## DOCUMENT RESUME

ED 050 930 SE 008 281

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| AUTHOR | Ausubel, David P. |
| TITLE | The Use of Ideational Organizers in Science Teaching. Occasional Paper 3. |
| INSTITUTION | ERIC Information Analysis Center for Science Education, Columbus, Ohio. |
| PUB DATE | Mar 70 |
| NOTE | 21p. |
| EDRS PRICE | EDRS Price MF-$0.65 HC-$3.29 |
| DESCRIPTORS | *Cognitive Processes, *Curriculum, *Learning, *Learning Theories, Teaching Methods, *Theories, Verbal Learning |
| IDENTIFIERS | Advance Organizers, Ausubel, Biological Sciences Curriculum Study (BSCS) |


ABSTRACT

In this third Occasional Paper in the Science series of The Science and Mathematics Education Information Analysis Center, Ausubel explains the nature and theoretical rationale of "organizers", abstract, general, and inclusive statements presented prior to new learning tasks to provide specific relevant anchoring ideas in the learner's cognitive structure. Types, functions, and values of organizers are illustrated by examples drawn from elementary, secondary and college level instruction, usually, but not exclusively, in science. The second half of the paper concerns some content issues in current science teaching, and the BSCS courses are used as illustrations of the points made concerning level of sophistication; overemphasis on analytic, quantitative and experimental aspects of science; the naturalistic approach; and the relative emphasis on basic and applied sciences in the school courses. These aspects of science courses are considered generally, not only in terms of the use of organizers. There are some concluding comments on curriculum planning by diverse teams of specialists, rather than teams of learning theorists, subject matter specialists, or evaluators, and on the disadvantages of single-unit, in contrast to integrated, curriculum development. (AL)

OCCASIONAL PAPER SERIES - SCIENCE
PAPER 3 - THE USE OF IDEATIONAL
ORGANIZERS IN SCIENCE TEACHING



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SCIENCE EDUCATION INFORMATION
REPORTS

OCCASIONAL PAPER SERIES - SCIENCE
PAPER 3 - THE USE OF IDEATIONAL
ORGANIZERS IN SCIENCE TEACHING

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March, 1970

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## INTRODUCTION

The major assumption underlying my advocacy of the use of ideational organizers in science teaching is that the potential meaningfulness of a learning task depends on its relatability to a particular learner's structure of knowledge in a given subject-matter area or subarea. From this it follows that cognitive structure itself, that is, both its substantive content and its major organizational properties, should be the principal factor influencing meaningful learning and retention in a classroom setting. According to this reasoning, it is largely by strengthening salient aspects of cognitive structure in the course of prior learning that new subject-matter learning can be facilitated. In principle, such deliberate manipulation of crucial cognitive structure variables -- by shaping the content and arrangement of antecedent learning experience -- should not meet with undue difficulty. It could be accomplished (1) substantively, by using for organizational and integrative purposes those unifying concepts and principles in a given discipline that have the greatest inclusiveness, generalizability, and explanatory power, and (2) programmatically, by employing optimally effective methods of ordering the sequence of subject matter, constructing its internal logic and organization, and arranging practice trials.

## THE NATURE AND THEORETICAL RATIONALE OF ORGANIZERS

One of the principal reasons for rote or inadequately meaningful learning of subject matter is that pupils are frequently required to learn the specifics of an unfamiliar discipline before they have acquired an adequate foundation of relevant and otherwise appropriate anchoring ideas. Because of the unavailability of such ideas in cognitive structure to which the specifics can be nonarbitrarily and substantively related, the latter material tends to lack potential meaningfulness. But this difficulty can largely be avoided if the more general and inclusive ideas of the discipline, that is, those which typically have the most explanatory potential, are presented first and are then progressively differentiated in terms of detail and specificity. In other words, meaningful learning and retention occur most readily and efficiently if, by virtue of prior learning, general and inclusive ideas are already available in cognitive structure to play a subsuming role relative to the more differentiated learning material that follows. This is the case because such subsuming ideas when established in the learner's structure of knowledge (1) have maximally specific and direct relevance for subsequent learning tasks, (2) possess enough explanatory power to render otherwise arbitrary factual detail potentially meaningful (i.e., relatable to cognitive structure on a non-arbitrary basis), (3) possess sufficient inherent stability to provide the firmest type of anchorage for detailed learning material, and (4) organize related new facts around a common theme, thereby integrating the component elements of new knowledge both with each other and with existing knowledge.

