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By-Connelly, F. Michael

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Common approaches to ordering the curriculum content of a scholastic discipline include a hierarchical structuring of the discipline's major concepts and a view of inquiry as learners solving problems. Other approaches include logical prerequisite, concept inclusion, generalization, concept interrelationship, chronology, and subject matter. Countering these views is an approach called "patterns of enquiry," which addresses specific problem areas of a discipline, resulting in a set of logical conditions for curriculum determination. Three principles from biology--(1) antecedent-consequent, classification and taxonomy; (2) structure-function, classification and taxonomy; and (3) structure-function, energectics--illustrate the application of this view to the determination of curriculums for the genecological study of communities. (JK)

THE ONTARIO INSTITUTE FOR STUDIES IN EDUCATION

DEPARTMENT OF CURRICULUM

*CONCEPTUAL DISCIPLINARY STRUCTURES AND THE CURRICULUM[1]

F. Michael Connelly

Two key terms in the recent decade of curriculum development are "structure" and "enquiry". Few authors writing for or about a particular curriculum omit treatment of these terms.[2] It is widely held that structure and enquiry point the way to meaning and to transfer of training. Accordingly, new curricula are seen, not as mere up-datings of disciplinary knowledge, but as the embodiment of a new, or at least renewed, idea. To borrow a term from Dewey, it appears as if the curriculum maker has developed a new "logical form" to guide his enquiry.[3]

For the most part, new curricula treat structure as if it were a matter of a hierarchical organization of concepts and enquiry as if it were a matter of learners solving problems. We will see that these conceptions are supported, perhaps borrowed, from studies in cognitive psychology. I will show that these conceptions misrepresent the character of knowledge in several ways of importance to curriculum and I will describe a more adequate conception of structure in terms of patterns of enquiry.

Disciplinary Structures Implied in Psychological Studies

The psychologist, of course, makes no claims about the character of knowledge. His disclaimer resides in the familiar distinction between logical and psychological structure. He either begins with a given body of organized knowledge and works out the psychological processes by which the knowledge may be learned, or he works out the learning processes and assigns to the curriculum worker the task of re-ordering the logical in terms of the psychological. In both cases a conception of disciplinary structure appropriate to the curriculum is implied in the psychologist's work. Ausubel's work is an instance of the former and is seen in the following exchange.

> ... you seem to be putting the emphasis on learning as a kind of transmission of a body of stuff, whether it be in the book or in the voice of the teacher or structured by the teacher according to a proposition in an experiment or an experience in an ideal textbook.

Dr. Ausubel "that's right".[4]

Bruner's work on classification processes in enquiry is an instance of the latter.[5] Here, the curriculum maker is asked to treat disciplinary concepts as entities to be classified. For instance, Bruner treats the creation and discovery of the neutrino and the creation and discovery of Pluto as instances of the use of "empty categories".[6]

