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The Potential Role of Agriculture in Science Teaching

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While the role of science in agricultural education is fairly well understood, the potential role of agriculture in science teaching seems to have been, so far, a neglected issue. The educational potential of agriculture stems from the diversity of its components and on the tangibility of some of these components. The web of intellectual and practical activities which is called agriculture embraces most of the elements of modern science teaching, whichever orientation this teaching may wish to adopt: enquiry-experimental or socio-technological. As a science based human activity, it may provide the educator with a unique combination of educational opportunities, in a context which is authentic and accessible to the pupil and to the teacher.

The idea of a stable agriculture, based on a tradition which is transmitted from generation to generation, has been gradually replaced by the image of an ultra-modern enterprise, whose rapid evolution is propelled by the progress of science and technology. Consequently, modern agricultural education cannot anymore limit itself to the acquisition of technical skills, of a "savoir-faire," or of recipes which are transmitted from father to son and from teacher to pupil.

The role of sciences, especially of biology, as part and parcel of agricultural education seems to have been universally recognized for a few decades [see for example 9; 14; 15]. Principles of physics, chemistry and several areas of biology are now, to different degrees and at various levels, included in most of the agricultural curricula. It is also agreed that the effectiveness of the study of these principles will depend on the ability of the pupil to recognize their applicability, and then to apply them correctly.

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AN EVOLVING NOTION: INTEGRATED SCIENCE

In order to demonstrate the applicability of scientific principles and to make their transfer easier to the pupil, the educators of the sixties recommended the eradication of the artificial partitions which separate agriculture from biology in the educational system. An "integrated" interdisciplinary science, often called "AGROBIOLOGY," was to become the basis or even the core of the agricultural scientific curriculum [9].

Later, the very notion of integrated science began to evolve. The integration as understood at this time is performed mainly between the so-called "fundamental" or "pure" sciences, such as physics or biology, and "applied" sciences (agronomy, agrotechniques, etc.). The pure sciences deal with questions of the type "What can be done?", whereas the applied sciences try to answer, with the help of technologies, questions of a different type: "How can it be done?". However, claims Blum [2], between these two questions, there is another one, no less important but too often ignored: "Should it be done?". This third question refers to human motivations, to moral considerations, to the evaluation of human activities and to the process of decision making which underlies such activities; it therefore concerns the *general education* of the pupil. The introduction of such a question in the scientific curriculum is an important innovation. When teaching is so conceived, agriculture is not anymore considered as an objective, but also as a *means:* such teaching enhances on one hand the importance of scientific agriculture in rural development, and on the other hand, the consequences of human interventions in nature [2, p. 35]. Programs of agrobiology which were not designed solely for agricultural schools now appeared. "Agriculture as an environmental science," for instance, published in Israel around 1970 [3], was taught in urban junior high schools.

Toward the end of the seventies, a new tendency emerged: human sciences were introduced into the scientific curricula. Typical names such as Science, Technology and Society [4], or Science in a Social Context [13] were given to these curricula. Around 1980, this evolution gained a great momentum. So far, in several western countries, a great number of curricula or units of the S.T.S. type have been developed, if not always widely used [12]. Kahle and Yager [10] presented new "indicators for the discipline of science education" in the following ways: (1) The teaching of science will focus on current scientific/technological/societal problems," (2) "Efforts to redefine and to improve science education will involve persons from all dimensions of the field," and (3) "A new rationale for science education as a discipline will reflect the nature of science, the nature of society/culture, the expectations of education, and the needs of human beings."

To sum up, the "integration of sciences" can be realized at two main levels. Integration of the "agrobiological" type is performed on the basis of scientific principles

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which are common to various areas of science and technology, and can be transferred from an area to another. Integration of the "general education" type goes one step further: it puts the scientific principles in the social context of human activities. It should be noted that the general education slant ("science, in perspective") has incorporated, not rejected, the agrobiological type of integration. The view of science education which has been described above corresponds closely to the *needs* and to the *educational potential* of agriculture.

Kormandy [11], in an article intended for *biology teachers,* predicts a continuous evolution of agriculture as a result of its interaction with the changing needs of the human population. As do many biology educators, he alloted to agriculture an important place in the field of *human ecology.* Agricultural educators too, must realize that the clients of today's secondary education will be fully active in the 21st century. They must be equipped with the necessary aptitudes and attitudes to cope with the applicative character of agrotechnical principles and methods, as well as with their rate of change. Agricultural education must not only lean on science, but also create a favourable climate for the study of science.

The *educational potential* of agriculture stems from the diversity of its components and from the tangibility, the concreteness, of some of these components. Diversity and tangibility are, as it will be shown, two crucial trump cards, thanks to which the educator can compose a remarkably meaningful curriculum on the theme of agriculture.

The theme will now be analyzed; then its "trump cards" will be studied.

