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SCOPE AND PLACE OF SCIENCE AND TECHNOLOGY IN GENERAL EDUCATION

K.2.1.

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S U M M A R Y

Two revolutions - the ending of the rule of one people on another and the integration of scientific research into economy in a unprecedent way - have profoundly changed the political panorama of our world. Nevertheless, the general aims of education have not altered with so drastic a transformation. We still think of education as the moral and intellectual development of boys and girls, the making of men, always with the ultimate goal of social happiness and fulfilment.

But if the essential purposes of education, based on the determination of public policy by public opinion and on the equality of all citizens before the law, continue to be the same, its content, both formal and informal, has perforce to be changed to meet the new situation. Science and technology must have a larger share in the educational process, so that every citizen may be able to adequately face the matters concerned with scientific and technological progress. The school, which is the central educative agency in society, has to give a scientific attitude to the people rather than an amount of facts or inert ideas. This holds true not only for the great and progressive countries but also, and especially, for the new and underdeveloped nations, which must progress at a very fast pace in order to attain almost at once the degree of development and sovereignity that in the past used to be reached in centuries.

No one can be literate, in the modern sense, until he has gained understanding and appreciation of science and its works. The teaching of science and technology at the elementary and secondary levels should prepare the citizens for that kind of understanding and appreciation, but should also afford the basis on which the best minds could build up their higher education. Science - taught as knowledge in the making and not as mere discipline - must become the core of the modern curriculum, but not to the exclusion or detriment of other subject matters and especially the humanities.

Attention should be drawn to the error of considering universal primary education as universal literacy (in the older sense) and of allowing the transformation of the elementary school in a selective phase of the educational process, thus failing to impart real and necessary knowledge (including scientific and technologic) to the whole population.

It is worth emphasizing the necessity of early detection of the children with really superior abilities in order for them to complete in lesser time their scientific formation.

The goals of science teaching at the elementary level should be attained as part of the whole school experience by the child. Only at the secondary level

can science be partitioned in its several branches, but always in such way as to give the student a clear idea of the existence of "growing edges" between them, i. e., of the fact that what really matters, in science teaching, is the formation of a scientific attitude and not naming or describing things.

The A. stresses the importance of linking the teaching of science to the necessities of the student and his environment. The scientific and technological subjects should be presented as problems to be solved. At the secondary level the historical approach is useful, not as the sole method of teaching but as a means of integrating science into the social background of the time.

The A. also stresses the misconception that consists of limiting the teaching of science to laboratory work. The exploration of nature and the careful observation of natural facts, followed when necessary by laboratory experiments, made whenever possible with equipment in the construction of which the student has participated actively, is a sound and inexpensive way of approaching science. In this connection the A. tries to explain and adapt to our changing times Alain's idea of making "resolutely retardatory" our pedagogical efforts.

Science and technology teaching, at all levels, must prepare for life and from its beginning should focus the interest of productive work and the respect for manual labour. One cannot forget that modern nations need a strong manpower of intermediate nature, which is supplied by people having only elementary or secondary education.

In a modern society all means of informal teaching of science (popularization, extension agents, extracurricular courses, science clubs and fairs, national science contests) should be developed.

The A. criticizes the tendency, so common in the underdeveloped countries, "to spend lavishly" at the university level in detriment of the primary and secondary ones, and to promote to university rank many functions that can well be attended to by people with a good primary or secondary education, immediately on leaving school or after some in service or vocational training.

At the university level, science, besides being intensely pursued in the scientific schools, should be infused in the curriculum of those schools which prepare people for the humanistic, philosophical and political careers. Although pure science is always necessary, a very important place, and even some priority, must be assigned to applied science, in the underdeveloped nations.

The emphasis given to science education and its practical results, including the preparation of manpower, and to the regulation by the state of the flow of the streams that go to the different specializations should not be sneered at as a Sovietic tendency. These needs are urgently felt also in the democracies. In the underdeveloped countries, if they are expected to rapidly progress and attain their ideal of full economic and political liberation, education in general and science teaching in particular must have the force and consistency of a national commitment, not to be confounded with any loose educational system that may allow for a wastage of human resourses.

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I - The new revolutions.