One of the more effective strategies that can be used for implementing the principle of progressive differentiation in the arrangement of subject-matter content involves the use of special introductory materials called "organizers." A given organizer is introduced in advance of the new learning task per se; is formulated in terms that, among other things, relate it to and take account of generally relevant background ideas already established in cognitive structure; and is presented at an appropriate level of abstraction, generality, and inclusiveness to provide specifically relevant ideational scaffolding for the more differentiated and detailed material that is subsequently presented. An additional advantage of the organizer, besides guaranteeing the availability of specifically relevant anchoring ideas in cognitive structure, is that it makes explicit both its own relevance and that of the aforementioned background ideas for the new learning material. This is important because the mere availability of relevant anchoring ideas in cognitive structure does not assure the potential meaningfulness of a learning task unless this relevance is appreciated by the learner. To be maximally effective, of course, the organizer must also be formulated in terms of language and concepts already familiar to the learner, and use appropriate illustrations and analogies if developmentally necessary. And since the substantive content of a given organizer or series of organizers is selected on the basis of their appropriateness for explaining, integrating, and interrelating the material they precede, this strategy simultaneously satisfies the substantive as well as the programming criteria specified previously for enhancing the organizational strength of cognitive structure.

The rationale for using organizers is based primarily on: (a) the importance of having relevant and otherwise appropriate established ideas already available in cognitive structure to make logically meaningful new ideas potentially meaningful and to give them stable anchorage; (b) the advantage of using the more general and inclusive ideas of a discipline as the anchoring ideas or subsumers (namely, the aptness and specificity of their relevance, their greater inherent stability, their greater explanatory power, and their integratave capacity); and (c) the fact that they themselves attempt both to identify already existing relevant content in cognitive structure (and to be explicitly related to it) and to indicate explicitly both the relevance of the latter content and their own relevance for the new learning material. In short, the principal function of the organizer is to bridge the gap between what the learner already knows and what he needs to know before he can successfully learn the task at hand.

## Function of Organizers

The function of the organizer is to provide ideational scaffolding for the stable incorporation and retention of the more detailed and differentiated material that follows in the learning passage, as well as to increase discriminability between the latter material and similar or ostensibly conflicting ideas in cognitive structure. In the case of completely unfamiliar material, an "expository" organizer is used to provide relevant proximate subsumers. These subsumers, which bear a superordinate relationship to the new learning material, primarily furnish ideational anchorage in terms that are already familiar to the learner. In the case of relatively familiar learning material, a "comparative" organizer is used both to integrate new ideas with basically similar concepts in cognitive structure, as well as to increase discriminability between new and existing ideas which are essentially different but confusably similar.

True organizers, thus defined, should not be confused with ordinary introductory overviews. The latter are typically written at the same level of abstraction, generality, and inclusiveness as the learning material, and achieve their effect largely through repetition, condensation, selective emphasis on central concepts, and prefamiliarization of the learner with certain key words. Summaries are comparable to overviews in construction, but are probably less effective because their influence on cognitive structure is retroactive rather than proactive relative to the learning task. They are probably more useful, in place of the material itself, for purposes of rapid review than for original learning. However, insofar as they may imply to some learners that the material they do not include is relatively superfluous, they may promote neglect of and failure to study or review much significant subject matter. C. W. Lathrop and C. A. Norford (3) found that neither overviews nor summaries appreciably improve the learning of instructional films.

The advantage of deliberately constructing a special organizer for each new unit of material is that only in this way can the learner enjoy the advantages of a subsumer which both: (a) gives him a general overview of the more detailed material in advance of his actual confrontation with it, and (b) also provides organizing elements that are inclusive of and take into account most relevantly and efficiently the particular content contained in this material. Any existing subsumer in the learner's cognitive structure which he could independently employ for this purpose typically lacks particularized relevance and inclusiveness for the new material and would hardly be available in advance of initial contact with it. And although students might possibly be able to improvise a suitable subsumer for future learning efforts after they become familiar with the material, it is unlikely that they would be able to do so as efficiently as a person sophisticated in both subject-matter content and pedagogy.

Organizers also have certain inherent advantages both over various kinds of intra-material organization (organizing aids within the body of the material), and over any existing subsumers within cognitive structure that could be used for organizati purposes. Unlike intra-material organization (executed in accordance with the principles of progressive differentiation and integrative reconciliation) that successively provides necessary anchorage for and differentiation of new ideas at a particularized level just before each new idea is encountered, organizers perform the same functions in advance at a much more global level before the learner is confronted with any of the new material. Hence, for example, a generalized model of class relationships is first provided as a general subsumer for all new classes, subclasses, and species before more limited subsumers are provided for the particular subclasses or species they encompass; and the various kinds of forests are first distinguished from each other before the component subforests and trees are similarly differentiated. Spontaneously existing subsumers in cognitive structure on the other hand, lack both particularized relevance for the new material (since the learner cannot possibly anticipate its precise nature) as well as the benefit of the sophisticated knowledge of subject matter and pedagogy available to expert programmers.