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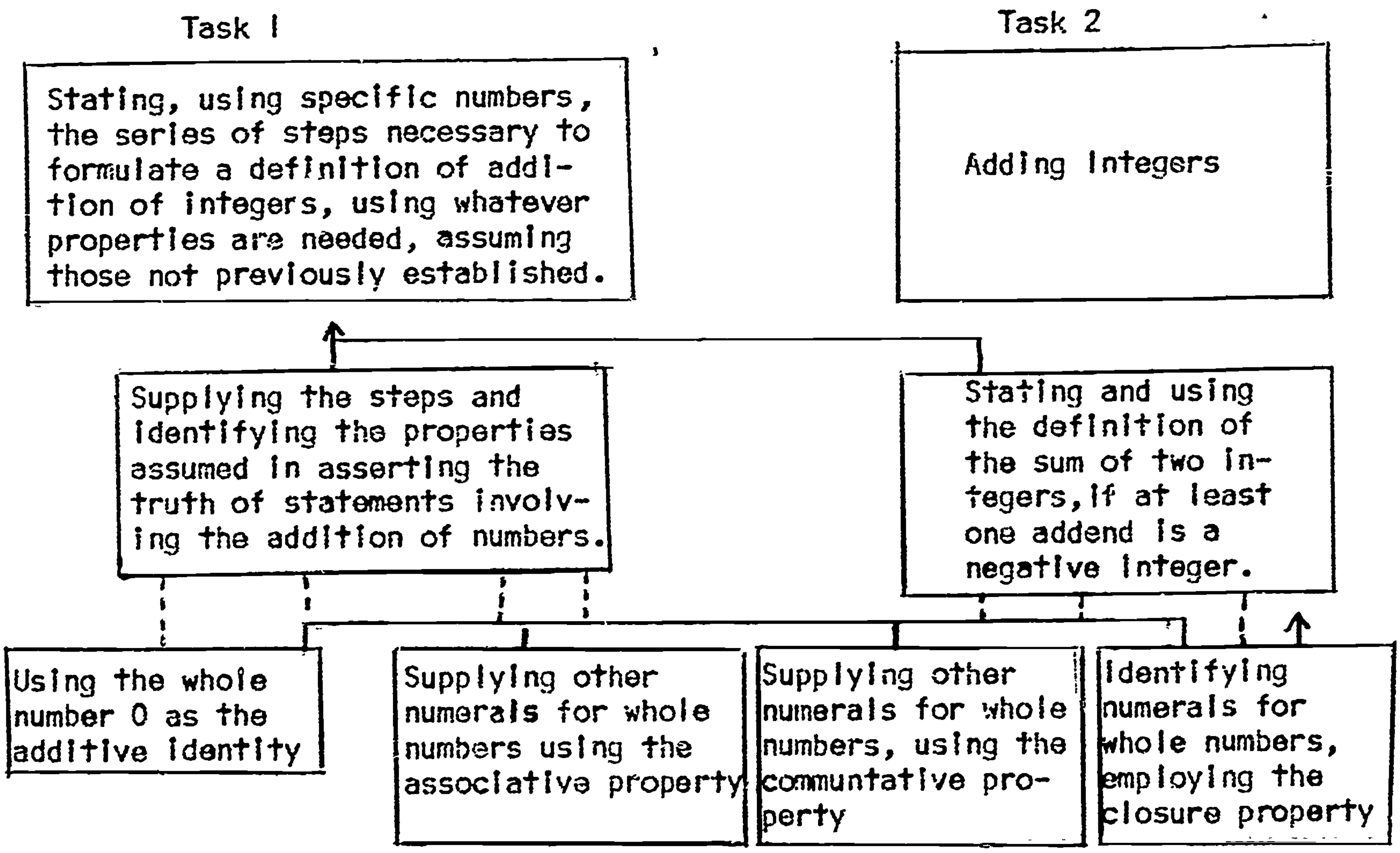
Let us briefly review parts of Gagne's, Ausubel's and Bruner's work. We will focus on the implied conceptions of the structure of knowledge and we will examine what those conceptions make of "meaning" and "transfer".

Gagne would have us organize the content of instruction into a sequence of prerequisite learning tasks hierarchically related from simple to complex. Different hierarchies overlap. The following is part of "the hierarchy of knowledge for the two final tasks of the present study" for a study of mathematics learning by Gagne.[7]



The implied conception of disciplinary structure in this view is that of sets of related hierarchically dependent statements of knowledge. For instance, the concept of a negative integer preceeds the principle of integer addition. Disciplines such as the social sciences, English and biology have large numbers of such structures while mathematics and physics have fewer such structures.

Ausubel would have us organize the content of instruction into a "hierarchical series of organizers (in descending order of inclusiveness) each organizer preceeding its corresponding unit of detailed, differentiated materials".[8] In the following passage, Ausubel describes the use of an advanced organizer for the learning of unfamiliar metallurgical knowledge.

> The experimental introductory passage contained background material for the learning passage which was presented in a much higher level of abstraction, generality and inclusiveness than the latter passage itself. It was designed to serve as an organizing or anchoring focus for the steel material and to relate it to the existing cognitive structure. Principle emphasis was placed, therefore, on the major similarities and differences between metals and alloys, their respective advantages and limitations, and the reasons for making and using alloys.[9]

The implied conception of disciplinary structure is that of a hierarchical classification of statements of knowledge in which the most general class characteristics are at the top and the most specific at the bottom. The paradigm for this conception is the biologists organism classification system. In Ausubel's words "a generalized model of class relationships is first provided as a general subsumer for <u>all</u> new classes, subclasses, and species before more limited subsumers are provided for the particular subclasses or species they encompass."[10] This amounts to the common "Principles of X" textbook although even more general statements of disciplinary knowledge than are ordinarily found in these texts may be initially required. The seven "conceptual schemes" of science published by the National Science Teachers Association is illustrative of such statements.[11]

The various disciplines have the same structural form in Ausubel's terms, although some, such as the social sciences, are broader at the base than are others, such as physics.

