we read that "the outdoor observations should be separately recorded by the pupils".* The very thing that should have brought the problems of primary interest before the class, as well as data for their solutions, has been carefully excluded from regular class-work. Though the field for outdoor work in physics and chemistry is as extensive and fertile as in biology, no outdoor work beyond "the preparation of simple apparatus at home" is prescribed or suggested. Instead of beginning the study of capillarity in an investigation of such common phenomena as the rise of oil in lamp-wicks, of water in the soil, or of ink in blotting-paper, and then defining the conceptions derived from these investigations by laboratory experiments, the pupil is immediately introduced to capillary tubes. He soon gets the idea that he can "experiment" only in the laboratory and with laboratory apparatus.

To enable the pupil to devise and perform true scientific experiments (experiments whose need is apparent to him, and which he himself plans out and performs) and to relate the methods of experimental observation to the activities of everyday life, each lesson in science should be based on the out-door experience of the pupil. His out-door work should not be divorced from, but should form an essential part of the regular class-work.

The four general defects of the present course in method-training, namely, that method study is not outlined on the curriculum, that the programme is too extensive, that it is specified in

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*Report of the Minister of Education. Ontario, 1913.

too great a detail, and that it is divorced from the interest of the pupil and from the real life of the community, have so far been treated only in a general way. In the remaining part of the chapter, the influence of these defects upon the teaching of each particular method-habit and method-ideal will be briefly noted.

The development of the pupil's problem-finding ability depends upon the activity of his primary interests. The boy continues to be an enquirer so long as problems arising from his own free experience receive consideration. He must be made to feel that these are "worth while", that the study of science is concerned with just such things. But when all the concrete details of the course are specified in the programme, then the class problems are bound to come from the teacher rather than from the boy. His primary interests are supplanted to a great extent by foreign interests whose activity depends upon the will of the teacher or some other external agency. Recently I asked a first form class how many legs a spider had. One-half the class did not know, and very few of the remainder were certain. Not more than eight per cent. remembered having actually counted them, and many of these had done so in the public school. Now if the morphology of the spider had been of normal interest to the students, every one of them would have voluntarily counted the number of legs (at home), since all have had frequent opportunity to do so. And though many questions are asked by students during the morphological study from specimens, the questions are not the same as would be asked at home. The school questions arise from an abnormal interest created and kept active by the teacher. If the study of zoology were continued for some time such abnormal interests would no doubt become normal; but in the meantime the boy feels that his own experiences and problems are of little account in school life, and he drops them at the schoolroom door. Since elementary science is a general course subject, these problems and experiences should constitute the bulk of the course, because they are directly concerned with the ordinary things of life. If the course were restricted to general conceptions, and the concrete data from which these conceptions might be developed were left to the choice of the teacher and class, then the things the boy was interested in at home would be the things he liked at school. His own home problems would assume a new importance to him. If he found the teacher and class interested in knowing the very things he wanted to know, his eagerness to initiate investigations would be tremendously stimulated. And if he also discovered that he himself could actually carry out these investigations to a successful issue, his self-evolved problems would assume a still greater importance. They would become motives of successful activity. Just as a man likes to bowl because he can bowl well, the boy would like to investigate because he could investigate well.

With the partial exception of physical geography, all the sciences are now studied by the laboratory method. The pupil is trained to gather wisdom from first-hand experience. He is taught to base his conclusions on real evidence. But, as already indicated, laboratory experience is in many respects artificial and arbitrary. While general methods of investigations can be best taught in the laboratory where experience is simplified and freed from extraneous matter, still the pupil must learn the way and get into the habit of gathering data from the ordinary experiences of life. He will not live in a laboratory. His investigating methods must be related to and fitted for the surroundings of everyday existence. He must learn to observe and experiment upon the things he finds at home. These will form the real data for the scientific investigations of his mature years. But, at present, the outdoor work, instead of forming the basis of the regular class-work, is divorced from it, and receives scant attention. In the laboratory experience is manufactured instead of being organised. The boy who has seen railroad steel "buckle" during the summer, or has seen the smith setting a waggon tire, or has noticed the stove-lids "swelling", has learned from real data that iron expands when heated, just as truly as the boy who performs a carefully devised experiment at school. He has learned more; he has learned where to look for real evidence. When he goes out into the world, his methods of investigation will "fit in" with his surroundings, since they have been developed in connection with just such things. The laboratory should supplement, not supplant, the student's outdoor work. Those problems which the boy cannot decide by means of outdoor evidence may be carried to the laboratory and submitted to more accurate and more refined methods of investigation. Experimentation is simply controlled observation. Doubtful factors may there be established or eliminated, and the values of factors may be measured, but investigations should begin with outdoor data and make use of them as far as possible. To make a good citizen the boy wants a knowledge of practical everyday methods of investigation rather than of special theoretical methods.

The present plan of training in descriptive observation leaves little to be desired. The pupil is trained to examine systematically and accurately, and to use and have confidence in his own perceptive power. Given a specimen, he must see things for himself and describe things by himself. In the actual teaching practice, however, the present course is so extensive that the lessons have to be hurried over. The teacher can never be certain that all the members of the class have actually observed and found out for themselves the thing which is under discussion. If the present course were lightened, the teacher would be in a position to require each member of the class to write out his descriptive observations before any answers were taken, thus insuring independent work on the part of each. But if the present course is to be covered during the regular class periods this cannot always be done. As it is, the lesson is either broken up into a series of question—answer—note, question—answer—note, or the whole topic is treated by class discussion and then the student writes out his account. In either case there will be many in the class viewing the specimen through the eyes of other students. The high school inspectors demand that the notes in the students' note-books shall be written as the pupils make their observations. If this plan were universally followed (sufficient allowance being made at the time of inspection for defective observations which the students are more or less certain to make), though the note-books would not present as perfect an appearance, the aim of method teaching would be placed on an equal standing at least with the aim of knowledge teaching. The note-books would no longer be historical accounts of studies in biology. They would be true scientific note-books, with some parts erased, others crossed out, and with additions written in here and there, but on the whole resembling very much the civil engineer's loose-leaf pocket-book.

Then again, we probably have too much description for description's sake. The regulations require that all studies of form shall end in studies of function. But this is placing the two in a co-ordinate rather than a subordinate relation. Indeed to a certain extent function is subordinated to a study of form, rather than the reverse. As indicated previously, each specific form or scheme of making observations should be adapted to a specific purpose. If a student is examining a plant for the purpose of classifying it, his observation scheme will be quite different from the one he would use in a study of its economic value, or from that followed in a study of cross-fertilisation. Were general scientific conceptions alone outlined on the course and the concrete material used in their study left to the teacher and class, a special relation would be established between each particular purpose and the method of observation suited to it.

But while the present plan of teaching descriptive observation is on the whole very good, and improving every year, there is at present practically no training in those methods of experimental observation more nearly akin to science study. As seen in Chapter III, experimentation is a method of study in which the student first draws up a list of possible causal factors, then purges this list until he finds a working hypothesis, and lastly proceeds to test this hypothesis in certain definite ways. "Laws have been discovered by something like a happy guess from very rough observations, while the confirmation of the guess depends on methods of greater refinement which generally depend altogether on a knowledge of the law itself they are intended to prove".* If scientific investigation is a mode of thinking, it is quite certain that the student, to receive training, must do that thinking.

After careful investigation I have found that the majority (no exceptions among those asked) of the science masters in the Province dictate to their pupils detailed outlines of the experiments to be performed. These are taken from the Manual of Suggestions, from text-books, or are devised by the teacher. As a rule, only one experiment is performed to establish each law or principle or general conception. The pupil performs the experiment, that is, goes through the mechanical operations as directed, and from the result is led to formulate some generalised conception. Either Chapters II and III are entirely wrong, or this is not a training in scientific methods of investigation. Experiments thus performed may vividly impress certain information, or may illustrate certain principles, but the teacher, not the student, thinks them out. If a mathematical master wrote out the solution of each problem to be solved, and required the student merely to do the multiplying and dividing, that student would receive little or no

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*Cumming: "Electricity", p. 33.

training in the methods of problem-solving, although he might receive a training in elementary mathematical operations. "The essence of heuristic method is that the pupil learns to think for himself, not that he learns to do certain things with his hands, though that, too, may be involved. There is nothing in the heuristic method, for example, if a pupil in a chemical or physical laboratory works 'experiments' which have been dictated to him by his teacher. To him they are not experiments at all, for the essence of experiment is the mental planning of what is to be done and the clear conception of why it is worth doing. If on the other hand the pupil does this mental part of the work, it is comparatively unimportant who carries out the actual physical manipulation".* As in the study of descriptive observation the child is trained to see for and by himself, so in experimental observation he should be trained to think out his own solutions.