Pedagogic Value of Organizers

The pedagogic value of advance organizers obviously depends, in part, upon how well-organized the learning material itself is. If it already contains built-in organizers and proceeds from regions of lesser to greater differentiation (higher to lower inclusiveness), rather than in the manner of the typical textbook or lecture presentation, much of the potential benefit derivable from advance organizers will not be actualized. Regardless of how well-organized learning material is, however, it seems reasonable to expect that learning and retention can still be facilitated by the use of advance organizers at an appropriate level of inclusiveness. Such organizers are available from the very beginning of the learning task, and their integrative properties are also much more salient than when introduced concurrently with the learning material. To be useful, however, organizers themselves must obviously be learnable and must be stated in familiar terms.

Progressive differentiation in the programming of subject matter is accomplished by using a hierarchical series of organizers (in descending order of inclusiveness), each organizer preceding its corresponding unit of detailed, differentiated material, and by sequencing the material within each unit in descending order of inclusiveness. In this way not only is an appropriately relevant and inclusive subsumer made available to provide ideational scaffolding for each component unit of differentiated subject matter, but the ideas within each unit as well as the various units in relation to each other, are also progressively differentiated--organized in descending order of inclusiveness. The initial organizers, therefore, furnish anchorage at a global level before the learner is confronted with <u>any</u> of the new material.

Hence, when undergraduates are first exposed to organizers presenting relevant and appropriately inclusive subsuming principles, they are better able to learn and retain completely unfamiliar ideational material (1). Differential analysis in another similar study showed that the facilitating effect of organizers is greatest for those individuals who have relatively poor verbal ability and who therefore tend spontaneously to structure such material less effectively (2).

Generally speaking, therefore, it makes good organizational sense if the presentation of more detailed or specific information is preceded by a more general or inclusive principle to which it can be related or under which it can be subsumed. This not only makes the new information more meaningful and enables the student to anchor more easily forgotten specifics to more easily remembered generalizations, but also integrates related facts in terms of a common principle under which they can all be subsumed. Thus, for example, in a physics, engineering, or biology course, the general characteristics of all regulatory or cybernetic systems should be presented before considering any particular regulatory or cybernetic system. The latter, in turn, should be explicitly related to the more general principles, showing how they exemplify them. This makes for some redundancy, but such redundancy, in turn, greatly reinforces the general principles. Of course, the general principles themselves must be stated in terms and concepts that are already familiar to the learner. Many teachers and textbooks are guilty of introducing complex and detailed information for which no adequate foundation had been laid in terms of organizing, unifying, or explanatory principles.

Thus a substantive introductory statement of the principal new ideas to be considered in the chapter, stated at a high level of generality and inclusiveness, to which the more detailed information in the chapter can be related, could be very helpful in learning the latter information. For example, a brief overview of the chief propositions underlying Darwin's theory of evolution would be of greater functional utility in learning the more detailed mechanisms through which evolution operates, or the different kinds of evidence for evolution, than the kinds of historical or anecdotal introductions provided in the three BSCS textbooks in introductory biology (much folksy biographical information about Darwin or anecdotal material about how he arrived at his theory). The same applies to introductions that merely list the topics to be covered.

If the new learning material (for example, the Darwinian theory of evolution) is entirely unfamiliar to the learner, the organizer might include whatever established and relevant knowledge presumably exists in his cognitive structure that would make Darwinian theory more plausible, cogent, or comprehensible. The organizer itself (a highly general and inclusive statement of Darwinian theory) would thus be learned by being related to generally relevant and congruent knowledge already present in cognitive structure, making explicit both its relevance for the latter and its own relevance for the more detailed aspects of or supportive evidence for Darwinian theory; and these detailed aspects (the learning task itself) would then be subsumed under the organizer. If the new learning material is not completely novel (for instance, later presentation of Lamarck's theory of evolution), the organizer might point out explicitly in what ways the two theories are similar and different. Thus, whether already established anchoring ideas are nonspecifically or specifically relevant to the learning material, the organizer both makes this relevance more explicit, and is itself explicitly related to the more differentiated content of the learning task.

It is not only desirable for the material in each chapter to become progressively more differentiated (to proceed from ideas of greater to lesser inclusiveness), but for textbooks as a whole (from one chapter to another) to follow the same organizational plan. The spiral kind of organization in which the same topics are treated at progressively higher levels of sophistication in successive sections, is an extension of the same principle. Textbook series in a given field that are intended for use at different instructional levels (elementary school, high school, undergraduate, and graduate) can also follow this organizational plan. In this instance there is a progressive increase in scope, depth, complexity, level of abstraction, and level of sophistication at successively higher grade levels, with the earlier acquired knowledge serving as a foundation for the more abstract and complex material introduced later. In addition, however, some entirely new topics are introduced at the higher levels, since many advanced topics are too complex and abstract to be taught successfully on an intuitive basis.

