

THE ARTICULATION OF CHEMICAL EDUCATION BETWEEN HIGH SCHOOL AND FIRST YEAR UNIVERSITY

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ABSTRACT

A critical examination is made of the division of teaching into stages, compartmentalized and poorly defined pedagogically, such as high school and college. Some of the problems facing modern education are pointed out, and new moulds suggested for academic formation on the high school and college levels, in an attempt to establish objectives other than traditional ones. The idea is likewise suggested that the most important adjustment is not in the correlation of topics or themes within the same discipline for study at different levels, but in the total formation obtained from them that will establish the conditions whereby the individual learns to know and to do, and will set the basis for continued study on a higher level later on.

The wording of the title of this paper, in itself, appears to be an indication of the purpose of analysing correlation of the teaching of chemistry at high school and college levels within the traditional framework of the organization of studies. As a matter of fact, we must admit that the educational structure in most countries and particularly in the USA, France, Spain and others, as well as in Latin America, is based upon a compartmentalization of the studies that divide rigidly the different levels of instruction and attempts to fix distinct and separate goals and contents for each.

Nevertheless—and few writers have dealt with this topic—due consideration must be given to the fact that although these various levels in education have existed since very early times, those which characterize our present systems reflect and are a consequence of a definite social structure and a concept of education derived from this social order.

The actual levels in education, lacking a really valid pedagogical justification and giving the impression that schooling is a discontinuous process are, basically, the manifestation of a bias that would relate education to the traditional social classes (the threefold division of lower, middle and upper) and would maintain, through this selfsame education, a social structure, now being surpassed, which still strongly affects any thought of renewal that might attempt to go beyond the surface of the problem.

LEVELS OF EDUCATION

If we analyse the educational levels which are the subject of this talk—those

corresponding to high school and college—we shall see that studies for the professions are conceived in terms of the division of labour which took shape during the last century, based on the assumption that professional men and women perform those activities that society requires and that, as the antecedent for professional instruction, the high school must aim at providing an all-round culture especially knowledge oriented towards the professional fields that our society has rigidly delimited. Within this picture, it is easy to discover the outlines of the contribution made to the education of the Jesuits by Cardinal Acquaviva, later absorbed by the Enlightenment and which still finds expression in our day in the Napoleonic reform of French education which has set up the main directives for the organization of studies in many countries.

Although this is not the time to analyse the foregoing situation, it does seem convenient to point out, albeit in a rather cursory and perhaps superficial manner, its implications for Latin America especially, and the problem posed by its continuance within academic structures.

Until quite recently, universities were often responsible for the training of professional men and women, frequently unneeded by society, who encountered serious difficulties in finding employment. In technical careers like chemistry, what universities particularly sought was to prepare people skilled in a limited number of technical operations, trained within an encyclopaedic educational process opposed to creative activity and with a narrow and one-sided view of the issues.

The Napoleonic reforms in education and the encyclopaedic concepts from which they originated have been important factors in curriculum reorganization both at the high school and at the college levels. This reorganization has partly meant including the largest possible number of subjects in striving for dispersion rather than concentration and depth in learning and, above all, in taking greater care in the teaching of 'things', as Marañón says, than in giving an adequate and well-integrated education.

The traditional reforms in studies—principally in developing countries—have involved complementing existing curricula with additional subjects corresponding to new fields of knowledge or to the broadening of the traditional fields without taking into account either the evolution in the concept of teaching or the experience that has been acquired through the years in its application. This situation is not much different from that which prevails in fully developed countries. In fact, here we may discern two independent situations between which there is no clear interaction. On the one hand, a deep preoccupation with education that has resulted in changes applied to the oldest concepts in the educational process: for example, the idea that it is necessary to forget the premise that teaching is centred in the person of the teacher and that the broader his knowledge and the greater his capacity for expressing it, the greater, likewise, the efficiency of the educational process, has been replaced by that which maintains that it is more important to take into account the psychology of learning.