It may be contended that if the student intelligently follow the different experiments (thus performed), if he be led to see the reason for each step, he will "catch on" to the general methods followed. If the experiments performed were real scientific investigations, this would be true. No doubt his conceptions of methods would be rather vague and confused since these would not have been explicitly taught him, but an intelligent student under a painstaking teacher would get a fair knowledge of method. But the present series of prescribed experiments are not real scientific investigations at all. The pupil who does "catch on" gets a false knowledge of method.

At present students form so-called general conceptions from the results of single experiments or single experiences. A general conception based on a single experience is a contradiction of terms. The concrete judgment, which alone can be justly pronounced, may be accompanied by a guess at some more general conception; but this remains nothing more than a guess, until its probability has been estimated by submitting it to the test of other experiences. The need, the method, the habit of doing this constitutes the essence of scientific method. "One of the chief advantages derived from the teaching of natural or physical science should be the recognition by the pupil of the difficulty of arriving at truth and of the need of caution in making inferences

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*Welton: "Logical Bases of Education", p. 256.

from insufficient evidence".* The student who gains his knowledge of method from the present experimental course receives an impression of research quite opposite the true method-ideal of all scientific investigation. The "one experiment to one principle" plan teaches him that general truths are absolute and may be derived from one experience rather than that general truths are probable and must be deduced from many experiences.

If the student has failed to grasp the fundamental method-idea of all real scientific investigation, surely it is most improbable to suppose that he will be able to "catch on" to correct method-habits through the performance of dictated experiments. Neither in the Manual of Suggestions nor in the Physics text-book are to be found true qualitative experiments whose function it is to discover causal factors through a process of trial and elimination. An examination of science note-books from different schools, and an inquiry among the science teachers of the Province show that the real qualitative experiment is seldom, if ever, used. The student does not draw up a preliminary list of possible causal factors and then test each by the method of "difference" or "concomitant variation". It is very doubtful whether many students have even a faint idea that they are testing an hypothesis at all. In some of the science note-books (from the better class of high schools) each record starts out with the purpose of the experiment, for example, "To show that solids expand when heated". On the face of it, it is evident that this does not record an experiment, but a demonstration. The student has not a doubt in the world as to the outcome of the process. The teacher and text-book have both told him that solids expand when heated, and he merely expects to see a sample of that expansion. The pupil cannot select, test, and choose among causal factors, since the dictated experiment simply thrusts the right factor upon his notice. He is told in fact, if not in words—"This is the causal factor; watch it work!" The true method is just the reverse—"You see the causal factors working; find them!" He can never become familiar with the "Method of agreement" since one experiment (for him) proves one principle. The "method of difference" requires that at least two experiments shall be performed, in one of which the factor to be tested is present, while in the other it is absent. Since he performs a demonstrative rather than two comparative experi-

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***Ibid.*: p. 260.

ments, he cannot "catch on" to this method either. Since only the factor given him by the teacher is in mind, he will not see the necessity of guarding against the influence of other possible factors.

It would seem as if quantitative experiments were, in many cases, substituted for qualitative. A causal factor should be discovered before it is measured. Qualitative experiments should always precede quantitative. While in the curriculum we find that "the relation between the volume and pressure of a gas" is specified before the "proof of Boyle's Law", yet inquiry and an examination of science note-books reveal the fact that many teachers begin the study of Boyle's Law, Archimedes' Principle, etc., by quantitative experiments, thus requiring the pupil to measure a factor which is as yet unknown to him. This fault is, in the main, due to poor teaching, and can be charged against the present curriculum only so far as the latter fails to specify the teaching of methods as part of its content.

On the other hand, any intelligent boy can get a fair grasp of the "method of concomitant variation" as used in many of the quantitative experiments now employed. Variations are made in a causal factor and a mathematical relation is established between the measure of the variation and the measured change in the result. Possibly the use and importance of the "method of averaging results" to obtain a final conclusion is neither intelligently taught nor its practice insisted upon. While the majority of quantitative experiments used are good, others are vicious. In the study of buoyancy an experiment is outlined in which the pupil is directed to balance a brass cylindrical cup containing a solid brass cylinder just fitting inside it. The solid cylinder is then removed, hooked below the cup and immersed in water. On filling the cup with water the original balance is restored. Neither the method nor apparatus are those employed in real investigation, but have been devised by learned scientists to illustrate principles already discovered and formulated. They are the products of mature minds, not the tools of inquiring minds. The principle of buoyancy may be beautifully illustrated, but not investigated, by such an experiment. Unless the boy already knows the answer he will be unable to manipulate the apparatus, and if he does know the answer he is not investigating.

The present course of dictated demonstrative "experiments" tends to foster rashness in forming judgments, and even encourages mental dishonesty. In the study of "expansion due to heat" the student heats a flask of water, which has been stopped with a doubly perforated cork through which a glass tube and a thermometer are thrust. When the flask is heated the water rises in the tube. From this one experiment he is led to discover that water or even any liquid expands when heated. A week later when studying "the maximum density of water" he performs an experiment in which the same apparatus is used, only this time it is placed in a freezing mixture. From this experiment he concludes that water between certain temperatures contracts when heated. Mental honesty is sacrificed to secure uniformity. The first generalisation is rash; in fact it is impossible, since the only conclusion to be drawn from a single experiment must be concrete and specific. General and abstract conceptions from their very nature must be the product of a number of experiences. Such experiments surely must "cultivate that habit of rashness in drawing conclusions, and that inability to estimate the force of evidence which it is the special task of education to replace by the very opposite qualities".*

It is evident that the present course in dictated demonstrative experiments not only gives the student false method-ideals of scientific investigation, but that, with the exception of the "method of concomitant variation" as found in certain quantitative experiments, he receives no training in the method-habit of research. The only remedy is to abolish entirely the present course of dictated experiments, and to place the teaching of scientific methods on the same footing in the curriculum as the teaching of scientific knowledge. At present the science teacher is strictly forbidden to dictate notes; he should be strictly enjoined from dictating experiments.

It may be objected that such a plan would require too great an expenditure of time. If all of the present programme were to be taught this way, it would indeed require too much of the school time. But we have already referred to the fact that it is not necessary to use the scientific method in teaching all the curriculum. It is to be used until the pupil is able to handle it. It is not so much a way of teaching as a thing to be taught. Although it is profitable to teach the specified knowledge along with and by means of the method, still much of this information can be taught

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*Welton: "Logical Bases of Education", p. 259.

by other means after the pupil has become familiar with the use of the method. When the concrete details have been eliminated from the biology course, the curriculum will be much shortened. During the past three years I have been testing the lower school classes in different parts of the physics course. With the exception of a few experiments, such as the electrolysis of water, the entire course has been tried out in sections during that time. I am positive that the entire two-year course (with the exception of a few topics which should not be in it anyway) can be covered within the required time, the pupil using the true scientific method throughout.

It may also be objected that results obtained in this way will not be sufficiently accurate. Again we see the insistence upon knowledge-teaching rather than method-teaching. One might as well insist that a boy learning arithmetic should use an adding-machine. But the objection is not true. Boyle discovered the law named after him by means of apparatus far more simple than that used in the present class-room. The careful manipulation of simple apparatus will bring results the accuracy of which will be as delicate as the mind of a boy can appreciate or the requirements of ordinary life demand. The averaging of the results obtained by different members of the class will, as a rule, very closely approximate the established principle. But if a training in scientific methods of investigation is essential to good citizenship, the boy *must* receive that training, no matter what has to be thrown overboard in the way of theory or present practices.