In instances where new concepts are introduced that are similar or related to, but not identical, and hence confusable, with previously learned concepts (for instance, instinct and imprinting; fermentation and respiration; spontaneous generation and preformationism; elimination and excretion; behavioral versus physiological or morphological adaptation; variation as both a cause and product of evolution), it is advisable to point out explicitly the similarities and differences between them and to make this connection in both contexts. This practice integrates knowledge by making relationships between concepts explicit; by preventing artificial compartmentalization and the proliferation of separate terms for concepts that are basically the same except for contextual usage; and by differentiating between ostensibly similar but actually different concepts. Ignoring such relationships between later-appearing and previously-learned content assumes, rather unrealistically, that students will independently perform the necessary cross-referencing by themselves.

Organizers that are intended for elementary-school pupils should be presented at a lower level of abstraction and should also make more extensive use of concrete-empirical props. They should take into account rather than ignore pre-existing organizing principles (preconceptions) in the learner's cognitive structure. Often these preconceptions are based on widely accepted elements of cultural folklore that are very tenacious unless explicitly undermined.

## Pervasive Themes

Good organizational advantage can be taken of pervasive or recurrent themes that can integrate or interrelate many different topics or general ideas. The green version of the BSCS, for example, uses the beginning chapters on the "web of life" as an integrative device throughout the entire book. None of the three versions, however, makes adequate use of Darwinian theory as a pervasive organizing principle. Evolutionary theory can be related to such varied concepts as uniformity and diversity in nature; genetic continuity; the complementarity of organism and environment, and of structure and function; the classification of and interrelationships between organisms; population genetics; the role of sexual reproduction in producing diversity; the geography of life; and the need for a self-replicating mechanism as well as the biological significance of mistakes in self-replication. It is obviously necessary for pervasive themes to be introduced early in a book if they are to serve an integrative function. But in the yellow and blue versions such themes (for example, regulatory mechanisms, homeostasis, cybernetic principles, the relationship of theory to data) often do not appear until late in the game.

In addition, the nine basic substantive themes of the three texts are not organically related to the actual content of the yellow and blue versions. In the yellow version, after being listed formally in the first chapter, they are presumably forgotten and are no longer identifiable in the content itself. The same is true of the blue version except that the themes are distributed quite randomly on separate pages scattered through the text. In the green version, on the other hand, the themes emerge naturally from and are organically related to the content of each section.

Preconceptions and Organizations

The role of preconceptions in determining the longevity and qualitative content of what is learned and remembered is crucial, and may well be the most important manipulable factor in the individualization of instruction. Unfortunately, however, very little research has been conducted on this crucial problem, despite the fact that the unlearning of preconceptions might very well prove to be the most determinative single factor in the acquisition and retention of subject-matter knowledge.

In any case, anyone who has attempted to teach science to children or to adults for that matter, is painfully aware of the potent role of preconceptions in inhibiting the learning and retention of scientific concepts and principles. These preconceptions are amazingly tenacious and resistant to extinction because of the influence of such factors as primacy and frequency; because they are typically anchored to highly stable, related, and antecedent preconceptions of a more inclusive nature; because they are inherently more stable (for example, more general; less qualified; expressive of a positive rather than inverse relationship; predicated on single rather than multiple causality or on dichotomous rather than continuous variability); and lastly because resistance to the acceptance of new ideas contrary to prevailing beliefs seems to be characteristic of human learning. Some of the reasons for individual differences in the tenacity of preconceptions probably include those that are related to cognitive style, to such personality traits as closed-mindedness, and to self-consistent individual differences in generalized aspects of reductionism in cognitive functioning.

General findings regarding the role of cognitive organizers would appear to have significant implications for those aspects of individualization of instruction that are related to the problem of preconceptions.

It seems plausible to suppose that if advance organizers can be used in nonindividualized fashion generally to bridge the gap between what learners already know and what they have to learn at any given moment in their educational careers, then individualized organizers, specially tailored to the particular preconceptions of a particular learner, will have an even more facilitating effect on meaningful learning and retention. Unless proposed organizers take explicit account of, and attempt explicitly to extinguish, existing preconceptions, it seems likely that these preconceptions will both inhibit related new learning of more valid scientific concepts and principles and eventually assimilate, through memorial reduction, the proposed new ideas designed to replace them. A very common preconception, for example, among elementary-school children is that the outer integument constitutes a kind of sack filled with blood: prick it at any point and it bleeds. Actually this is not an implausible hypothesis. Is it conceivable therefore that one can effectively instruct such children about the circulatory system without taking into account and trying to undermine the relative credibility and explanatory value of this preconception as compared with that of a closed system of vessels?