THE TEACHER'S ATTITUDE

On the other hand, there has been a succession of three stages in the attitude of the teacher towards his students: authoritarianism which has been an

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important cause for the rebelliousness of youth; complacency which has been reflected in the grave irresponsibility of so many generations of students; and finally encouragement, the only one accepted at present as tending towards a true creative formation.

From a more technical point of view, the discussion has revolved not around modifications in the structure of studies—even though this matter has attracted the serious attention of educators whose works have received scant consideration—but rather around the ideal content of a learning process the general structure of which apparently must not be touched, with a partial and unilateral analysis which is the product of isolated studies in each subject, with consequent loss of focus for the whole.

In this way and in our field of chemistry, different currents have arisen which follow courses so fickle that we might almost think we are dealing with fashions. Some have at certain times pretended to base teaching in chemistry upon descriptive instruction with various shadings as regards the relation of practice to theory, and at others upon general principles alone, when physical chemistry has acquired a more prominent place in the overall picture.

Each of these currents has been studied by people of the highest level of competence and the result has been the production of papers as well as books that endeavour to serve as a basis for education and are commendable insofar as their contents have been the work of qualified scientists, but that prove inapplicable because they involve one-sided and incomplete viewpoints.

I do not know if I am wrong in thinking that the agenda for this gathering is still swayed by these ideas and that, once again—and this in itself may have its usefulness—we are attempting to re-examine a field that has been thrashed over for many years by very capable and scholarly research.

LATIN AMERICAN PROBLEMS

It would seem, however, that we should go farther and look into the problem at greater depth and from new viewpoints, in the measure of the demands of our society and of our own development, attempting to determine what education must be in our milieu and keeping the idea in mind that the great challenge to our universities at this moment, particularly in Latin America, is the preparation of our countries for entry into a science oriented society.

I will make a brief digression here. When we think of the development of our peoples, we do so almost always in the supposition that we must follow paths that other countries have trod when they have come up against problems such as those with which we are now faced, forgetting the lessons of history and showing a lack of imagination that cannot but be regrettable. As a matter of fact, I believe that no conscious person who attempts to analyse these situations in the full awareness of the consequences that have been brought about by the growth of civilization in highly developed countries considers that we should attain the same objectives. It is essential, rather, to fix our own goals, different in the measure that our life-styles are different, and taking into account that we have been fortunate enough to see in which direction a similar evolution might lead us.

This brings us to the conclusion that the channels of development must also be diverse. So as not to enlarge unnecessarily upon the theme and analysing

only the educational process before us, we may see clearly that our actual situation differs radically from that which existed in other countries when they went through our present stage of development.

In effect, when the modern evolution of higher education started in countries now highly developed, the problem of elementary education had been solved and the rate of population growth at the high school and college levels was always low, less than five per cent save for a few exceptional and transitory cases. Our Latin American countries find themselves in the difficult position of not having solved the problem of elementary education, either qualitatively or quantitatively, yet with a population growth rate on the high school and college levels closely approximating fifteen per cent or sometimes even higher.

Besides, all countries are faced with the problem of mass education, a problem that has been systematically misunderstood and for which only highly inadequate solutions have been proposed. It is presented as a situation consisting of a sudden increase in the number of those demanding education that can only be met by multiplying existing systems and, in consequence, material and human elements.

It has been said, for example, that what is most difficult is to find a sufficient number of instructors, disregarding the fact that the force from which these may be recruited has increased at least as rapidly as that of the students who require education.

LIMITING THE FIELD

The real question demanding an answer in education for the masses is not the one stated above, but the incontestable one that the multiplication of knowledge has proceeded with such a speed that it is not only impossible, but even puerile, to pretend to go ahead with ideas that are still derived from the principles of encyclopaedic instruction.