CHAPTER VII

SOME EXPERIMENTAL LESSONS

Study of buoyancy introduced by a lesson on flotation. Establishment of preliminary list of possible causal factors. Purging of list by use of method of difference and concomitant variation. Generalisation. Informal use of method of agreement to substantiate the generalisation. Lesson on buoyancy. Lesson on practical applications of the principles arrived at.

THE training process cannot be reduced to a set of fixed rules. Different topics will require different methods of treatment, and the details of subject-matter will vary with the class and with the school. The general conception of scientific method has been developed in the previous chapter. Illustration lessons will be given in this chapter in order to show the way this conception is to be correctly applied.

In Chapter VI, Section II, a way of teaching buoyancy, contrary to the ideas of scientific method, was discussed. The following is not a model lesson, but a synopsis of the efforts of an ordinary class to make use of the true scientific method in organising their vague ideas and experiences of buoyancy. Instead of developing the idea of flotation as a corollary to the principle of buoyancy, as is usually the way, the conception of buoyancy has been evolved from the idea of flotation, because the pupil has had more experience with phenomena exhibiting the latter. The last few minutes of the previous lesson had been skilfully directed to the discussion of flotation, and the pupils were asked to find out what they could about the subject at home.

During the following lesson, the pupils were first asked to suggest possible causal factors of flotation, what made an object sink or float. One suggested that, as wood floated and stones and iron sank, the substance of the object used was one factor. A second said that iron ships floated. The first replied that the ships were really made of wood with just a thin sheet of iron on the outside. A third remarked that canoes were sometimes made of pressed steel, and a fourth remembered a toy metal ship at home. The first answered, that while a small iron ship might float, a large one would sink. It was agreed that "substance", "shape", and "size" were to be listed as possible factors. Another pupil remarked that a person could float more easily in salt than in fresh water. This caused another to recollect that eggs floated in pickle brine. The "fluid used" was added to the list; and no other possible factors being suggested, each one on the list was examined in turn. Four minutes of class time were used in making the list. Twice the teacher had to check discussions which tended to pass into the second stage before the first was completed.

The majority agreed that "size" could be eliminated, giving as reason that icebergs or large logs of wood floated as well as small pieces of ice or wood. A few maintained that, though the larger object might float, it sank deeper in the water. The class were given large and small blocks of wood of the same thickness. After experimenting with these in tanks of water they all agreed to cross out "size" from the list. Among the first four a sharp discussion regarding "substance" arose. They compromised on the statement that if objects were of the same shape the material affected their flotation. But when the discussion came to "shape", it was evident that Number One was not yet convinced. She and her supporters still maintained that a ship made entirely of iron would not float. They agreed that boats made of sheet lead would do to test the case, though one of her opponents objected that, lead being heavier than iron, the test would not be fair to his side of the question. Number One, driven into the last ditch by the results of experiments tried with boats made of sheet lead, declared that, if the sides were very thick, the boat would sink. A boy said that the first boat he made was not very deep, and sank when placed on the water. This caused another to remark, that the boat he made leaked and sank. This result seemed so obvious that the class laughed. The results obtained from experiments with thick-sided boats and shallow boats plainly perplexed them, as no one could state a relation between shape and flotation. The boy whose leaking boat had been the subject of mirth spoke up and said that, since his boat in sinking had not changed its shape, shape was not a factor at all. Just as the teacher inquired what caused the boat to sink, the class-bell rang, and the class were requested to think over the question at home.

At the opening of the following lesson many were ready with examples to show that the weight, rather than the material or shape, should appear on the list as a causal factor. Having previously studied "density", they were soon in a position to state that when an object was not as dense as water it floated on water. The discussion, especially in regard to boats, emphasised the fact that it was the density of the entire object that had to be considered. The next topic for discussion was the "nature of the fluid used" as a causal factor. They wished to experiment with the liquids which they had used the week before in the study of specific gravity, and found that the wooden blocks floated deeper in coal-oil than in water, deeper in fresh water than in salt water, deeper in water than in mercury. One group demonstrated the fact that a coin would float on mercury, another group that coal-oil floated on water. They speedily came to the conclusion that the density of the fluid used was the determining factor. The general conclusion drawn from these qualitative experiments was that an entire object less dense than a fluid floated on the fluid; the denser the fluid the higher the object floated.

Reference was now made to a question which had been asked some time before, as to what weight a vessel would carry without sinking. One or two thought the boat could be loaded until it was as heavy as water. But since the majority were not certain, they tried the experiment of placing weights on a block of wood until it just floated in water. Then the volume of the block was determined by measuring its dimensions: the weight was ascertained in some cases by using a balance, in other cases it was calculated from the specific gravity which had been determined the week before. One class and two homework questions were given as to what weight a raft of given dimensions and having a certain specific gravity would carry without sinking in water.

On the following day after the home-work was taken up, someone inquired how balloons floated. The teacher asked what happened to a block of wood placed near the bottom of a tank of water. He was told that it rose to the surface, since the block was less dense than the water. From this the pupil reasoned that the balloon rose, because it was less dense than air, and that it would continue to rise until it reached a stratum of air whose density was the same as that of the balloon. In the lesson on specific gravity the class had found that a quart of air weighed about one gram. Some questions as to the lifting power of a balloon were now given them.

The weight of a floating block and of a submerged block of wood was then discussed. The class soon agreed that in the first case the weight was zero and in the second case it was a negative quantity. They were then asked if the weight of a piece of iron submerged in water was lessened. One boy remarked that it was easier to lift a rock in water than out of it; but, as most of the class were doubtful, they tried weighing pieces of lead, copper, iron, and limestone tied by a string to a spring balance, first in the air and then in the water. Possible causal factors were then suggested and listed on the blackboard. Those given were: "density", "size", "shape", "material" and "fluid used". "Material" and "shape" were rejected without recourse to experiments. The class then tried different sized blocks of the same substance, and the same sized blocks of different substances, first in water, then in coal-oil, and then in salt water. They concluded that the two causal factors of buoyancy were the size of the object and the density of the liquid. To get an exact statement of the relation, the experiments were repeated, the volumes of the various blocks being first ascertained in cubic centimetres. It was found that each cubic centimetre of the various objects used lost one gram in weight when weighed in water and 9 grams when weighed in coal-oil. Part of the recess period was used before the law was finally determined, and formulated thus, "that each cubic centimetre of an object immersed in a fluid lost the weight of one cubic centimetre of the fluid".

The following lesson was more or less open and dealt with applications of the idea of buoyancy. Each group was given a mixture of sand and sawdust, and asked to separate the two substances. Each group successfully solved the problem by shaking the mixture in a beaker of water. But when they were given a mixture of sand and sulphur to separate, only about half the number of groups were able to solve the problem independently by using the process of sedimentation. At the most, however, only a hint was required to put the others on the right track. The uses of this process in gold-mining, cleaning grain, etc., were then discussed, and reference was made to the formation of strata in sedimentary rock as the process was revealed on the near-by lake shore. The method of raising sunken vessels and the watertight compartments of ships were also discussed. As the end of the period drew near, the question as to the cause of buoyancy came up. This formed the starting-point for the study of "pressure at a depth" and "Pascal's Principle", which formed the topics of the following lessons.

The above, being examples of actual lessons and hence falling short of ideal conceptions, still show that the ideas of scientific method outlined in Chapters III and VI can be applied in the ordinary school. The lessons were founded upon and resulted in the organisation of primary experiences of the pupils. The topics dealt with matters relative to the life of ordinary citizens. The pupil's problem-finding ability was developed, since a great part of the time was devoted to answering, or rather giving the pupil opportunity to answer questions raised by himself. Conceptions were founded on real data. The pupil devised his own experiments and passed just judgments on the results. General conclusions were extracted from a number of experiences, and during the first lesson, at least, the original generalisation had to be modified and recast. The general conception was related to different classes of phenomena, and the pupil was given practice in making practical use of his knowledge.