Thus a seemingly important precondition for constructing individualized organizers for instructional units in science is to ascertain what the more common preconceptions of learners are by means of appropriate pretests, and then to match suitable tailored organizers with pupils exhibiting corresponding preconceptions. If I had to reduce all of educational psychology to just a single principle, I would say this: "Find out what the learner already knows and teach him accordingly."

"Conceptual Schemes" Approach to Science Teaching

The organizer approach to providing general and inclusive ideational scaffolding for detailed learning material in science should not be confused with the notion that the same set of conceptual schemes can serve to integrate the substantive content of all of the scientific disciplines (4). In my opinion, on philosophical grounds, no set of conceptual schemes or principles of scientific method is applicable to all sciences. Each science has its own idiosyncratic undergirding themes and methods of inquiry. An all-encompassing set of conceptual themes is apt to be characterized: (a) by a level of generality that is reminiscent of the philosophy of science, and hence beyond the cognitive maturity and scientific sophistication of elementary and high school students; and (b) by far-fetched relevance and applicability to many scientific disciplines. The seven conceptual schemes prepared by the NSTA Curriculum Committee are characterized by both of these features. They are both stated at a high level of generality, and are applicable to the physical sciences but not very applicable to biology, psychology, and the social sciences. But, even if an epistemologically tenable set of principles comprehensive enough to embrace all sciences with equal aptness and relevance could be formulated, its very utility (its transferability to the separate sciences, its ability to serve as superordinate subsumers for the less general themes characterizing any single discipline) would obviously be dependent on its being understood and applied at the high level of generality implicit in any such formulation. On developmental grounds, however, elementary-school pupils could, at the very most, hope to understand these themes at an intuitive (semi-abstract. semi-general) level if at all; and high-school and undergraduate students would typically lack sufficient sophistication in a wide enough variety of sciences genuinely to understand principles at this philosophical level of generalization about science.

The solution to this problem of curriculum development in science lies not in abandoning the "conceptual schemes" approach. This would be throwing away the baby with the bath water. The "conceptual schemes" approach is philosophically, psychologically, and pedagogically sound, provided that it is modified so that a separate set of conceptual schemes is made available for each particular discipline. However, to seek one set of conceptual schemes that attempts to encompass all science is as illusory as seeking the fountain of youth or the philosopher's stone.

## SOME CONTENT ISSUES IN CURRENT SCIENCE TEACHING

Turning aside now from the question of ideational organizers to the related and equally fundamental question of choice of substantive content in secondary school science teaching, I would like to consider three general issues in this latter area--desirable levels of sophistication, the naturalistic versus the analytical-experimental-quantitative approach, and the "basic" versus the "applied science" approach. In each case I shall draw my illustrative material from the BSCS materials--the one content area and particular curriculum with which I am most familiar.

### Level of Sophistication

In the yellow and blue BSCS versions, it appears as if little effort was made to discriminate between basic and highly sophisticated content--between what is appropriate and essential in an introductory high-school course and what could be more profitably reserved for more advanced courses. These versions include topics, detail, and level of sophistication that vary in appropriateness from the tenth grade to graduate school. Only the green version gives the impression of being at an appropriate level of sophistication for a beginning course. And since the unsophisticated student cannot be expected to distinguish between more and less important material, he either throws up his hands in despair, learns nothing thoroughly in the effort to learn everything, or relies on rote memorization and "cramming" to get through examinations.

The blue version, especially, appears sufficiently sophisticated and challenging to constitute an introductory college course for students who already have an introductory biology course in high school as well as courses in chemistry and physics. It is true, of course, that subjects once thought too difficult for high school students (for example, set theory, analytical geometry, and calculus) can be taught successfully to bright high school students with good quantitative ability. But in the latter instances, students are adequately prepared for these advanced subjects by virtue of taking the necessary preliminary and sequentially antecedent courses in mathematics. The blue version, on the other hand, presents biological material of college-level difficulty and sophistication to students who do not have the necessary background in chemistry, physics, and elementary biology for learning it meaningfully. It should also be remembered that college-level mathematics is not considered appropriate for all high school students, but only for those brighter students with better-than-average aptitude in mathematics who are college-bound and intend to major in such fields as mathematics, science, engineering, and architecture.

An introductory high school course in any discipline should concentrate more on establishing a general ideational framework than in putting a great deal of flesh on the skeleton. Generally speaking, only the framework is retained anyway after a considerable retention interval; and if more time is spent on overlearning the framework, plus a minimum of detail, than in superficially learning a large mass of oversophisticated and poorly understood material, both more of the important ideas are retained in the case of students taking the subject terminally, and a better foundation is laid for students who intend to take more advanced courses later.