1. We are living on the crest of two of the greatest revolutions humanity has ever faced. The first of these revolutions which were aptly recognized by David Ben Gurion (1), is the ending of the rule of one people on another and the second is the scientific revolution. The latter is not to be confused with the industrial revolution that began to take place in the eighteenth century and was due rather to the inventive and mechanical genius and ambition of certain isolated people than to the influence of organized scientific research on the affairs of the society.

(a) The political revolution implies the necessity of rapid growth for the new and underdeveloped countries, and this growth, which for many a nation means a transition that in the evolution of man took as a rule thousands of years, has to be made, according to Abba Eban (2), almost at once. Only with the help of science and sound technology can this ideal of national liberation be achieved.

(b) When we speak of the scientific revolution we are not focussing the mere pursuit of the applications of science and technology by society, but the acknowledgement of the economic and practical relevance of scientific research and its integration into the economy at an unprecendent way, as emphasised by Shils (3).

2. Today the destiny of any community is definitely tied to the quality and quantity to the science and technology it cultivates. Science is being heeded not only by its value as a means of obtaining pure knowledge but also as a reservoir on which the nations can draw the necessary elements of their progress and from which technology outgrows. Pure science is no longer envisaged as a hobby of some persons who like do dwell in ivory towers. According to Katzir (4) it is now plainly recognized that, apart from their impact on the philosophy of the time, by destroying many mystical ideas and generating new views of life and nature, science and technology shape human life and mold economic structure. Great technological advances, he says, can now be correlated to some fundamental changes in the conceptual approach of modern science, i.e., they do not derive from "organized common sense", as it was usual to think, but from basic scientific concepts which are highly abstract symbolic forms.

3. What we have just said goes to show the essential role of science as an element of national sovereignity, a theme brought to light many years ago by the late Lord Rutherford (5). This function of science in the modern world throws a heavy burden and responsibility on education and, especially, on science education in today's society.

II - The Aims of Education

4. Of course, the general aims of education have not altered with so drastic a transformation in the political panorama of the world. We still think of

education as the moral and intellectual development of boys and girls, the immediate goals of which are skill, information and formation, the ultimate goals being the building up of a happy, progressive and fulfilled society. These immediate goals might be summed up as the making of men, and endeavour naturally associated with the idea of change, not of change as an end in itself, but rather as a means to an end, what amounts to say that it must be directed toward that purpose of social happiness and fulfillment through the development and cultivation of the human abilities. In the modern society, as in the old one, these changes continue to be from ignorance to knowledge, from capacities to abilities and from instincts to ideals, as pointed out by E. J. Power (6).

III - The content of education

5. If the fundamental aims of education in a free society, based on the determination of public policy by public opinion and on the equality of all citizens before the law, are still the same, its content, both formal and informal, has perforce to be changed to meet the new situations. Science and technology must have a much larger share in the educational process, at all levels, as the world changes at an unprecedent pace.

(a) Determination of public policy by public opinion and equality of all citizens before the law imply that all citizens should possess the same basic ability to understand the issues confronting society in order for them to be able to participate effectively in the process of political choice which lies at the bottom of the democratic way of life. If intended to secure progress by individuals and Government, in a democratic society, this process is only possible through a constant and unbound search for truth and the freedom to be guided by it. For reaching such scope, nothing better than a scientific attitude.

(b) The emphasis that modern pragmatism has given to the theory of whole-man education also comes to stress the need for a larger amount of scientific knowledge in general education, for science is today probing much more deeply than at any other time the mechanisms of the life of body and mind, as well as of their relationships, and what could formerly be interpreted in vague, academic and highly speculative terms is being now scientifically understood. Since every member of any community is a potential educator, we come to the conclusion that his scientific background must be much larger than it was hoped for in the past. This observation is still more valid when we think of the professional educators and the school which we recognize as the central educative agency in society.

(c) In the past it was possible for a rather underdeveloped community to live a peaceful and balanced life based on the dominance of a cultivated, and sometimes highly cultivated, class that ruled over the great illiterate majority which was not attained by the impact of the ideas and progresses going on in distant countries. But today, when the "unit of survival" is becoming so increasingly larger as to be confounded with humanity as a whole, that situation has practically disappeared from the earth's face. This shows how world-wide and urgent is the problem of adequately establishing the right scope and place of science in education.