Bruner would have us organize the content of instruction into categories and sets of related categories. By convergent strategies of enquiry, the learner discovers the categories hidden from him by the curriculum. This is seen generally, in the following account of experimental procedure.

> Let us set before a subject all of the instances representing the various combinations of four attributes each with three values...An array of 81 cards, each varying in shape of figure, numbers of figures, color of figure, and number of borders... The subject is then told that we <u>have a concept in mind</u> (my emphasis) and that certain cards before him illustrate it, others do not, and that it is his task to determine what the concept is... His task is to choose cards for testing, one at a time, and after each choice, we will tell him whether the card is positive or negative. He may hazard an hypothesis after any choice of a card, but he may not offer more than one hypothesis after

> any particular choice... He is asked to arrive at the concept as efficiently as possible.[12]

In the main, this procedure describes Bruner's later work on student discovery of mathematical rules.[13] Here, students move from material manipulation and representation of the rules to symbolic manipulation and representation of the rules.

The implied conception of disciplinary structure is that of a set of related categories. For instance, the concept of biological continuity, the concept of tragedy in literature and the associative, distributive and communitive laws of mathematics become curriculum categories.[14] A further implication about structure is that the origins of knowledge reside in processes of classification and these processes are the same for researchers and learners. Bruner writes "The development of formal categories is, of course, tantamount to science-making..."[15] and "I shall operate on the assumption that discovery, whether by a schoolboy going it on his own or by a scientist cultivating the growing edge of his field, is in its essence a matter of ..."[16] Concepts, it is implied, exist at different levels of abstraction.

In brief, the implication in each of our psychologists is that of structure conceived in terms of outcomes of enquiry. Gagne emphasizes a hierarchy of logical dependencies while Ausubel emphasizes a hierarchy of inclusions. The latter conception is also suggested in Bruner's emphasis on categories. Bruner includes enquiry as a structural term and, in his treatment of enquiry as the discovery of categories implies, as does Ausubel in his treatment of outcomes as inclusion items, that knowledge exists as a kind of superclassification system.

What becomes of meaning and transfer in each of these conceptions? Our interest here is in the implied meaningfulness and transferability of disciplinary materials and not in behavioral performance, idiosyncratic cognitive structure or ability.

For Gagne meaning is a matter of upward prerequisite relations among knowledge units in a hierarchy. For instance, the meaningfulness of the statement "A contour line is a line of points of equal elevation" resides in its dependent relations with such statements and concepts as "A map is a pictoral representation of the dimensions of physical features","elevation", "sea level" and so on.[17] Transfer is a matter of the position of a meaningful statement in and among hierarchies. Thus, once the meaningfulness of "elevation" is established in its prerequisits "elevation" transfers meaning to the statement about maps. Likewise "elevation" transfers meaning to the statement "Atmospheric pressure is inversely related to altitude" in another hierarchy.

For Ausubel, meaning resides in downward relations among statements of knowledge in a hierarchy. Here, meaning is conferred by a prior and a more general statement upon a more specific statement. For instance, the meaningfulness of an account of the happenings leading up to and during Lincoln's presidency resides in the described happenings being instances of the characteristics of revolution generally. Transfer is a matter of a specific statement having similar characteristics to another meaningful specific belonging to the same general class. For example, a description of the revolutionary events in Cuba in the 1950's is meaningful by virtue of the meaningful structure established for the American Revolution. Similarity between specifics also gives rise to transfer between related hierarchies. Thus, in American History, the War of Independence, the American Revolution and the growth of representative government and the two party system have such similarities as the demand for minority rights and the influence of geographical diversity.