A THEME: AGRICULTURE

Agriculture, as a complex human activity can be presented in the following way. In order to be able to satisfy basic human needs, i.e., to contribute to the well being and to the survival of the expanding and developing human population, agriculture must:

1. intervene in nature, by modifying some natural processes. This intervention is performed
2. by men
3. on behalf of men
4. by means of technologies
5. and of scientific knowledge
6. acquired through scientific research, the aim of which is to clarify, then to control natural processes;
7. this intervention, of an essentially economic character,
8. creates ecological
9. and moral problems.
10. The treatment of these problems, undertaken by men, on behalf of men, by means of scientific and technological methods, and of scientific research, is very often hampered by economic and social constraints;
11. the well being and the survival of mankind, and to a certain extent the status of agriculture and of the agriculturist in society depends, at least partly, on the success of this treatment.

(The term "agriculturist" refers here not only to the producing farmer, but also to all the active members of the agricultural community.)

Such a description of agriculture is obviously open to interpretation. However, it illustrates the richness of agriculture, as a central theme from which a full scientific education may be derived: a series of scientific concepts and principles, inserted in the heterogeneous and interdisciplinary context of a human enterprise. The agricultural context, meets closely the requirements of Ausubel's [1] "meaningful learning." It is "meaningful" when conceived as a series of practices which situate the principles of a domain of knowledge within a significant context, thus illustrating the logical and hierarchical relations which prevail between these principles. It is significant, in that sense, that it may allow the pupil to grasp problems and to ask pertinent and valid questions.

THE TRUMP-CARDS

I. Agriculture and the Transfer of Principles

The meaningful learning of principles depends on the ability of the pupil to recognize their relevance and their applicability to appropriate situations, and then to apply them correctly. However, the transfer of principles is a complex mental operation, which cannot be left to chance. Inasmuch as techniques of transfer can be taught (i.e. pupils can be trained to transfer), agriculture offers unique opportunities.

Agriculture, of its own nature, puts abstract theories into practice. From this point of view, the main advantage of agriculture is that practice takes the form of agrotechnical procedures which, together with their outcomes, are *observable* in (school) farms, and accessible to the pupil in school settings. Confronted with the *concrete* solutions of complex problems, the pupil may learn to identify the principles which underlie these solutions, to study their mode of application, as well as to analyze the *authentic* situations in which the principles are applied [6]. These objectives can be reached only if the teacher considers agriculture as a means, not only as an end, and organizes his pedagogical activities accordingly. The key word here is *accessibility.* According to this view of the role of agriculture in science teaching, once pupils have understood how a scientific principle is applied in an agricultural situation, they have grasped the meaning of the principle.

So far we have referred mainly to "theoretical situations." But agriculture also displays many advantages at the level of practical tasks.

II. Agriculture and Experimental Learning

The agrotechnical procedures are not only observable, but also very often *reproducible* at school. The pupil may, relatively easily, intervene personally in natural processes. In the junior high-schools of the cities of Israel, the pupils obtained flowers out of season by applying the principle of photoperiodism: this result, which can be obtained with a few pots of flowers and a lighted veranda, is only one example of the various and often surprisingly effective experiments which the pupils can perform, with limited means. Obviously the farm of an agricultural secondary establishment offers much greater possibilities; still, it has been shown that many agricultural experiments of great scientific significance could be performed in the small gardens of city-schools [3].

The relative ease with which pupils can "reproduce" agrotechnical procedures makes it possible to base the acquisition of various abstract concepts on experience. Also, discovery or enquiry learning may be enhanced by well designed small "field experiments," and the involvement of the pupils is reinforced by the very tangible nature of the products of the experiments—roses, lettuce or chickens.

III. Agriculture and the Discussion Method

Discussion in the classroom is generally considered to be a useful and productive method of teaching, which improves the assimilation and the retention of concepts and is "characterized by . . . educational objectives related to complex thinking processes" [7]. Unfortunately, it is also more or less admitted that, in most cases, teachers are not skilled enough to initiate and maintain fruitful discussions [8]. In fact, pupils do not tend to discuss the principles of a discipline, because in their eyes it would be tantamount to challenging the knowledge, the wisdom or the activities of well-known scientists. However, our observations have shown that in an integrated area of activity such as agriculture, the *mode* of application of principles could quite often be the source of lively discussions. This is because, owing to the tangibility of the agrotechnical problems, the pupils can grasp the controversial aspects of the suggested technical solutions and feel entitled to express personal opinions. The divergences of opinions which are raised when the teacher skillfully presents alternative solutions to the problem under discussion, keeps the discussion, in which *scientific principles serve as arguments,* alive. The didactical qualities of such discussions cannot be elaborated here, but it should be noted that, in an agricultural context, they are easily exploited.