The great problem consists of realizing that it is impracticable to provide even a minimum of the existing information; that the matter is not solved by giving more as the fund of knowledge increases, but rather by establishing schools in which the major stress will not be on informing but on forming; in determining the absolute minimum which allows an individual to unfold and move adequately in a changing society; in meeting problems that future years will present and which we may even anticipate in part; in not narrowing the outlook of those we are educating but, on the contrary, in giving them a true vision of our evolution; in gaining their proper place in the surroundings in which they will seek fulfilment; in qualifying them for adaptation to conditions which tend to change ever more rapidly; and in making them realize that science, technology, and, in general, all situations in life are undergoing constant modification, although there are values that continue to have the same force they had hundreds of years ago and that form the basis for our concept of life.

If at some time, and even today in certain spheres of activity, the work of the specialist in a very limited field of science or technology is not only feasible but necessary, it must also be admitted that people are needed who do not act in a narrow-minded way or find themselves constrained by specialization when they take part in the solution of great problems.

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I judge, therefore, that we must start from a different premise in dealing with the topic defined by the title of this talk and forget the many prejudices to which we have been subject in the course of our academic formation, fully accepting that education is a continuing process that begins in childhood and should end only with life itself, that we cannot speak with seriousness about these matters without establishing as clearly as it may be possible for what we are going to educate, and for what we are going to teach, and how we must go about it in view of the different age levels that we have to deal with.

We cannot analyse all the stages in education, even though this might seem desirable and even necessary in order to avoid the accusation of superficiality. We shall limit ourselves to the discussion of only two types of education: that which is provided to persons whom we are endowing with high qualifications to carry out a life activity (college level), a profession adjusted to known moulds, that must, however, be fully analysed so as to enlarge its scope and adapt it to previously non-existent needs; and that, less advanced than the first (high school) which is given to students who have had, in general, nine or ten years of schooling, whose ages vary roughly between 13 or 14 and 16 or 18 years, and who, in consequence, must receive an education concomitant with their age and with the role that individuals at that stage of maturity must play within our society.

TEENAGERS AND CHEMISTRY

If we stop to think about this, we cannot fail to consider many other factors in addition to those that generally serve to form our opinion: in other words, what is to be taught in high school chemistry so that students, on moving up into college, may know the basic principles of this discipline, falls into the background in order to give way to the consideration of a process which is almost inverse to the above: what global preparation or training does an eighteen year old require that will qualify him to be useful to society on the one hand, and on the other, to move ahead into fields of professional study without losing sight in either case of his adequate placement within the social order.

We cannot overlook the fact that the foregoing also has practical implications that require immediate solutions. There are still important currents of opinion that maintain that education must only be given to an élite or select few. They state that the number of those who study is always in inverse proportion to the quality of instruction, and that there are biological and other factors that disqualify many from receiving education, as well as other fallacies that are evidently meant to bolster the status quo of privilege.

No one really immersed in educational problems can imagine even for a moment that education is going to continue to be limited to small sectors of the population. It is necessary to consider that if such instruction is to be carried out in a realistic sense, the demands on resources will be ever greater and the amount of financing will, in many cases, exceed possibilities at a given historical moment in many countries.

In the face of this, one must admit that educational systems have to be simplified and made more efficient; that it will not be possible to carry everyone through a time- and money-consuming process which results in a type of education often only minimally useful in view of what a given person is called

upon to perform; that we must not attempt to train for all the different levels and functions which are required in a given field following a single, invariable system; that we must keep in mind that not everyone reaches the terminus of established studies and, consequently, that it is necessary to find other alternatives, as for example setting both vertical and horizontal objectives for each school term in high school and college. The result of such a process would be that, at any stage in their education, those who cannot go ahead with their studies will have training that will make them useful to society and permit them to be self-dependent.