For Bruner, meaning resides in the properties and relations among categories. From our point of view, this amounts to intensive definitions of categories along with accounts of the way categories are related. For instance, a meaningful biological statement might read "Photosynthesis is the process by which some autotrophic organisms convert carbon dioxide and water into organic molecules in the presence of radiant energy. Respiration is ... Photosynthesis and respiration are materially related through biochemical conversion pathways and are functionally related in biological balances of various kinds". Furthermore, meaning exists at different levels of abstraction. Thus, it is meaningful to treat photosynthesis in terms of the difference in color and growth rate of plants grown in the dark and plants grown in the light. It is also meaningful to treat photosynthesis in terms of sequences of symbolically related chemical equations balanced in terms of atoms and calories. Transfer is a matter of attributes used for classification; it is also a matter of the formal similarities between categories of knowledge; and it is a matter of the generalizability of strategies of enquiry in classification. The meaning of the category "photo-chemistry" is transferred to photosynthesis via the attribute "light-energy". The meaning of the category "photo-reaction" is transferred to the category "enzymereaction" via the common formal properties of reactants, products and mediator. Strategies of enquiry used in the discovery of the category "photo-reaction" transfer to, and make more efficient, the discovery of the category "enzyme-reaction."

In short, each of our psychologists treat meaning and transfer in terms of the properties and relations of the products of disciplinary enquiry. We shall see that this is only part of the story.

Disciplinary Structures in New Curricula

For the most part, the terms used to account for the psychologists' conceptions of structure adequately account for the disciplinary structures of new curricula. For instance, Senesh and his group working in social science use a related set of concepts treated at various levels of abstraction at different grade levels.[18 19] Thus, in Economics concepts are described as being hierarchically organized and logically dependent upon one another with the "scarcity" concept at the top. The concept of specialization, for example, emerges "Because of scarcity, man has tried to develop materials to produce more in less time, or more with less material and in shorter time. Various types of specialization were discovered in order to overcome a conflict of unlimited wants and limited resources".[20]

The CHEM Study course treats structure in terms of concepts classified within concepts.[21] In the first set of chapters, a number of ideas such as atomic-molecular theory and chemical reactions are presented. A second set of chapters returns to these ideas in terms of such concepts as equilibrium and molecular structure. Finally, a third set of chapters deal with the ideas in details of, for example, elements and compounds. The use of broad generalizations as a structural element is seen in the BSCS biology materials.[22] Here, nine "themes", e.g. biological continuity, run throughout the course and serve to anchor concepts treated in different parts of the course.

The adoption of a coherent, stable and logically dependent disciplinary structure gives rise to three ways the new curricula misrepresent knowledge. These misrepresentations are, 1. A discipline has a single structure. 2. The outcomes of enquiry are coherent and durable. 3. Different statements of knowledge have the same logical status. Let us turn to these misrepresentations.

Curriculum developers have tended to treat disciplinary structure as something to be discovered and have asked "What is the structure of X?". The proper question is "In what terms should a discipline be structured for curricular purposes?". We have seen that logical prerequisite, concept inclusion, generalization and concept interrelationship may serve to describe disciplinary structure. It is also possible to describe disciplinary structure in terms of chronology, subject-matter (e.g. different types of organism in biology), points of interconnection with other disciplines, problems, and so on.

The choice and use of a single structure is critical when that structure is seen as something to be repeated in the curriculum at different grade levels. What happens to Senesh's economics over a twelve year span? Is an economic structure with scarcity at its apex and specialization as one of its major concepts appropriate to a "possible" local world of material plenty, automated job function, a massive leisure class, and a liberally educated people? Conceptual changes are commonplace in the sciences. Geneticists, for instance, no longer account for particulate inheritance, in terms of "beads-on-a-string". In the short run a curriculum based on a single conceptual structure represents the discipline as being conceptually stable; in the long run the discipline is represented as being unexpectedly unpredictable.

Associated with this misrepresentation is the failure of the curriculum to distinguish between the logical status of different statements of knowledge. Consider, for example, the two statements "Apes and Men have a common ancestral origin" and "Competition among three races of early man in South Africa gave rise to the dominance of one and to the extinction of the remaining two". The first statement amounts to an assumption in the study of hominid evolution. Its verifiability resides in the complexities of evolutionary theory and in lines of research such as comparative anatomy. While the meaning of "common ancestral origin" may change, we expect the statement per se to have considerable durability. The second statement must be taken much more tentatively than the first. Its verifiability is based, on the one hand, on a few bones and cultural artifacts found at one location in South Africa. On the other hand, the statement is verified in terms of the ecological concepts of competition and dominance each of which is subject to different meanings and each of which is debated upon in the research literature. These differences in meaning between the two statements are not reflected in a curriculum concerned merely with outcomes of enquiry.