(d) All that we have said points to the necessity of good science teaching for every citizen, irrespective of the career contemplated by him. No one can be literate in the modern sense until he has gained unerstanding and appreciation of science and its works. No one is able to make judicious public decisions in a democracy until he has acquired the ability to see the problems in the light of the scientific considerations bearing upon them.

6. We should not, however, lose sight of the fact that the school must also provide opportunities for making the best possible use of available resources concerning science manpower. This means, as the members of the Science Manpower Project instituted at Teachers College, Columbia University (7), put it, 1) provision of challenging programs for the more able students, so that they may progress at a rate consonant with their abilities, 2) provision of appropriate programs for young people of somewhat lesser ability, from whose ranks technical assistants and aides of various types must be drawn, and 3) the fostering of scientific

interests and the provision of appropriate guidance for students who are contemplating careers in science or technology.

7. Fischer (8) has aptly defined the two kinds of fundamental interests in science education by saying that "the public school must educate both producers and consumers of scientific services".

IV - The core of the curriculum

8. Bentley Glass (9) states that science must become the core of the modern curriculum, but at the same time advises that this does not imply emphasizing scientific studies to the exclusion or detriment of others. "The core of the apple is certainly not the whole apple. Yet it gives the rest of the apple meaning, - here lie the seeds without which, in a state of nature, there would be no more apple trees and no more apples." From this "core concept" he tries to show how to infuse the curriculum with science and accordingly change the teaching of the other disciplines. We refer the reader to the original paper by the well known geneticist.

9. It is time to clarify the meaning of the word science used throughout this text. If we were to follow the late Charles Singer (10) in his opposition of science to discipline, meaning by the former knowledge in the making, a process, "the growing edge between the known and the unknown, between the desert and the sown", we would have to distinguish between the separate places of science and scientific disciplines throughout the educational process, since both of them are necessary - the study, or else, the practice of science with a view to forming the scientific attitudes, and study of the disciplines in order to give the indispensable degree of information. From a practical point of view it seems, however, unnecessary to make such otherwise sound distintion, since the reader may at any moment see by himself when we are referring or emphasizing science as a process and science as a discipline.

V - Universal literacy and education

10. Lewis (11) rightly denounces the tendency which is prevalent in the new and underdeveloped nations to "spend lavishly" at both ends of the educational scale, while neglecting secondary education. He blames the fetish of universal literacy and universal primary education, and this is undoubtly correct if we think of universal literacy and education as the mere transformation of illiterate men in literate ones and not as process of formation that gives to every citizen a sound attitude and the ability to integrate adequately into his milieu. What we see, at least in Brazil, according to Anisio Teixeira (12), is the failure of education at this level. We would not dare say that we spend as lavishly at the primary level as we do at the university level. But we spend in a very inadequate way since we are not able to give a complete and formative education to most of those entering primary school; much on the contrary, this kind of school is highly selective and, unfortunately, we are not even in a position to say that it selects the brighter or intellectually more gifted children, but recognize that it picks up the economically stronger or those who are from the beginning eagerly directed toward the intellectual careers due to the superior status of the white collar job and the feeling that to work with one's hand is below the dignity of a truly respectable man.

(a) In such a school, science, considered from a dynamic point of view and not as mere information or the teaching of inert ideas, in the sense given by Whitehead (13) to that expression, has been practically absent and, if present, it would really matter very little, for the knowledge imparted by it would only serve the minority that happens to come out of this highly selective machinery, a minority which, after all, would have new opportunities to learn science at the later steps of the educational ladder. But we would rather think of elementary education as universal as well as formative. And we feel that, however large the amount of money spent at this kind of education, it could hardly be considered excessive even in a poor country.

11. Since in the underdeveloped nations, where there is an urgent need of skilled manpower of all levels, the number is very large of children whose formal education does not go farther than elementary level , it follows

easily that we should pay much attention to the sound scientific formation in elementary school along with a good education for community life. On the other hand, as in the underdeveloped and new countries the elementary teaching is sometimes insufficient and the local conditions do not afford real opportunities for every child to go through school or remain there for the time necessary to his formation, one must always be aware of the necessity of developing all possible means of extracurricular teaching of science and technology.