QUALIFICATION AND TRAINING

No one can deny that schooling has been and is still a great experience for humanity; however, we cannot conclude that it is the only way to train individuals. It goes without question that experience acquired in life prepares many for carrying out certain tasks. From this stems the expediency of considering, at this very moment—although such a course may still be unacceptable to many—the need to have institutions of learning perform two clearly distinct and equally important functions: the educational one through a variety of systems, and the one which consists of acting as an organ for evaluating, with a diversity of intent, the qualifications of individuals, both those obtained through formal education and those acquired from practical or working experience or any other of the means whereby human beings learn to do things. We shall finally reach a point where educational needs can only be met with the collaboration of all: everyone will, at one and the same time, have to teach something to, and learn something from, others.

And this is not easy. We must be fully conscious that prudence is required to prevent the experiment from leading to the destruction, the world over, of traditional educational systems and to a cultural regression of momentous and fatal consequences. Besides, it is also difficult because any educational system yet devised has in one way or another been a reproduction of earlier ones, and all have intended to perpetuate the existing order of social relationship and especially the inequality of social classes. Breaking with the above evidently implies new mental attitudes that will lead to very important structural changes which, curiously enough, students have perceived intuitively before educators themselves. Suffice it to make an analysis of the ultimate consequences of what they, the students, term 'revolutionary reform', explained as the action by which the educational institutions would be transformed into instruments of social restructuration.

On reaching this point, we must ask ourselves the following question: What preparation is required of those who intend to enter high school?

Some countries, and this remark constitutes a brief parenthesis, are already looking for new systems that will provide different alternatives as pre-requisites for entrance to this level of instruction. These requirements vary in keeping with certain factors, such as age and previous formal schooling and are demanded only of those who wish to enter an advanced education cycle after completing the previous one.

Older candidates who have not followed a regular schooling are asked to comply with other requirements in view of the fact that they may have been

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formed under different, non-academic conditions and that their motivations are different.

As this exposition is based upon premises that imply a consideration of orthodox school organization, it is deemed advisable to go more deeply into the problem.

TEACHING NATURAL SCIENCES

It is illogical and incongruous to locate the natural sciences in a relatively unimportant and marginal position in the education that is given to children from kindergarten to the first year of high school. It is evident that such methodology and curriculum organization not only contribute minimally to a knowledge of science, but are the main factors in an intellectual deformation of children which precludes favourable attitudes that might guide them towards a scientific vocation.

Of course, this must not be taken to mean that we are proposing that children should be given formal science courses, and especially the compartmentalized ones that we know, but it is also irrational to deny that a contribution can be made from an early age towards the development of skills and aptitudes that may foster their vocation, through simple experiments and individual assignments that may permit an easier future assimilation of scientific training. I do not believe that any educator working at the high school level is particularly concerned about his students' having acquired bits of information in this or that field of science.

On the other hand, there is not the slightest doubt that high school and college teachers would be in a better position to educate students if these had already been trained in a series of procedures that can be learned at a fairly young age: observing, measuring, analysing, experimenting, reasoning, etc., and who likewise knew how to express the results of these operations. A disproportionate measure of a high school and college teacher's time is expended in the effort to rectify deficiencies and malformations caused by previous instruction.

We can now state that no teaching curriculum, course or syllabus can be planned or established without first fixing the pre-requisites or antecedents demanded for its application; without describing it adequately and clearly determining its objectives. One of our common failings is to programme courses only partially and imperfectly, and to teach them in isolation, without setting up horizontal and vertical relationships with other components of the educational process.

THE ART OF EDUCATION

It is not out of place to mention that if we analyse the organization of studies in various successful academic institutions throughout the world, it becomes evident that the curricula and the content of a syllabus vary widely from one place to another. This brings us to the conclusion that there is no one rule or magic pathway to obtain optimum results in the teaching of a specific discipline. Education is an art, and, as such, may render valuable accomplishments through widely different means. And not only this. It is evident that a good plan carried

out with incompetent teachers produces poor results, and vice-versa. In a similar way we must insist that experiences cannot be transferred without change from one given set of external conditions to another. What may prove profitable in an institution with a select student body, numerically small and economically well-off, will be impracticable where conditions are different.