Patterns of Enquiry

An alternative to conceptions of disciplinary structure in terms of outcomes of enquiry is one conceived in terms of the logical processes of disciplinary enquiry. My work in ecology is illustrative and uses as its structural unit a "pattern of enquiry".

A pattern of enquiry is a process in which principles of enquiry are specified to problem areas giving rise to a set of logical conditions for enquiry. Principles of enquiry are the concepts in which any given enquiry has its origin. For instance, a researcher may treat a school and its related units as a system of economic flows with inputs, translocation, outputs and sub-systems. Another researcher may treat the same school units as a set of structurally related parts each of which perform one or more administrative functions for the set.

According to Schwab, principles function in enquiry by providing the terms in which problems are formulated; by dictating the data required and, therefore, delimiting procedures necessary to obtain the data; and, finally, by providing the terms in which data are interpreted and new knowledge formulated.[23] This is illustrated by Schwab's account of the biological principle of structure-function.

> In this conception the 'whole' has its place. It is a 'going' concern with a certain character or nature. That character or nature is expressed through a number of capacities characteristic of it. Thus the character or nature we call 'animal' is expressed through a catalogue of capacities and activities as familiar as it is venerable, that is, ingestion, digestion, distribution and assimilation, excretion, locomotion, integration, reproduction, and so on ..... These capacities and activities, in turn, make certain demands. There are conditions that must be held within bounds and needs that must be supplied if they are to be maintained. It is here that the 'parts' play their role. They are servants of the whole, supplying its need as well as constituting its visible existence ...... Organs, in turn, may be treated as wholes while we investigate, as their parts, the tissues, the variety of cells, even the microstructures, which compose and maintain them ..... The leading question we are to ask in each such investigation is clear enough. What is the role of each part in the whole economy? It is at this point that the conception makes its crucial committment, sets forth the notion which is at once its greatest strength and its sorest point. That notion, the location of every part, and its observable actions of or in every part are all appropriate to, neatly fitting for, the role it plays in the whole.[24]

There are four such principles of biology. They are the principles of antecedent-consequent, structure-function, homeostasis and regulation.[25]

A problem area is a class of disciplinary problems. For instance, in the above school system illustration an economic problem is involved in the first statement and an administrative problem in the second statement. The analytic terms of a discipline are, in part, dependent on the problem area attacked. Accordingly, the problem areas, to a certain degree, require different data and exhibit different methods and techniques. Let us illustrate these differences by a brief comparison of the ecological problem areas of genecology and distribution.

The problem area of genecology is concerned with the genetic relationships between groups of organisms and their environment. Some of the major terms of genecology are ecotype, selection and gene frequency. One of the first problems in genecology is to determine whether different appearing populations do, in fact, represent two ecotypes or whether they merely reflect phenotypic plasticity. To obtain informative data reciprocal transplantation of representative members of the two populations is required. The transplant phenotypes are then compared with their new neighbours and with the parent populations.

The problem area of distribution is concerned with giving accounts of the kinds, numbers and distribution of organisms on the landscape. Some of the major distribution terms are population, density and distribution. One method of obtaining informative data is by quadrat sampling of the landscape (Quadrats are defined, localized spaces on the landscape). Organisms falling within the quadrat are classified, counted and their position noted. The composition of different quadrats is compared to other quadrats on the landscape.

I have described five problem areas in ecology.[26] They are the problems of classification and taxonomy, energetics, nutrition and metabolism, genecology, and distribution. Since patterns of enquiry arise from the specification of principles to problems there are a total of twenty possible patterns of ecological enquiry and, accordingly, twenty possible forms of statement of ecological knowledge. Each of these statements has its own logical status. Let us compare three patterns of enquiry and their resulting forms of knowledge.

Antecedent-Consequent - Classification and taxonomy: Here, communities are treated either in terms of the overlapping distributions of their component species with respect to environmental differences or in terms of the coassociation of their component species. In the first case data are collected on the distribution of species relative to environmental differences and gradiants. In the second case data are collected on the presence or absence of species or on the coassociation of species as determined, for instance, by distance between individuals techniques.