CHAPTER VIII

THE SCHOOL AND THE CURRICULUM

Topics in a general course subject should not receive technical treatment. The terminology employed should be that used in ordinary life and a vernacular nomenclature substituted for the present technical system of biological classification. Principles of science as organising centres. An undifferentiated course in which the common physical phenomena of life are grouped about scientific principles. Essential knowledge that does not lend itself to heuristic methods of investigation in high schools. Laboratory and library teaching should go hand in hand.

SINCE the content of any course depends to a great extent upon the place that course occupies in the school system, and since it was maintained that in the subject of elementary science the subject-matter must lend itself to the teaching of method, it has been found necessary to discuss many aspects of the present course in Chapters V and VI. The business of this chapter will be to tie up the loose ends of that discussion, and to consider more especially those features of the programme having a distinct value as knowledge.

In Chapter VI it was shown that the requirements of method-training demand that at least part of the course should treat of topics of primary interest to the student. He must bring problems concerning these to the school, and he must discover data to be used in solving them in his everyday surroundings. His methods of investigation must have been acquired in connection with the study of commonplace topics in order that they may be directly transferred from the school to practical life. Chapter IV maintained that since elementary science was an essential feature of general rather than special education, preparing the student for the ordinary duties of citizenship, the content of the programme should deal with the common rather than the special technical aspects of science study. Thus we see that the knowledge requisite to good citizenship, and the topics required for the purposes of method-training are of the same general character. The entire curriculum should, therefore, be based upon the common experience of the average boy or girl.

But in Chapter V it was shown that the course in zoology was expressly based upon a technical scheme of classification. As a result much time is devoted to technical descriptive study of specimens. "Comparison of a grasshopper with a cricket or cockroach, leading to the recognition of the order Orthoptera" is a topic clearly suited to special rather than general education, yet it is placed on the curriculum for the work of the third week. Throughout the entire course in this subject the study of function is treated as an adjunct to the study of form. But even from a scientific point of view, form is subjunctive to function. Only in technical classification, which forms a small, though important part of the study of science, is the study of form in itself of dominant importance. The student is not interested in technical classification, but he is interested in the living activities of animals. Instead of making each specimen in turn the organising centre of the student's ideas in zoology, his conceptions should be arranged about functional activities. Instead of studying all there is to know about a grasshopper, then all about an earth-worm, then a bird, and then a cat, he should study the locomotion of animals, their breathing, how they sense the outside world, etc. For example, in the study of respiration, he will find out how mammals, fish, and insects breathe, how their organs of respiration are adapted to their respective environments, the physiology of the process, and finally a hygienic study of respiration in relation to his own well-being. The boy's ideas would then be organised about a true scientific conception centre. The concrete material could be eliminated from the programme and left to the choice of the class and teacher.

The course in botany rests upon a larger foundation of common experience. It is organised to a much greater extent about plant function. Many of the general topics and all of the sixteen specified experiments deal with vital activities of plant life, rather than descriptive studies of form. Other general topics deal with economic relations. On the other hand the "identification of plants by means of a flora" tends to unduly emphasise technical descriptive teaching. "Stem structure in dicotyledons and monocotyledons", "varieties of axial and terminal types of inflorescence", "seed structure in dicotyledons, monocotyledons, and gymnosperms" are topics much more closely associated with the study of technical classification than with the experiences and interests of ordinary life. However, on the whole, if technical classification and its attendant topics were removed from the present course in botany, very little fault could be found with it. Certain topics might be more intimately related to the study of physical principles in which their explanations are to be found. But the greater part conforms to the primary interests of the child, to the knowledge of use to the average citizen, and readily lends itself to treatment by scientific methods of research. The present course in physics and chemistry is also subject to little criticism in respect to its academic nature. Perhaps too much stress is placed upon the metric system of measurement throughout the course. It is something that, unfortunately, the pupils will have little use for in out-of-school life. If the present teaching of it will tend toward its general adoption throughout the country, it might with profit be retained upon the programme. But the fact that it is used in all measurements in special science-study is absolutely no argument in favour of its retention. It is not the function of a general course to teach the A, B, C's of a special course. The pupils never become familiar with it in a two-year course. When we speak of a gram the only idea that comes to their minds is that of a small brass weight, but when one refers to a pound there comes to mind a picture of an iron weight, a cube of butter, a packet of tea or coffee, etc. There can be no doubt but that mathematical conceptions in the science course will mean more to the student if expressed in the English system of measurement. And it is very doubtful whether the student at the end of a two-year course becomes so familiar with the use of the metric system and so aware of its advantages that he will favour a change in that direction when he leaves school.

Where the content of the programme is excessively technical in character, a great deal of technical terminology in the language of instruction is associated with it. For instance, to make intelligent use of a flora, a pupil must be familiar with the use of from two to three hundred technical terms. Technical terms may be divided roughly into two classes: those for which there are no popular synonyms such as dicotyledons, vertebrates, corolla, etc., and those having popular synonyms, such as epipetalous (growing on the petal), tarsal (ankle), petiole (leaf stalk), etc. When the former denote ideas with which the pupils are familiar, they should be used in class. There is an ever-growing tendency to make use of such terms in ordinary life. But the latter class of terms are of use only to the scientist. They do not form part of the language of everyday life. When used in the schoolroom the attention of the pupil is distracted from the idea to the spelling, pronunciation, and sometimes the definition of the term. A great deal of time and energy is wasted in teaching words for which the pupil will find no real use. In this case the popular synonym should be employed. Not only is it the term used in ordinary life, but being already associated with the idea in the mind of the pupil, it helps to concentrate rather than dissipate his attention.

To teach the nomenclature of technical classification in biology to junior pupils is absurd. To the scientist knowing their derivation, these names have meanings, but to the junior pupil they are meaningless, unpronounceable, unspellable words, labelling or libelling some well-known plant. The function of any system of classification is two-fold. It must give a plant a distinguishing name, and it must indicate morphological relations between the plant and other plants. The technical system which has common use in different countries and different languages is of great value to the scientist whose range of study is not confined to local districts. In the wide world of his activity it is necessary that every species shall be so named that a reference made to it will be clear to all nations and all men. But the boy lives in a different world, a world in which plants have old familiar names, names as a rule more strikingly characteristic of the plant than the corresponding technical ones; names he has read in old books, and reads in modern magazines and newspapers. If it is essential that a scientist shall use and be familiar with the nomenclature used in the world of science, is it not equally reasonable to affirm that a boy should learn those popular names employed in ordinary reading or conversation? The popular name designates the plant in the words of the ordinary citizen just as truly as the technical name does in the words of science. As an indication of morphological relations the name "Ranunculaceae" has no advantage over the popular name "Buttercup Family"; nor the generic name "Ranunculus" over "Crowfoot"; nor the specific name "Pennsylvanicus" over "bristly".

Identifying plants supplies possibly the best means of training the pupil in methods of accurate systematic observation. But to take full advantage of this practice, a flora should be prepared in which common names and popular terms are substituted for the present technical nomenclature and terminology. A standard system of classification in the vernacular would overcome a possible difficulty arising from the fact that some plants are known by different popular names in different localities. Such a change would make the study of classification much more interesting and popular with the students. They would merely continue in a more systematised way an informal, out-of-school study. The average student, on entering school, is able to name from thirty to fifty wild plants and as many (or more) cultivated specimens. This knowledge could be readily organised to form the basis of the study of classification, if the scheme of classification proceeded along lines already familiar to the student. He knows several species of maple, of oak, and of apple trees. From the common characteristics found in each group and sub-group, he easily arrives at the idea of the family and the genera.

I do not think the student should begin the study of classification by making use of the key or flora. He should get a conception of grouping directly from the study of specimens. For instance, a boy in a fruit district knows that there are a number of different trees all known as apple trees, another group known as peach trees, and still another as plum trees. In the first group there are spies, greenings, kings, crabs, etc. Similarly, in the second and third groups are to be found different kinds of peach and plum trees. A comparison will also disclose to him the fact that plum, peach, and apple trees have many common characteristics, and that in many respects they are quite distinct from oak trees or cedar trees. Such a study will give him a conception of the meaning of family, genera, and species. He should in this way become fairly familiar with several family groups before he begins a formal study of classification by means of a flora. If a popular nomenclature is used he has already done a great deal of classifying in an informal way. And if a simple terminology is used in the flora adopted, he will be able to utilise intelligently a key as soon as it is placed in his hands. In this way he will be enabled easily to classify sixty plants whereas he classifies twelve now, and that with difficulty.