IV. Agriculture and the Intervention of Man in Nature: Decision Making

The agricultural context provides the pupil with an opportunity to appreciate the implications of the science based intervention of man in nature. The three questions raised by Blum, "what can we do", "how can we do it" and "should we do it," are germane to any important decision in agriculture. Some people may argue that these statements are too general to be really efficient in the field of education, and yet this is precisely where the specific educational potential of agriculture is the most pronounced. It can be shown that in agriculture the scientific and technological knowledge, though indispensable for the process of decision making, is never sufficient. Problems of economy, of organization, of morals and of ethics will always influence the process of decision making. The pupil will therefore be in a position to appreciate rationally the strength and the limits of the contribution of science to human decisions, and this indeed represents one of the main objectives of science education.

In fact, agricultural education can demonstrate in a very striking way that science, by the very act of solving one problem, creates another one. Fertilizers "kill" lakes; insecticides, by upsetting some biological equilibria, cause problems which may be no less severe than the ones they were to solve. The agricultural enterprise can therefore not be satisfied with recognizing and understanding the problems it encounters or creates. Being bound to act, it is bound also to react continuously. The effects of the actions and of the reactions of the agricultural community become exceptionally tangible, explicit and meaningful when the pupil is induced to ask himself and to discuss with peers, teachers or specialists some enlightening questions, such as: "why should an insecticide be replaced by another?"; "why should a field be sprayed twice, if the first spray was supposed to have been effective?"; "why should we use insecticides which, together with the harmful insects, destroy their natural predators?"

The pupils who have become able to ask such questions have reached a very high level of cognitive performance: they are now able to perceive and to define problems. The pupils who have become able to answer these apparently simple questions have not only acquired knowledge of agrotechnical methods and of a surprisingly large number of biological principles, they have also become able to appreciate the consequences of the control and modification of natural processes. They may have assimilated fully the natural laws which govern these processes.

Defining problems, suggesting solutions and evaluating their possible consequences, this is the scope of agricultural education; this is also the realm of science education. This is what agriculture has to offer to science and to general education.

V. Agriculture, Natural Sciences and Statistics

Because of its essentially quantitative character, agriculture illustrates clearly the statistical aspects of natural sciences. Every observation or experiment in agriculture will relate to populations (or to samples) of organisms, and as such, will inevitably demonstrate the phenotypic heterogeneity of these populations. There will always be some measurable differences between individual yields (yields are what agriculture is about). No input-output function will ever produce an ideal curve. The teacher may make use of the problems of interpretation which result from the variability between and within populations, to sensitize the pupils to the aspects of probability which prevail in the natural sciences. Traditional education tends to under-emphasize these aspects and as a result the pupils do not distinguish clearly theories from certainties. When confronted with the authentic and tangible variability of data and results which, as stated above, are part and parcel of any agricultural activity or experimentation, the pupil may have opportunities to assimilate some basic concepts of statistics, such as mean, deviation from the mean and variance, sampling, probability and significance of differences. These concepts may be treated intuitively or formally; in fact, as in the case of the purely scientific concepts, an intuitive perception may precede the formal learning of the concepts.

To sum up: having been trained to think quantitatively, the pupil should develop a better understanding of the laws of nature, (this, again is one of the most desired achievements of modern science teaching) and also should acquire a few—important in themselves—concepts of statistics.

CONCLUSION

To describe the educational potential of agriculture means to uncover the inventory of objectives which can be achieved, provided that the teaching activities are planned and organized with these objectives in mind. This condition being rarely met, the educational potential of agriculture is seldom realized. Sporadic investigations [e.g. 16] about the influence of *traditional* agricultural studies on performance in high school biology brought about quite equivocal results. However, there are excellent reasons to try to make use, in science education, of the specific characteristics of the agricultural context.

(1) *Concerning Agriculture in Rural Schools.* According to the modern vision of science education, the sciences are an integral part of the general education of all the "clients" of any educational system. It would therefore be very unwise to limit the scope of the teaching of agriculture to the study, sophisticated as it may be, of some specific techniques. This would imply a narrow curriculum, whose scientific components would be chosen solely in relation with the techniques. This type of narrow vocational education does not do justice to the potential scope of agricultural education. When conceived as an enriching component of science education, the teaching of agriculture corresponds better to the needs of the future agriculturist, from the socio-human as well as from the agrotechnical point of view. The main idea should be one of mutual enrichment, of a synergistic action between "pure" science and agriculture, aimed at a highly meaningful teaching.

(2) *Concerning All Educational Settings.* The web of intellectual and practical activities which is called agriculture embraces most of the elements of modern science teaching, whichever orientation this teaching may wish to adopt: enquiry-experimental or socio-technological. As a science based human activity, it may provide the educator with a unique combination of concrete opportunities, in a context which is authentic and accessible to the pupil and to the teacher. Various agricultural activities and experiments can be relatively easily reproduced or simulated, on a large or limited scale, according to the possibilities and the policy of the school.

The potential advantages of the agricultural context should be carefully considered by science educators everywhere.

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