VI - Science teaching at the elementary school

12. The goals of science teaching at the elementary level were clearly enunciated by Burnett (14) and consist of developing scientific-mindedness and critical abilities, helping children to interpret their environment and contributing to increased health and safety, to a basis of reality for other schoolwork and to effective social learnings.

(a) These goals should be attained as part of the whole school experience by the child, what amounts to say that children should not be taught any special and isolated discipline called "science" or "sciences". We must remember that every child is something of a scientist in his curiosity about his environment and himself, in his natural drive to discover how things are, what they are made of and how their parts are assembled.

13. It would be preposterous to think that the school should eschew giving the pupils a certain amount of basic information, but we need to be careful not to make of the transmission of information the sole aim of education. Whitehead's words are still timely: "The result of teaching small parts of a large number of subjects is the passive reception of disconnected ideas, not illumined with any spark of vitality". Those teachers who only consider the informative purpose are very often led astray by the misconception that the more information they transmit, the better. Knowledge, to be fruitful, must be conquered rather than received. It is more meaningful for the child to learn to think and face critically the facts of life than to know all the ready made answers the books present to the problems they raise. The jug and mug techique, so well stigmatized by Newsom (15), is always bad in science teaching, and much more so at the elementary level, when the risk is great of stifling the natural curiosity of the child in the "pedagogical tunnel", to use Rous's wording (16).

(a) A rural elementary school might, for instance, give a sound basis for making a better farmer out of the common pupil coming from the farms. In the same way should act the school that teaches those coming from industrial workers' homes. Such an orientation would of course reinforce the stabilizing function of the school but would not necessarily mean the transformation of the school into a centre of premature specialization that might hinder the development of the individuals with other tendencies or ideals. It is worth stressing that the elements of the school environment should serve as the principal motivation for the teaching of science at the elementary level in such a way that the child may find in it a means of integration and not of unrootment.

14. We can no longer accept as science learning the mere effort of identifying or naming things, or describing them. Much on the contrary, we like to emphasise the effort to solve problems about things. This is the way that leads children to a critical and scientific attitude which applies not only to problems of science but also to any other question facing them. This is the way that gives children the ability to properly direct their curiosity, to be openminded and critical (not jumping to conclusions), to seek reliable sources of evidence, to avoid superstition, to be careful and accurate in their observations.

(a) Starting whenever possible from the facts and necessities of the environment and of the pupil, the teacher will find many opportunities to lead children into the ways of science. They will often meet the opportunity to try and experiment in the laboratory, however small or primitive may it be, but one must always remember that nature is itself a huge and not expensive laboratory where many experiments can be tried and made, besides offering children, at every moment, good stimulus for careful observation. At this level of science learning

it seems very important to us the process of observation which the teacher may enrich with the leaven of critical analysis.

(b) A word of caution should here be advanced. We speak against fencing children prematurely in a laboratory where they do not see things as they really are but occupy themselves with models or theoretical conditions. At this stage of learning every laboratory experiment must have its raison d'être in the facts of daily life or in the problems of the community. It is meaningless to expect from children science for science'sake;

(c) What we have said enhances the fundamental role of the teacher if we aim at the formation of people with a scientific attitude. The preparation of such teachers is a formidable task to which the Government, especially when imbued with the idea of universal literacy instead of universal basic knowledge, do not pay much attention in the underdeveloped countries. The teacher must be a scientific-minded person himself, able to face the ever changing needs of the community and the pupils and to meet every new class and every new pupil as something really new and different, which must be separately considered and, what is very important indeed, cherished. To be efficient, the teacher has to make an appraisal of the needs which can effectively motivate their pupils, and these needs are not to be gathered as mere averages in the textbooks - a point aptly emphasised by O. Frota Pessoa (17).

15. Much more difficult than having scientific-minded teachers is to have cautious ones, not eager for stressing the interest of everything that is novel and spectacular in detriment of what is scientifically fundamental. In this sense the teaching of science must be "résolument retardataire" (decidedly retardatory) according to Alain (18). This is specially true regarding the underdeveloped nations, where there are still many things to explore and study in the immediate environment and by rather crude means. Devastating to the formation of the scientific mind of the child is the emphasis so frequently laid on the latest technological advances for a simple matter of novelty.