The flora should embrace common cultivated plants as well as wild plants. The pupils of the present generation, as a rule, are more interested in the former than in the latter. The city man or woman knows far more about different varieties of the rose than he does of the buttercup family. The agriculturalist is interested in different kinds of grass, wheat, or corn. In my first form this year I found that nearly all the pupils could name and give a fair description of ten fruit-trees, but that very few could name and describe off-hand more than four or five forest trees, and most of these were selected from the shade-trees of the town. Very few of us get much benefit from a knowledge of wild flowers. We never see them frequently enough. But many a man and woman has become interested in rose-culture, because by chance they have become acquainted with the forms and beauty of the different varieties. If both wild and cultivated plants were included in the flora, the study of classification could be more closely adapted to the interests of all the students, and would more fully satisfy the needs of the average man or woman.

In Chapter VI it was shown that the programme lent itself much more readily to the needs of method training if the general scientific conceptions to be taught alone were specified, and the choice of concrete material were left to the teacher and class. In Chapter IV it was maintained that the present need of the boy was not for more facts, but for an organisation of facts already in his mental possession; that the need of the man was not so much in the line of concrete information as in the possession of mental centres of organisation whereby information obtained by him could be assimilated and made fit for use. Conceptions of scientific principles form just such gravitation centres, through which a knowledge of the physical world about him is actively organised. Education, in other words, should be dynamic, not static; the boy should not be adjusted to a fixed environment but given the power of adjusting himself to a changing one. Hence the needs of method training unite with the needs of knowledge-teaching in emphasising the important position that the general conception of science should occupy on a study programme.

Speaking broadly, the present course in physics is organised about general causal conceptions. Reference is also made to the main classes of phenomena in which each is exhibited. The present course in biology is, on the whole, organised about general formal conceptions of type, while the course in physical geography is grouped about conceptions of contiguity. For instance, the curriculum in physics reads: "principle of the mechanical powers, Pascal's Law, pressure of liquids at a depth, Archimedes' Principle", etc. The curriculum in zoology reads: "the study of a grasshopper, a spider, a centipede, the order Orthoptera", etc. The curriculum in physical geography runs: "changes on the earth's surface, the atmosphere, the ocean", etc. Conceptions of form, though important, are not fundamental centres of mental organisation. The boy may be familiar with the structure of a dozen different flowers, or types of flowers, but this information has no real meaning to him until it is related to the causal conception of cross-pollination. Now this causal conception and two others are, alone, specifically mentioned in the biology course. That other causal conceptions are supposed to be taught is suggested in the note on the general scope of the work. "These morphological studies are not to end in the study of form—there must be a constant effort to interpret the meaning of the form to show the relation of form and function".* This is good so far as it goes, but the fact remains that while the morphological studies are outlined in minute detail, the study of causal conceptions is only implied. Suppose the course in physics read: "the study of a water-pump, the structure of a dam", etc., and made no mention of the principles in which these forms found explanation, is it reasonable to suppose that conceptions of the principles of science would be as well established in the mind of the student? The course in biology should be recast. General biological conceptions together with the chief forms in which they are exhibited should be specified as lesson-topics. Although a study of classification as outlined in previous paragraphs should be included in the course, it should not overshadow the course as it does at present.

But the present course in physical geography cannot be reorganised after this fashion. Its causal principles are to a great extent the same as those involved in the study of physics, chemistry, and biology. To re-organise the course so as to found it upon a study of causal conceptions, rather than conceptions of contiguity, would be to duplicate in part these other subjects. The present course dissociates the study of phenomena and the study of causal conceptions. The pupil studies winds in the chapter on "The Atmosphere", ocean currents in the chapter on "The Ocean", and convection currents in the physics class. But since the pupil does not study convection until he enters the Middle School, he is

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*"Report of the Minister of Education, Ontario," 1913, p. 394.

really engaged in investigating the phenomena, winds and currents in which the idea of convection is exhibited, before he has grasped the idea itself. Numerous other instances might be given where the pupil investigates phenomena in the physical geography class, whose explanation depends upon conceptions afterward developed in the physics or chemistry classes. If the pupil is to study these phenomena at all intelligently and scientifically, it must be in connection with the principles upon which their explanation depends. But if principles must be established in the physical geography class and again investigated in the physics class, a great deal of work will be needlessly duplicated. Even were the course in physical geography recast in such a way that explanatory laws would be established in the physics class previous to the study of relevant phenomena in the geography class, there would still be the break in time, interest, and study concentration. The study of topics at present contained in the physical geography course should be taken up at the same time as, and be directly associated with, the study and establishment of causal principles upon which their explanation depends. Winds and currents should be studied in connection with convection. Rain, snow, and dew should be associated with the investigation of "change in state". Certain topics in biology, such as animal and plant food, metabolism, movement of liquids in plants, etc., should also be studied at the same time as the establishment of physical or chemical conceptions which underlie them. These dissociations evidently arise from the premature differentiation of the science course into five special sciences. Reasons were given in Chapter IV for believing that the student would receive a better training if the science course were not so divided. The above-mentioned difficulties in the practice of teaching would seem to substantiate the conclusion arrived at in the previous chapter. The elementary science course should not be differentiated into special science studies, but should consist of topic groups, in each of which some general conception of science is established and studied in relation to all of its chief fields of application, so far as such are of interest to the average citizen.

So far we have considered the teaching of scientific knowledge in connection with the training in scientific method. But there are certain facts of science of such value in themselves that all pupils should be familiar with them. Since the time that may be devoted to science teaching is necessarily brief, and since the equipment of the average High School is limited, the child cannot obtain all this information by heuristic methods of investigation. He cannot study the germ theory of disease, the chemistry of foods, etc., in the laboratory. Had he ever so much time, or were the equipment of the school ever so extensive, a great deal of such investigation would be beyond his capacity. He will have to gather much of this information from books or be told it by the teacher. Heuristic methods should not be made the Shibboleth of all teaching in the science class. So long as the pupil has sufficient training to enable him to understand the scientific method and to apply it in the ordinary affairs of life, other methods of gathering information may be used. Since the aim is to give the pupil information, not training, short cuts are in order. So long as the pupil has sufficient actual experience in his home life with certain topics to make the thing which is studied real to him, there is no reason why he should not utilise the same sources of information as his elders. Life is too short for any man to establish scientifically more than a small part of the knowledge necessary to right living. "We are astonished often to note that it required the combined labours of many eminent thinkers for a full century to reach a truth which it takes us only a few hours to master".* The successful man of affairs is he who is most able to make use of the experiences of others. The main thing is that the child shall be so trained in the scientific method that he will be able to use it when occasion demands and that he shall be so familiar with the process that he will be able to tell when others have correctly used it in arriving at conclusions. The pupil must be trained to make use of the library as well as the laboratory. He must learn to use his training in scientific methods as a criterion with which to test the statements made in his general reading. Such a student will not "swallow" all the conclusions of pseudo-scientists in current magazines and newspapers. He will not freeze the family out trying to burn coal ashes. He will not invest in costly preparations advertised as "getting more heat from your coal". He will not follow first one food crank and then another.

The school course should be potential as well as kinetic. The student should leave school with an eagerness to pursue his studies

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*Mach: "The Monist," Vol. VII, p. 175; quoted in "Applied Sociology" (L. F. Ward), p. 102.

further. The science student should have a deep interest in the scientific movements of the age. I think it is a great pity that in our revolt from "book science" we have gone to the other extreme in our secondary schools and condemned everything that is not "laboratory science". The student must become interested in "book science" if he is to pursue his studies in after years. The articles he reads in books, magazines, and newspapers must stimulate and guide his efforts when the teacher is no longer at hand. He must associate his science study with these forces while he is at school. Laboratory teaching and library teaching should go hand in hand. And in this way alone will he arrive at a balanced yet true conception of the world of nature around him.