Oversophisticated detail is not only unnecessary and inappropriate for a beginning course, but also hinders learning and generates unfavorable attitudes toward the subject. The student "can't see the forest for the trees." The main conceptual themes get lost or become unidentifiable in a welter of detail. Both the average student and the student not particularly interested in science would tend to feel overwhelmed by the vast quantity and complexity of detail, terminology, methodology, and historical material in the blue and yellow versions. And a student who feels overwhelmed by a subject tends to develop an aversion toward it, and to resort to rote memorization for examination purposes.

It is not necessary for a beginning student to be given so much sequential historical detail about the development of biological ideas, related experimental evidence from original sources, and pedantic information about all of the various misconceptions and twistings and turnings taken by these ideas before they evolved into their currently accepted form. As a result, the ideas themselves --which are really the important things to be learned-- tend to be obscured and rendered less salient. This practice also places an unnecessary and unwarranted burden on learning and memory effort--effort that could be more profitably expended on learning the ideas themselves and the more significant aspects of their historical development.

To give students the flavor of biology as an evolving empirical science with a complex and often circuitous history, it would suffice to cite several examples. It is unnecessary to give the detailed ideational and experimental history of every biological concept and controversy. Unsophisticated students also tend to be confused by raw experimental data and by the actual chronological and experimental history underlying the emergence of a biological law or theory--especially when long quotations are given from original sources that use archaic language, refer to obscure controversies, and report findings and inferences in an unfamiliar and discursive manner. It is sufficient (as the green version does) to review the historical background of biological concepts in a schematic, telescoped, simplified, and reconstructed fashion, deleting most of the detail, and disregarding the actual chronological order of the antecedent ideas and their related experiments.

Overemphasis on Analytical, Quantitative, and Experimental Aspects of Science

One of the characteristic of the curriculum reform movement is an overcorrection of the unnecessarily low level of sophistication at which many high school subjects have been and still are taught. In the sciences this tendency is marked by a virtual repudiation of the descriptive, naturalistic, and applied approach and an overemphasis on the analytical, experimental, and quantitative aspects of science. In introductory high school biology, for example, much of the new content consists of highly sophisticated biochemical material that presupposes advanced knowledge of chemistry on the part of students who have no background whatsoever in this subject. The implied rationale of this policy is Bruner's untenable assertion that any concept can be taught to any person irrespective of his level of subject-matter sophistication.

By any reasonable pedagogic criterion, introductory high school biology should continue to remain predominantly naturalistic and descriptive in approach rather than analytical and experimental. This does not imply emphasis on descriptive information or on disconnected facts unrelated to theory, but on explanatory concepts that are stated in relatively gross and descriptive language, instead of in the more technical, quantitative, and sophisticated terminology of biochemistry and biophysics. In short, high school biology should concentrate on those broad biological ideas that constitute part of general education--physiology, evolution, development, inheritance, uniformities and diversity in life, ecology, and man's place in nature--rather than on a detailed and technical analysis of the physical and chemical basis of biological phenomena or of the morphology and function of intracellular microstructures. This is particularly true for the substantial number of students who will receive no further instruction in biology. As a matter of fact, there is still much significant but as yet unexploited conceptual content in introductory biology that can be treated in much more sophisticated terms at a descriptive level, without having to resort to the depth of biochemical and cellular detail given in the yellow and blue BSCS versions.

Naturalistic Approach

Contrary to the strong and explicitly stated bias of the blue and yellow versions, there is still much room in introductory biology for the naturalistic approach. It is much more important for the beginning student in science to learn how to observe events in nature systematically and precisely and how to formulate and test hypotheses on the basis of independent sets of naturally occurring antecedents and consequences, than to learn how to manipulate an experimental variable and control other relevant variables by design in a laboratory situation. The former approach not only takes precedence in the student's intellectual development, and is more consonant with his experimential background, but also has more transfer value for problem solving in future "real-life" contexts. To dogmatically equate scientific method with the experimental-analytical approach also excludes, rather summarily from the domain of science, such fields in biology as ecology, paleontology, and evolution, and such other disciplines as geology, astronomy, meteorology, anthropology, and sociology.

This bias against the naturalistic approach has already reached the point where pupils are being taught that cause-and-effect and explanatory relationships between independent and dependent variables can be warrantedly inferred only if the independent variables under investigation can be reliably manipulated and if other relevant variables can be adequately controlled. This pseudo-scientific dictum ignores both statistical methods of control and the more important fact that controlled experiments in nature occur spontaneously every day in the week, inviting the student of science merely to formulate and test relevant hypotheses without any need whatsoever for experimental manipulation and control.