The function of a university specialized in the preparation of élites differs, even in purely technical aspects, from what can and must be the practice in an open university—a national university for example—within which simultaneous and divergent objectives must be attained for student populations that, because of their heterogeneity, reflect the social sectors of the nation itself.

On the basis of the remarks previously made, we shall attempt to set down general criteria in connection with what we conceive to be adequate teaching for high school (we cannot deal exclusively with chemistry), and make some suggestions concerning the college level. The proper adjustment between both levels is, in our opinion, the outcome of the application of these criteria and it would be a harmful mistake to try to establish other types of adjustment in the matter of themes or topics and in that which relates to the detailed course content on both levels.

(1) The organization and structure of teaching in high school should take into consideration the definition of instructional objectives at the previous levels of schooling, as well as at those which correspond to the level in question.

(2) Teaching should be understood as a total, all-inclusive process within which each subject matter fulfils a specific function and, in balance with the others, contributes to achieving the prescribed educational objectives. No subject can be studied or be programmed independently.

(3) Starting with high school, it is advisable to set terminal objectives for each school cycle, as well as horizontal ones for each portion of the cycle so that the individual may be in a condition to be self-dependent at any stage of his studies in the event that he is unable to finish the cycle.

To accomplish this it is necessary to consider high school as a stage of learning that combines classroom study with laboratory work (not in excess of 20 to 24 hours per week), that provides a basic cultural background in the sciences and the humanities and includes training in shops and labour centres that may enable a person to acquire technical and professional skills. At this level—and this is most important in the case of chemistry—not only theory but also practice must be taught; not only the what but also the how; in sum, the aggregate of knowledge that will enable students to be incorporated into productive activities while they study or to find adequate employment if they give up their schooling.

(4) The high school cycle must be permanently interrelated with colleges or departments (Colleges of Liberal Arts, Schools of Engineering, Dentistry, etc.), as well as with research institutes, and should be in process of constant renewal. The changes that it systematically undergoes should adjust themselves to a definite plan conceived by officials of more advanced educational and research institutions.

(5) In conclusion, as has already been pointed out, the high school should provide a common cultural background in the sciences and in the humanities that will allow students to understand and go more deeply into the problems of nature and society, and should likewise enable them to enter any of the existing

professional careers or any innovative courses on the college level that would make possible interdisciplinary study and research of variable duration. This training would qualify persons who could address themselves to the solution of many problems that present-day graduates cannot approach and that demand not only the intimate collaboration of now unconnected professional groups, but also the understanding, on the part of those undertaking such a study, of the methods used by the humanities and of those used in the sciences.

If the college curriculum is thus interpreted, the problem of just what to teach, in chemistry for example, is to a certain extent of secondary importance.

In the above we have often repeated the statement that the fundamental problem of teaching resides not exclusively in what is taught; besides, there is already a relevant consensus among a majority of educators as to the desirable content of the programmes for individual subjects.

THE GOAL OF TEACHING

The real problem lies in the attitude and the goal to be achieved through teaching. For example, if one speaks of Le Chatelier's principle and explains it solely by means of the exemplification of the displacement of equilibrium in some reactions, only a very poor and limited idea is given. If, on the other hand, the principle is explained in its entirety as the expression of a great evolutionary phenomenon of adaptation to environmental conditions, indicating the sense in which chemical processes take place under varying circumstances, such an explanation will influence the educational process in a totally different way.

If, instead of teaching processes described in books requiring, in general, raw materials that are not to be found in the pupil's own country, the student is, through practical examples, made to understand some processes important for the industrial development of his country, and if, besides, his interest is increased by studying as a whole the industrial, economic and social problem that requires the practical application of such a process, he will see the explanation in a different light and will feel that many of the anxieties that have concerned student thinking in our own day can be alleviated.