16. These methodological considerations which we are making en passant should not be looked upon as a detour from our main objective. It is almost impossible to determine the scope and place of science in the elementary level without having in mind the way science is to be taught.

17. To accelerate their process of development the new and underdeveloped countries should be particularly aware of the necessity of early detection of children with really superior abilities in order for them to complete in lesser time their scientific formation and be led to the positions where they may be more useful to society and science. This does not mean, of course, a plea for premature specialization but for a more ready tapping of the scientific potential of the nation.

VII - Science at the secondary level

18. The scope and place of science at the secondary level depends very much on the meaning assigned to such phase of the educational process. In many countries the secondary education is erroneously thought of as a mere bridge that leads from primary school to university. If correct, this point of view would justify shaping the secondary curriculum, and accordingly the scientific disciplines therein, in such a way as to fit it precisely to the university entrance examinations. But we should rather envisage secondary education as essentially formative, as a stage where the abilities that the primary school began to develop attain full maturity. One should be able to come out of it well prepared to face life as a competent and conscious citizen and to enter most of the technical professions successfully either immediately on leaving school or after a small vocational or in-service training (for instance, the "sandwich courses" referred to by Sir John Cockroft (19), in which longer periods of work and education will alternate). At the same time one should get sufficient knowledge to be used as a basis on which to establish higher education.

19. In the secondary education the teaching of science should be illuminated, in a higher plane, by the same general spirit of the elementary school. The young man or woman should face and work out more complicated problems than those

presented to the boys and girls at the elementary level. The student should learn to look for careful information in the libraries, to interview specialized people, to get in touch with the research work done at the scientific institutes, to integrate teams organized for studying the natural resources of the place where he lives, for discussing problems related to them, etc. As at the secondary level the student meets science or the sciences as different subject matters, he may easily run the risk of taking them as mere fossilized disciplines with no "growing edges" between them and also unrelated to the humanities. This should not be allowed to occur. Important though it is, the teaching of science should not contribute to stifle the pupil's mind by prematurely transforming him in a narrow specialist. To avoid this difficulty the teacher might use whenever possible the historical approach, so well developed by Conant (20), to show the growth of the scientific ideas and their relationships to the social background of the time. In this endeavour it would be better to get the most intimate cooperation of the teachers of science and the humanities, in order for the students to obtain a unified vision of the evolution of man's works.

20. We think that the secondary level of education is a decisive opportunity for strengthening productive work and respect for manual labor. Technology, always linked to scientific principles, should play here a decisive role.

VIII - The university fetish

21. Since we are studying the scope and place of science in the general education, we might well abstain from considering the university level, which really gives specialized education to some chosen few. But it is worth turning back on our steps and reconsidering what Lewis said about the tendency to spend lavishly at the university end of the educational scale, in the underdeveloped countries. He is quite right. The word university has become a fetish and the university degree something cherished almost only for the social status it confers on people. Many enter university for the sake of getting a degree and not for any professional or cultural ideal. At the same time many professions that only require a secondary education followed sometimes by training in service or in vocational schools (agricultural agents, practical engineers, bookkeepers, laboratory technicians, all kinds of semiprofessional work) are promoted to university rank, what amounts to enlarge and at the same time to debase the purpose of the university and general quality of its teaching. As a rule, where these things happen the university usually ceases to be selective. This begets a very important trouble, by creating at the same time an excess of inadequate graduates and a shortage of technicians, whose number should be at least five times the number of university graduates required. Without this intermediate class of manpower the action of the graduates slows down or even collapses.

(a) In the countries where the above mentioned situation prevails, one should not forget that many of those people who only go through university to get a degree and a better social status, later on become political or administrative leaders who can profoundly affect the organization of the comunity. It would be better, of course, to try and reformulate the ideals and purposes of the universities in order to restore them to their natural place as institutions of really higher learning, only accessible to the best minds in search of a superior professional or cultural formation. But, as things are now, it would be worthwhile to provide adequate general science teaching in order to complete the rather literary or philosophic information those people receive. This would at least give them a better chance to understand fundamental problems of the community.