Retention of the naturalistic and descriptive emphasis, and of some applied content, in introductory high school biology is thus consistent with the fact that tenth-grade biology is the terminal course in science for many students. It is also more consistent than is the analytical-experimental approach with the tenth-grader's existing background of experience, his interests, his intellectual readiness, and his relative degree of sophistication in science. This proposed emphasis is also in no way inappropriate for those students who will subsequently take high school physics and chemistry, as well as more advanced biology courses. These latter students would be much better prepared, after taking such an introductory course, for a second course in biology, in the twelfth grade or in college, that takes a more quantitative and experimental-analytical approach, introduces more esoteric topics, and considers the biochemical and biophysical aspects of biological knowledge. By this time, they would also have the necessary mathematical sophistication and greater experience with experimental methodology.

## "Basic" versus "Applied" Science Approach

The strong emphasis in the yellow and blue BSCS versions on "basic science" principles, and their relative lack of concern with applications to familiar or practical problems, is in accord with current fashionable trends in science education. Current curriculum projects have tended to overemphasize the basic sciences (because of their great generalizing power and relative timelessness), and unwarrantedly to denigrate the role and importance of applied science in general education. If the aim of the science curriculum is to acquaint the student with the goals and limitations of the scientific enterprise, and to help him understand, as an end in itself, the conceptual meaning of the current phenomenological world that confronts him, it cannot afford to overlook the applied sciences. They constitute a significant aspect of modern man's phenomenological and intellectual environment, and hence an important component of general education. Knowledge about such subjects as medicine, agronomy, and engineering should be taught not to make professional physicians, agronomists and engineers out of all students, or to help them solve everyday problems in these areas, but to make them more literate and intellectually sophisticated about the current world in which they live.

The time-bound and particular properties of knowledge in the applied sciences have also been exaggerated. Such knowledge involves more than technological applications of basic science generalizations to current practical problems. Although less generalizable than the basic sciences, they are also disciplines in their own right, with distinctive and relatively enduring bodies of theory and methodology that cannot simply be derived or extrapolated from the basic sciences to which they are related. It is simply not true that only basic science knowledge can be related to and organized around general principles. Each of the applied biological sciences (for example, medicine, agronomy) possesses an independent body of general principles underlying the detailed knowledge in its field, in addition to being related in a still more general way to basic principles in biology.

Applied sciences also present us with many strategic advantages in teaching and curriculum development. We can capitalize on the student's existing interest in and familiarity with applied problems in science to provide an intellectual and motivational bridge for learning the content of the basic sciences. Previously acquired knowledge in the applied sciences, both incidental and systematic, can serve as the basis for rendering basic science concepts and propositions both potentially meaningful to the learner and less threatening to him. There is also good reason for believing that applied sciences are intrinsically more learnable than basic sciences to the elementary-school child, because of the particularized and intuitive nature of his cognitive processes and their dependence of the "here and now" properties of concrete-empirical experience. For example, before the tenth grader ever enters the biology class, he has a vast fund of information about immunization, chemotherapy, the symptoms of infection, heredity, and so forth. Finally, knowledge in the applied sciences probably is retained longer than knowledge in the basic sciences because of the greater frequency of their subsequent use (by virtue of more frequent applicability to intellectual experience in adult life).

## ORGANIZATIONAL ISSUES IN CURRICULUM PROJECTS

Finally I wish to consider several organizational issues in the curriculum reform movement: Who should prepare curriculum materials, direct versus teacher transmission of curriculum materials, and the single-unit versus the integrated curriculum approach.

Collaboration of Subject Matter, Learning Theory, and Measurement Spe .alists

A basic premise of all curriculum reform projects is that only a person with subject-matter competence in a given discipline should prepare curriculum materials in that discipline. Only such a person is sufficiently sophisticated: (a) to identify unifying and integrative concepts with broad generalizability and explanatory power in the field: (b) to perceive the interrelationships between different ideas and topics so as to organize, sequence, and integrate them optimally; (c) to comprehend the process of inquiry and the relationship of theory to data in the discipline, in order to select appropriate laboratory exercises and to integrate process and content aspects of the curriculum program; and (d) to understand the subject-matter content well enough either to prepare textual materials lucidly himself, or to judge whether others have done so.

To be pedagogically effective, such curriculum materials also have to conform to established principles in the psychology of classroom learning and must include evaluative devices that conform to established principles of evaluation and measurement. Obviously, it is difficult for any one person to possess all three competencies. But a pure educational psychologist or measurement specialist cannot really collaborate with a subject-matter specialist in producing curriculum materials and measuring instruments - apart from communicating to him general principles of learning theory and measurement.