CHAPTER IX

THE CURRICULUM

Knowledge required by citizenship, an inquiry. The syllabus—general remarks. Training in methods; problem-finding; real evidence; descriptive observation; investigation of causal relations; preliminary list; hypothesis; methods of difference; agreement; concomitant variation; averages; methods of practical application. Subject matter.

IN order to discover what aspects of scientific knowledge were of real use to the average citizen, eighty-nine letters were sent to different people throughout the Province. In these letters they were requested to write out on a prepared schedule just what things of a scientific nature they found interesting, outside the special technical interest of their particular occupation. Sixty-seven replies were received. Of these, sixteen were of such a general nature that they afforded no specific data whatever. I then interviewed some fifty-four persons along the same line of inquiry. The results obtained by personal interview were much more satisfactory. From a knowledge of the lives of these persons, I was able to discriminate between things that they actually found interesting and things that they merely thought they would like to be interested in. For instance, a doctor who has a large country practice, when I interviewed him on this subject, told me that "it was a splendid thing for boys and girls to know all about the birds and trees and things they see about the country; they will get so much pleasure from a knowledge of these things when they grow up". I was out driving with him some weeks afterwards and found he scarcely knew a crow from a blackbird, or a beech from a birch. He had studied botany and zoology at school and university, and in the practice of his profession had ample opportunity to become familiar with these aspects of nature had he so *wished*. Such imaginary interests, where discovered, were scored out in the schedule. I had less opportunity of thus checking over the answers obtained by letter.

Of the one hundred and five whose replies were such as could be utilised, forty-three were graduates either of universities or of university professional schools, thirty-nine had received a secondary school education, and the remaining twenty-three were what are usually called self-educated men, that is, they had made the best of an ordinary public school education. They were all good citizens, and had made more or less of a success in life. The occupations followed by them were: Medicine, 9; Dentistry, 9; Civil Engineering, 4; Law, 8; Druggists, 7; Ministry, 10; Farming (including fruit-growing), 16; Banking, 6; Merchants, 13; General Business, 4; Manufacturing 11; Mechanics, 8. The majority of these lived in small towns, and so their replies are not representative of purely urban or purely rural life.

In the schedule were specified the several special sciences and the main departments in each. The results are as follows:

BOTANY.—Four were interested in the technical study of botany (morphology, and physiology) for its own sake. Forty-three found pleasure in a knowledge of the natural plant life of the community in which they lived. Five of these were familiar with technical nomenclature; the remainder knew plants only by their popular names. Seventy-eight were interested in cultivated plants, seventy-one having either flower or vegetable gardens of their own. Several of the professional men in towns owned small farms in the vicinity, more as a hobby than for the profit to be derived from them. I have not included farmers among those interested in plant culture, though I believe in many cases more than a professional attention was devoted to it. Though only four were engaged in a purely technical study of botany, probably eighty were interested in particular aspects of scientific botany relative to certain works or amusements pursued by them. As one man said: "I don't want to be a wise guy, but I want to know all there is to know about growing roses".

ZOOLOGY.—Forty-eight were conversant with the elementary morphology and physiology of animals. The majority of these were horsemen, dog-fanciers, chicken-fanciers or sportsmen. While a large per cent. of the total number were fairly well versed in human anatomy and physiology, I think a horseman invariably knew more about a horse, or a chicken-fancier about a chicken, than either did about his own body. Thirty-two, the majority being sportsmen, were interested in wild animal life. These seemed to regard school-knowledge on the subject with calm contempt. "You have to live it," said one. "Look at old D—— who taught science up there (the high school) for three years and never could tell a sawbill from a mallard a gun's length away." Forty-six (including farmers) found both pleasure and profit in the study of domestic animals, horses, dogs, chickens, etc. One peculiar feature about the whole subject of animal zoology was the sharp line of division between those who were interested and those who were not. In botany the interest gradually shaded down, but a man either knew a lot about certain animals or he knew nothing at all about the subject. If we include hygiene and sanitation in the subject of zoology, ninety-four were interested in this aspect. This was the high water mark of interest shown in any topic. Some of the comments are given below: "They are of greatest importance in modern civilisation with its increasingly complex conditions". "If properly taught ninety per cent. of the practice of medicine would be eliminated." "Absolutely necessary in all occupations of life." "One of the two or three useful subjects." "What caused four hundred cases of typhoid in our town——? Pure ignorance." "The viscera of a man are his machinery and it takes a trained engineer to look after them." In nearly every case it was strongly emphasised that the school should teach the pupil about his body and health and how to look after them.

PHYSICS.—In some respects nearly every one, while in others scarcely any one, seemed interested in the study of technical physics. No one, I think, was interested in this subject as a whole, although nearly every one was more or less intensely concerned about certain aspects of it. For that reason it will be best to treat it in sections. Seventy-nine were interested in domestic physical science—heating, ventilation, etc. Here are some of the remarks. "Every house in Canada *must* be heated and *should* be ventilated. Not one in a thousand including furnace 'experts' have more than vague ideas on the subject." "Imperative for the maintenance of our normal physical condition, too often open to attack." "Every householder should know fuel values, light values and power values." "A fool can burn two ton of coal where one would be sufficient." "I sold B—— an electric water-pump, but do you think I could sell his wife an electric iron? Women don't 'get wise' to good things." Twelve were interested in the study of light in as far as it applied to photography, and nineteen musicians knew something about the science of sound. Seventy-eight were interested in some form of mechanics, though in several instances this interest may have been vocational in character. Nearly every man seems to have a natural, almost instinctive liking for machinery of some description. "Emphasis on this division for all common machines and many of the rarer class." "Laws that govern them." "It is well for a man to be able to help himself" (referring to the common use of machinery). "The superior intelligence of the amateur worker will often discover new and improved lines of practice." In respect to this last quotation it is strange how many men are dreaming about or working at inventions of some kind or another. I believe that one out of every four or five has made some attempts in this direction during his lifetime.

GEOLOGY.—No one seemed particularly concerned about the study of geology except two civil engineers. I suspect that I would have received more favourable replies from Northern Ontario. "Nice to know about." "Rather interesting." "Those who want to study mines and minerals should be sent to special schools," were some of the replies.

PHYSICAL GEOGRAPHY.—Here also the replies were indefinite and unsatisfactory. No one seemed deeply concerned about it. It did not touch the daily life of the majority. "Helps one in reading." "Interesting from a conversational point of view." "N.G. So few will take up continent building as a means to make a living, that it is not worth while." "If it can be made *useful* to the majority of those to whom it is taught, then teach it." These replies indicate the attitude of the majority towards the subject.

CHEMISTRY.—Only two were interested in the study of technical chemistry. Many of those interested in practical botany were familiar with a certain amount of agricultural chemistry. "The present smatter of theory is worse than useless. Arrange a system of chemical analysis of soil, so that any one with a secondary school education, or for that matter a public school education, may determine the fertiliser necessary to make a field produce profitably the crop desired." The medical men (including doctors, dentists, and druggists) without exception declared that the chemistry of foods should be taught in outline in the school.

Other remarks on general topics were as follows: "Certainly all give pleasure in the pursuit of them and all are more or less useful since all divisions in science are intimately connected, but, broadly speaking, does not one pick up more knowledge from everyday unavoidable conversations and observations on these subjects than from the schools? Hence I would suggest special stress should be laid on those subjects of which a knowledge is obtainable only by direct studies." "Thorough understanding of underlying laws." "Much of the stuff taught is useless. Whoever wants or would benefit from it will acquire it with no assistance. Perhaps one in a hundred would benefit. Why burden the other ninety-nine?" "A thorough practical scientific training to live in a scientific age." "I read with avidity everything of a scientific nature from 'Jules Verne' up."

From the column of remarks I gather that the average demand is for a general course in science with emphasis upon those features pertaining to personal and domestic well-being.