22. Purely academic is the discussion about the convenience or not of introducing technology and applied science in the universities. Applied science and technology have indeed penetrated the universities, causing sometimes great trouble by disrupting well established medieval traditions, and Sir Eric Ashby (21) has given a clear picture of this process, which seems to us in accordance with the ideal of putting the university to the service of the community. This does not mean ignoring the ideals of pure culture and science but merely emphasizes that, even pursuing the most abstract and theoretical subjects, scientists and sholars in

the university should be counscious of the ultimate goal of their work, which is not their own personal pleasure but the welfare of the community. In other words, such men should understand and be proud of the fact that their efforts, remote as they may be from any application, converge with the works of many other scientists, scholars and technicians to improve man's condition. To those who, like Carmichael (22), seem to condemn the emphasis on science and technology for being practical, we would like to remember that no less practical is the alternate emphasis they give on providing one with "a realistic understanding of his heritage, of his physical, social, and biological environment, and of himself". The awareness of the welfare of the community marks the difference between an educational system with a consistent purpose of social utility and one which only dissipates knowledge at a high price. Sir Eric Ashby is right when he says that the university must have a "strong sense of responsibility to society"; but he wisely qualifies this phrase by adding that "the university's function is to give society not what it wants but what it needs."

23. Although keeping in mind that pure science has always to be cultivated in the university, one should remember that in the poorer and underdeveloped nations much attention, and even a certain priority, has to be accorded to applied science. Good scientific talent, when concentrated on matters of immediate interest that cannot be solved by the mere transplanting of alien techniques, can aid very much in the development of the country, and help creating better conditions for the cultivation of pure science at a later stage. To give such an use to that good scientific talent is not to degrade or waste it.

24. The place of science and technology at the university level is not limited to the scientific and technological schools and institutes. Also in the departments dedicated to the humanities there should be a place for them, in the same way as the schools which specialize in science and technology should afford opportunities for the student to get in touch with the humanities.

IX - Informal education

25. What we have said deals with formal education. At all levels there is, however, an urgent need of informal education through all means. Popularizations of science, when correctly done (23) has a fundamental role in keeping citizens aware of the progresses in science and the problems created by them. Extension agents have a great role in bringing agricultural education directly to rural people. Science clubs and fairs, as well as local and national science contests, contribute very largely to reveal and tap vocations that otherwise would go unnoticed.

26. To sum up, in modern society science is not to be looked upon as something only to be studied and considered by the chosen few whose intellectual abilities bring to the highest steps of educational ladder. Since it permeates the whole life of the community, it has to be faced and understood in general terms by all citizens.

X - Final comments

27. Some cautionary words might here be said with a view to especially considering the scope and place of science in the new and underdeveloped nations.

(a) The attitude should not go unchallenged of those who see in the emphasis given to science and the practical aims of education a peculiarity of the Sovietic system. In the democratic countries this emphasis has also been hailed as necessary by many educators;

(b) One should also oppose the attitude of those who sneer at the idea of linking education to manpower preparation, as if this would necessarily mean obliterating the philosophical and humanistic studies or ignoring the formation of free men. As a matter of fact, all the educational effort, idealistic though it may be, results in the production of some kind of manpower, physical or intellectual, on which depends the progress of the nation;

(c) The regulation by the state of the flow of the human streams that go to the different specializations is not to be criticized in those countries which need to progress at a fast pace. What those nations cannot and should not allow

is the wastage of human resources that the looseness of the educational system favours in detriment of the public interest;

(d) Leaving aside the ideological indoctrination, which may also be done in the democracies with a view to strenghtening the democratic ideals, what seems to mark a decisive difference between the Sovietic educational system, as it now works, and the one that takes place in some prosperous and economically stable democracies, is the total commitment (24) of the nation to the educational process. This total commitment is quite understandable in a country which wants to grow fast or, as it seems to be the case in Russia (25), to make a steady effort of economic recuperation, and is advisable as an educational policy in the new and underdeveloped countries. In this national commitment to education the teaching of science at all levels should have a great importance.

FOOTNOTES

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