This type of help, however, is inadequate for the actual collaborative task that needs to be done. In the actual operation of producing curriculum and evaluative materials that are sound on both subject-matter and learning theory-measurement grounds, the educational psychologist and measurement specialist can collaborate with subject-matter specialists.

Direct versus Teacher Transmission of Curriculum Materials

The availability of enrichment materials for individualized self-instruction brings up two additional controversial issues: (a) Shall these materials be prepared for direct use by pupils or should they be prepared for the subject-matter and pedagogical enlightenment of the teacher and transmitted to pupils indirectly through him? (b) Should particular enrichment materials be integrated with a sequentially organized series of curriculum materials, as for example, a treatment in greater depth of a particular topic in a given program of study, or should they be prepared apart from any explicit reference or applicability to such a series?

In my opinion, curriculum materials should be produced for pupils rather than for teachers. I agree with J. D. Novak (5) that when the content of a curriculum program is properly prepared and pretested for learnability and lucidity, and contains adjunctive feedback devices, there is little value in using the teacher as a filter through which the content of subject matter reaches pupils. Perhaps 0.1 percent of teachers can present subject matter as lucidly and efficiently as properly programmed materials can; and by "programmed" material I do not mean teaching-machine programs or programmed textbooks that granulate material into such small segments that its logical structure and interrelationships are no longer perceptible.

When programmed subject-matter material is transmitted to pupils directly, it not only reaches them more clearly and effectively, but can also be delivered on an individualized, self-paceable basis, and circumvents the conceptual and pedagogic limitations of nine hundred and ninety-nine teachers in a thousand. The teacher's role is not eliminated, but is channeled more into the stimulation of interest, the planning and direction of learning activities, the provision of more complete and individualized feedback in instances that are idiosyncratic to particular learners, the evaluation of achievement, and the direction of discussion about issues that are too controversial or speculative to be programmed efficiently. Typically, programmed materials would consist of texts that are written by subject-matter and learning theory-measurement specialists, in accordance with established psychological principles of presentation and organization; that are empirically pretested and suitably revised to guarantee the maximal lucidity of each idea; that contain searching tests of genuine understanding plus appropriate feedback after each self-contained subsection; that make provision for overlearning (consolidation) before new material is presented; and that provide for adequate review after progressively increasing intervals of time.

Single-Unit versus Integrated Curriculum Approach

I do not think that it is pedagogically tenable to produce science curriculum materials apart from an integrated plan encompassing each of the separate scientific disciplines at successively higher levels of difficulty from elementary school through college. A collection of supplementary grade-appropriate units in various scientific disciplines, even when used in conjunction with existing curriculum materials, presents many difficulties: (a) It does not further the construction of a sequentially organized curriculum in any particular discipline, at any grade level, that is logically coherent and systematic in its component topics; (b) Students fail to develop a conception of each scientific discipline as a sequentially organized, logically integrated, and coherently interrelated body of knowledge; (c) For a given discipline to be organized for optimal learning on a longitudinal basis, one must plan in advance for the articulation of the various levels of difficulty so that some topics are considered at progressively higher levels of sophistication, whereas other topics are introduced *de novo* when specified levels of sophistication are reached.

This kind of large-scale, integrated curriculum planning requires no greater "certainty in the minds of the specialists on exactly how science materials should be scheduled to guarantee learnings" than does the system described above for producing small unintegrated units of material. The same principles are involved but on a much more massive scale. One starts with the same tentative outline based on logical interrelationships between the component aspects of a discipline, as modified by pertinent developmental and learning theory considerations; prepares tentative units; and revises these units on the basis of try-out experience and/or alters their grade placement level. If this is done by a team, say twenty times larger than the one that is commonly envisaged, I believe that it can prepare an integrated science curriculum in the same length of time that it takes to prepare an unintegrated series of units. Admittedly this involves many more administrative problems; but if one adheres to the principle of immediate try-out of component units, there should not necessarily be any problem of "rigidity." The deficiencies in the existing large-scale, integrated projects stem more, in my opinion, from (a) untenable theoretical ideas about teaching and learning (e.g., overemphasis on the importance of discovery in learning; overemphasis on the "basic science," experimental-analytic approach); (b) uncoordinated team effort, resulting in the production of textbooks consisting of unintegrated units, and no pervasive organizing ideas that are organically related to the textual material (e.g., Blue and Yellow BSCS versions); (c) failure to try out the materials empirically until the entire series is completed; and (d) lack of active collaboration, on a day-to-day basis, of learning-theory and measurement specialists (who are also sophisticated in the subject matter) in the actual preparation of curriculum and measurement materials.

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