SYLLABUS

The following syllabus is for a two-year course extending from September to mid-June of each year, comprising three hundred and fifty lessons of thirty minutes each. With the exception of a few pieces of apparatus such as the air-pump, compound microscope, etc., the equipment should be individual in character and of such a simple nature that the student can easily understand and readily manipulate it. The flora used should be based upon a scheme of popular nomenclature and contain both the common wild and cultivated plants. While the course is more or less of a dual nature, aiming to train the pupil in the use of scientific methods of investigation, as well as teaching him the knowledge of science essential to good citizenship, the teacher should not divorce these two purposes. The pupil gains a much clearer conception of scientific knowledge when he employs scientific methods of investigation. And research methods must be associated with those aspects of the material world in relation to which they are specially employed. But while the two purposes unite in most of the actual teaching process to emphasise the fact that each aspect is of equal importance, the two are separately specified.

METHOD-TRAINING

The general conceptions of science specified in the course should be developed as far as possible on a basis of the pupil's out-of-school experience. The problems which the pupil brings to school should form an essential part of each lesson. He should be given opportunity to solve them in the laboratory, or to bring them before the class for discussion, and should be encouraged in every way to originate investigations.

Great care should be exercised by the teacher to insure that all the conclusions arrived at by the pupils are founded on facts. The pupil must be taught that the ultimate criterion in all science study is real experience. He should be taught to appeal to the real evidence of his out-of-school life, as well as the real evidence supplied by the laboratory. He should learn to listen and to read critically, applying this touchstone of scientific truth to the opinions of others.

In making descriptive studies he should follow fixed purposive methods, and should relate the forms of description used with the ends in view. There is no virtue in a mere accumulation of facts, nor any training in a purposeless arrangement of them. Observations should be accurate, adequate to the end in view, and neatly recorded.

In investigating causal relations a list of possible causal factors should be drawn up from the rough observations of the pupil's out-of-school life. The "method of difference" may be formally or informally used to test each factor, but the pupil should be familiarised with the dual form of experiment utilised in this case, and the reasons for its use. The resulting hypothesis should then be substantiated by the "method of agreement". The pupil should be led to see that every time the generalisation arrived at is used in successfully explaining a phenomenon, or producing and controlling it for practical purposes, that this also constitutes a use of the "method of agreement". If mathematical relations are to be established between cause and result the method of concomitant variation should be used, supplemented in every case by the "method of averages". Each of these four methods should be abstracted from the experiments in which they occur and studied as things in themselves. The purpose and mode of procedure in each case should be made clear to the pupil, and he should practise each until he habitually and successfully uses it. When he has obtained proficiency in this respect, short cuts to information along recognised roads will be in order.

The pupil should be taught to distinguish between the absolute judgments that may be pronounced on concrete experiences, and the probable judgments arising from several related experiences.

The truths of science are probable. The student must be able to estimate degrees of probability.

Each generalisation should end where it began, in the everyday life of the student. He should be trained to explain phenomena, always in a scientific way, by getting at the principles involved. He should learn to accomplish practical ends by recognising the applicability of scientific laws to the purpose in view, and then using these laws in concrete way.

SUBJECT-MATTER

SEPTEMBER TO NOVEMBER

Plant Nutrition.

The chemical constituents of plant tissues (water, ash, carbon, and inflammable gas).

The sources of plant food; root and leaf starvation.

Mineral foods; their effects on the growing plant; fertilisers, kinds and values; soil, forms and fertility.

Absorption of mineral foods; solution; root hairs; osmosis; the rise of underground water; capillarity; root depth; mulching; cultivation and drainage.

Origin of soil; various forms; artificial modification.

Animal Nutrition.

Chemical constituents of animal tissue; dependence of animal on vegetable life.

Function of foods to promote growth and repair, circulation, cleansing, and to produce energy; classification of ordinary food-forms; food values; food hygiene.

Vital energy from heat (warm and cold-blooded animals); heat from chemical combination; combustion of carbon and hydro-carbons; tests for carbon dioxide; the slow burning of hydro-carbons in animal organisms (breath test). Constituents of the atmosphere.

Animal Respiration.

Function of respiration; organs of respiration (lungs, gills, etc.); process of and hygiene of respiration.

Plant Respiration.

Night and day forms of products; organs of respiration; process of respiration.

Plant Metabolism.

Energy absorbed in chemical dissociation; plants and sunlight; photosynthesis, organs of.

Animal Metabolism.

The chief organs and their functions.

Plant Assimilation.

Movement of liquids in plants; direction and location of flow; growing parts; root pressure and leaf evaporation; cell tissue; fibro-vascular cells; cell nutrition; cell growth.

Animal Assimilation.

Circulatory system; cell tissue; capillary system; cell nutrition, waste, repair, growth; elimination of waste materials; hygiene.

Study at convenient periods of the wild and domestic mammals, fishes and birds of the locality.

15TH NOVEMBER TO 1ST APRIL

Measurements.

A simple study of the following in relation to out-of-school life.

Units and methods used in measuring.

Space measurements.

Time, solar and standard, how reckoned.

Mass, weight, density, and specific gravity.

Motion, velocity, and acceleration.

Momentum, force, work, and power.

Gravitation.

Centre of gravity; states of equilibrium.

Buoyancy; flotation; sedimentation and sedimentary rock.

Pressure at a depth; springs and water systems; water pressure; air pressure; barometer; pumps, etc.

Tendency toward spherical form.

Formation of mountains; shift of sediment; change in coastline; bending of strata; faulting, etc.

Form and motions of solar system; tides.

Molecular Force.

Molecular theory.

Molecular attraction; adhesion, cohesion, friction, tenacity, hardness, etc.

Molecular motion; diffusion; solution, solvents, saturation, alloys, hard water, salt beds, mineral veins, rock disintegration; conglomerate rock; crystallisation, rock crystals.

Molecular Motion.

Heat.

Temperature and thermometer.

Heat measurement; the calorie; specific heat.

Heat, pressure and expansion; expansion of solids; liquids and the peculiar expansion of water; gases, engines, explosives, etc.

Nebular theory; igneous and metamorphic rock; volcanoes; mineral dykes.

Change of State.

Three states of matter; latent heat.

Fusion and solidification; freezing point; casting, refrigeration, etc.

Vaporisation and liquefaction; boiling point; distillation; evaporation; humidity of the atmosphere, clouds, rain, dew, etc.

Rainfall; geographical conditions.

Study at convenient periods of the mechanical industries and geological features of the locality.

APRIL, MAY, JUNE

Reproduction.

Asexual, mere perpetuation of life; buds, slips, grafts, spores (scale insect), etc.

Sexual, the modification as well as the perpetuation of life; seeds, eggs.

Plant Reproduction (sexual).

Study of seed forms.

Germination; physical conditions, air, heat, moisture; preparation of soil, time of planting, sinking of the water table; rate of germination.

Growth of the young plant.

Organs of sexual reproduction; fertilisation; cross-pollination use, methods of artificial control, artificial and natural modification, heredity.

Animal Reproduction.

Hatching of eggs; artificial hatching; internal incubation in higher animals; heredity; breeding to purpose; care of offspring; growth of young.

Study at convenient periods of the wild flowering plants, grains and cultivated flowers of the locality. Classification of same. Plant collections.

SEPTEMBER TO JANUARY

Nutritive Adaptations of Plants.

Modifications of the root, stem, leaves and leaf arrangement to secure food, moisture, and light.

Plant societies.

Saprophytic and parasitic plants; economic relations of common forms; yeast, moulds, fungi, sour milk, etc.

Disease germs; spread of disease, flies, mosquitoes, water, food contagion, etc.; sanitation.

Nutritive Adaptations of Animals.

Modifications of the teeth of mammals, bills and feet of birds, mouths of insects, etc., in relation to habits of feeding.

Locomotive Adaptations.

Modifications of limbs and feet of mammals, wings and legs of birds, wings and limbs of insects, etc.

Sensory Adaptations.

General use of sense organs.

Structure and relation to environment and habits of life; organs of smell; organs of feeling, skin, antennae, fingers, etc.; organs of hearing, origin and transmission of sound, intensity, pitch; organs of sight, reflection and refraction of light, the eye and camera, microscope, colour.

Study at convenient periods of the forest and fruit trees of the locality. Classification of same.