It is important to point out here that the entire educational process must be carried out with the aid of what we have called 'package instruction', constituting a collection of all the necessary elements that will permit the student to know just what he must study, learn and practice, particularly the literature that he must consult, but not in the usual form of a list of books whose length exceeds by far the pupil's capacity for assimilation, but pinpointing the chapters and even the pages that he must read.

If this is done and the student is informed of the level he must reach in the course he is taking; if he is told where to find external aids for a better comprehension of what is presented in the class period; if this class period is used not only to give information but to acquaint the pupil with a method and a perception of how a problem must be approached, of the roads for reaching a solution and how such a solution is finally attained; if all of the above is complemented by evaluative systems distinct from the traditional ones and to which the student can return in order to judge himself; if he is taught self-correction following this judgement—a very important thing indeed—and if the evaluation that the institution itself carries out is based upon methods that

make use of various objective elements, then the educational system will acquire a different sense from that which it has today.

All this leads us to surprisingly simple ideas that may possibly be summarized as follows.

It would appear that the truly important considerations for those who study high school are: that they learn how to acquire knowledge and cultivate a liking for study; that they master their own language; in other words, that they learn to express themselves properly in speech and writing; that they learn to read—with all that this implies—and understand what they read; and that, in addition to their native tongue, they learn to master a second language, mathematics, indispensable not only because it acquaints them with a different system of communication, but also because it exercises the faculty of abstract and logical thought and provides a new approach to knowledge.

ALL-ROUND DEVELOPMENT

In addition to the above, the student must be made to understand the general and individual development of man in both humanistic and scientific aspects. This cannot be accomplished by steeping the pupil in rote learning, but by introducing him to the historicopolitical method and to the scientific method. In other words, history must be taught not through events and dates, but through the reading and analysis of consecrated texts on the subject so that the currents which have brought humanity to its present degree of evolution may be understood and its future anticipated and apprehended; science—chemistry in our case—must be presented not as an isolated subject but as a part of the natural sciences, and not on the basis of teaching ‘things’ and facts, but by trying to establish a consciousness of, or understanding for, the scientific method, making the student comprehend how science is contrived so that he may develop creative thinking.

If these basic elements are complemented by the experience of all those eminent figures who have contributed each in his sphere towards establishing the validity of what is worth while in our culture; if students are exposed to writers of the highest rank in all fields, we believe that they will receive a preparation allowing those who assimilate it to undertake successfully the study of any of the traditional professions that still prevail in our milieu, to initiate, on a professional level, studies different from those we now have inasmuch as present ones satisfy only part of the totality of society’s needs. This kind of preparation will produce people capable of carrying out these functions, who will have a different attitude towards studies, a different way of looking upon their mission in life and their duty toward society, and, in general, an ability to visualize man’s individual and collective problems from a point of view that has heretofore been alien, but which is much more realistic and efficacious.

All the above strengthens the idea that the correlation of chemistry between high school and college that we are attempting to study by means of the theme assigned to me for this talk, is to a certain extent but a partial concern if we think merely about programmes that simply mention topics and include only their logical ordering and perhaps, in addition, indicate the levels of knowledge required in these two cycles (high school and college).

If the problem is seen as we have attempted to set it forth, the evident

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conclusion is that the fundamental correlation in any type of teaching, as for example that of chemistry, between high school and college levels, consists of fixing a well-defined total objective in high school, through which is sought a more profound and classical formation which will give a fuller vision of the problems of man and his world in their true dimensions and will produce a degree of maturity in high school graduates that may permit them to perform college studies on the basis of the various aspects of their training, that is, that they have learned to read; that they know how to approach books with an appreciation for them; that they understand both the historical and scientific methods; that they know how to use their talents and capacities without, on the other hand, having to possess certain definite pre-requisites, as for example, the information learned by rote which at any moment can be consulted in a book.