JANUARY TO APRIL

Transmission of Heat.

Convection; ventilation; heating; winds; ocean currents; climatic modifications due to latter two.

Conduction; good and poor conductors; heat insulation.

Radiation; absorption and radiation, economic relations.

Seasons; geographic lines and their significance; climate.

Heat from combustion; value of fuels.

Electricity.

Electric heating; conductors; insulation; heat and resistance; heat and current strength; lightning.

Batteries and current strength.

Induced currents; voltage; transformer, spark coil, etc.

Mechanics.

Simple resolution of force, sailing-vessels, aeroplanes, turbines, etc.

Sources of energy.

Work equations; mechanical advantage, lever, pulley, inclined plane, screw, wheel and axle.

Pascal's Principle; hydrostatics; Boyle's Law; pneumatics, compressed air and its uses, etc.

Study at convenient periods of the mechanical industries and the minerals of the locality.

APRIL, MAY, JUNE

Reproductive Adaptations.

Storage of food for spring growth; annuals, biennials, perennials.

Storage of food in seeds; number of seeds; dispersion of seeds.

Storage of food in eggs; number of eggs; care and protection of young.

Permanence of the individual in higher forms of life.

Protective Adaptations.

Plant modifications; thorns, hairs, etc.

Artificial protections, sprays, etc.

Animal modifications; coverings, colour, mimetic forms and habits, flight, etc.

Evolution.

Fossil life.

Metamorphosis of the frog, of insects; the meaning; stages of growth in the individual.

Theory of evolution; natural selection; survival of fittest; heredity, cross-breeding and type variations; use and disuse of organs.

Social life and development; social animals.

Study at convenient periods of the insect life of the locality with special reference to economic aspects.

The six appended topics dealing with the study of the natural history of the community have purposely been left rather vague. An average of six lessons each should cover the work, but the time devoted to any particular topic will vary with the locality. Thus in Northern Ontario very little attention should be directed to the study of fruit and grain, a larger portion of the time being given to the study of mineralogy and geology. A large part of this work should be done by means of field excursions. The industrial establishments of the locality should be visited. The aim of these lessons is not so much to impart information or to train in methods, as to deepen interest in and to widen familiarity with the physical surroundings of the pupil's home-life; in short, to create enthusiasm.

CHAPTER X

SUMMARY AND CONCLUSIONS

THE function of the state school is to prepare the student for the future social activity of the citizen. Individual development is a means to this end, not an end in itself. In certain forms of social activity all citizens participate, some to a greater extent than others. Other forms engage the attention of particular groups only. Consequently state education must be partly general and partly special. A man's fundamental education should be developed in proportion as he advances along special lines. Hence, general education cannot stop at the end of the primary school course. It must be continued into the secondary school.

Elementary science is an essential feature of a general course in secondary schools. It is peculiarly suited to the interests of the child. It supplies a particular training in certain methods widely used in everyday life. These may be carried over from the schoolroom to the affairs of ordinary life; directly, if the schoolroom materials in connection with which they were developed are the same as those of the student's home environment; indirectly, if an idea of the value and applicability of the method to out-of-school affairs be given the pupil. The study of elementary science organises an important sphere of human experience, and pre-conditions the wise choice of a vocation. Hence it should form part of the lower school general course. This course should be obligatory on all students, entirely under state control, and unconditioned in any way by the entrance requirements of special educational institutions.

Method is an ordered way of doing anything. A method-habit is a series of reactions toward a definite end, initiated under certain conditions, and tending automatically to complete itself. Scientific research is just refined common-sense. The methods of thought used in the ordinary affairs of life are here used more accurately, more definitely, and in a more developed form. By super-imposing the methods of everyday thinking upon the methods of special research and then cutting the latter to pattern, the method-habits and method-ideals of science, which should form part of a general course subject, may be discovered. In both we find that problems are discovered, and that these are solved by an appeal to real evidence. In the process of solution, a rough working hypothesis is first formed. This is developed by means of just judgments passed upon systematically observed experience. Both the scientist and the man of affairs use the knowledge thus gained in the practical activities of life.

By bringing to school problems arising in connection with his home-life, and having them there solved as part of the regular school-work, the boy gains confidence in his own powers of initiation. He forms the habit of finding problems. Real experience is the only evidence admissible in scientific research. The boy must solve his problems by reference to this evidence. His conclusions must be founded on facts. He must be trained to use this touchstone in testing the opinions expressed by others. The reasoning of science and of ordinary life is probable, not demonstrative. The truths of science are probable, not absolute. The student must recognise this. He must learn to sift and weigh evidence, to form just, absolute judgments on concrete experiences, and to estimate the probability of conclusions founded on these judgments. He must become a careful, accurate workman. In discovering causal relations he must be trained in the drawing up of the "preliminary list", the eliminations of possible factors by the "methods of difference", the substantiation of the "working hypothesis" thus formed by the "method of agreement", and the measurement of causal relations by the method of "concomitant variation". He must learn to explain physical phenomena and to discover means to an end in the practical affairs of life through the application of scientific principles. He must be taught the formal use of these methods in the laboratory, and their informal use in out-of-school life.

At present the student in the Ontario High Schools receives little training in scientific methods. They do not appear on the curriculum as things to be taught. The present course is so extensive that the pupil does not get time to practise them. It is outlined in such detail that the pupil's problems do not receive attention and his method-habits and method-ideals are divorced from the activities of everyday life. The use of the "dictated experiment" does not give the pupil a chance to think out his own solutions. The solutions he obtains do not conform with any of the above-mentioned methods, with the exception of the method of "concomitant variation". Though the student receives plenty of exercise in the explanatory application of principles, he receives no training in using them as means to an end in doing things. Drawing abstract conclusions from single experiments or experiences, he becomes rash instead of cautious, forms absolute where he should make probable judgments and develops an inability to estimate the value of evidence. The course should be cut down and more closely related to the home life of the pupil. Dictated experiments should be abolished and scientific methods should be specified on the curriculum as things to be taught.

The subject-matter should conform to the needs of method-training, the interests of the child, and the requirements of citizenship. All three are represented in the out-of-school experience of the child. But this experience must be organised to form mental interest and gravitation centres. These centres are found in the principles and general conceptions of science. Hence the syllabus should specify the general conceptions to be taught, together with the chief classes of common phenomena in which each is exhibited. The concrete material should be left to the choice of teacher and class, to be derived from the out-of-school experience of the student. These general conceptions are rarely bounded by the confines of any of the special sciences. The course should not be differentiated into special science subjects. The pupil would gain a better conception of the provinces of the special sciences. He would more truly appreciate the meaning of "law" and would get a clearer idea of each particular principle and its range of application. The problem of correlation would disappear, time would be saved, and each topic stressed in proportion to its importance in real life.

The present course exhibits all the evils of premature differentiation. In physical geography unifying centres are found in conceptions of natural contiguity. Phenomena are studied apart from the establishment of explanatory causal principles. The biology course is based on type study, that is, on a system of technical classification rather than a system of causal relations. Neither the student nor the citizen is interested in the study of types or technical classification. True centres of mental organisation are not thus formed. An excess of technical description and technical terminology results. The present course in physics is comparatively free from these defects.

As many of the topics of the present course are of a concrete nature, the syllabus is peculiarly subject to change. An important fact to-day may appear of less importance to-morrow. These changes are disastrous to school organisation. No one class of men, particularly professional educationalists who are somewhat apart from real life, are in a position to represent the life of the average student or average citizen on the syllabus. The university as an organ of research should undertake this work. Pedagogical laboratories should be established. Scientific methods of investigation should be used to determine the actual experiences and needs of the citizens and students throughout the Province. The material thus discovered should be organised by specialists about scientific principles and conceptions. Educationalists should then arrange this in accordance with the mental growth of the child and the requirements of practical teaching. The true function of the Department is executive, not formative.

A course thus widely based upon the student's own experience, organised about true conception and interest centres, in which popular terms and names are substituted for technical terminology and nomenclature, will, in connection with a good training in the use of scientific methods, prepare the student for those activities of real life in which all school-life finds its end and being.

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