Classes are constructed on the basis of similarity between species with respect to either type of data. The resulting classification is thought of as being "arbitrary" and "objective".

Structure-Function - Classification and Taxonomy: Here, the community is conceived in terms of a set of "association" parts, identified by their dominant species and functionally associated with one another and with the whole community. Communities and their associations are tentatively described by an initial survey. Data are collected on the overlapping distributions of dominant species and, where communities do not fit the classification, on environmental conditions.

Communities are classified and named according to their dominant species or, for aberrant communities, according to the major environmental factor associated with the deviation.

Structure-Function - Energectics: Communities are conceived as systems of energy input, transfer and output. Each of these functions is brought about by one or more trophic level parts. Data are collected on species composition and species food habits. Quantitative data are collected on the biomass of trophic parts as well as on measures of energy metabolism, e.g. rate of production of carbon dioxide by the "dark-bottle" technique.

The data on species composition and food habits are used to construct a trophic level structure of the community. Each of the levels is seen as contributing to the overall energy balance and efficiency of the community as determined by the data on metabolism.

The significant difference between the first and second pattern of enquiry is one of principle and between the second and third pattern the significant difference is one of problem. The three resulting statements of knowledge cohere in terms of problems and principles.

According to this conception of structure, meaning is a matter of the relations of fact to outcomes of enquiry. The examination of patterns of enquiry allows for the articulation of knowledge with the subject-matter to which it relates. The student knows the grounds, limits and arguments for a statement of knowledge. The examination of patterns of enquiry in terms of problems and principles further increases meaning by articulating different forms of knowledge. For example, a statement in genecology is seen as being related in principle to a statement in classification and two classification statements are seen in terms of different principles and a common problem and not in terms of right and wrong.

Transfer is a matter of the degree of general use of the principles. For instance, ecologists, physiologists, sociologists and educators use, at one time or another, the principle of structure-function. The logical conditions imposed by principles are, of course, modified by problems and, to ensure maximum transfer, the curriculum planner must describe the modifications in principle brought about by problems. In a curriculum using a method of enquiry into enquiry[27] transfer becomes a matter of intelligent habit. I have described such a curriculum for ecology.[28] Here, the student uses original documents as his resource materials and engages in a discussion of the patterns of enquiry giving rise to different statements of knowledge. The student is trained to the habit of the recovery of meaning.[29]

COLLECTED FOOTNOTES

1Presented to Division B (Curriculum) of the American Educational Research Association, Los Angeles, California, 6 February 1969.

2See, for example, Heath, Robert W., Ed., "New Curricula," Harper and Row, New York, New York, 1964; Morrissett, Ed., "Concepts and Structure in the New Social Science Curricula," Social Science Education Consortium, Inc., West Lafayette, Indiana, 1966.

3Dewey, John, Logic: "The Theory of Inquiry," Chicago, Illinois, Holt, Rinehart and Winston, 1938.

4Ausubel, David P., "Some Psychological Aspects of the Structure of Knowledge," Education and the Structure of Knowledge, Stanley Elam, Editor, Chicago, Illinois, Rand McNally and Co., 1964, p.255.

5Bruner, Jerome S., Goodnow Jacqueline J., and George A. Austin, "A Study of Thinking," New York, New York, Science Editions, Inc., 1962.

6Ibid., p.14

7Gagne, Robert M., John R. Mayor, Helen L. Garstens and Noel E. Paradise, "Factors in Acquiring Knowledge of a Mathematical Task," Psychological Monographs, Vol. 76, No. 7, 1962, p.4.

8Ausubel, David P., "Some Psychological Aspects of the Structure of Knowledge," Education and the Structure of Knowledge, Stanley Elam, Editor, Chicago, Illinois, Rand McNally and Co., 1968, p.241

9Ausubel, David P., "The Use of Advance Organizers in the Learning and Retention of Meaningful Verbal Material," Journal of Education Psychology, 51, 1960, p.241.

10Ausubel, "Some Psychological Aspects of the Structure of Knowledge," p.241

11"Theory Into Action in Science Curriculum Development," NSTA Curriculum Committee, National Science Teachers Association, Washington, D.C., 1964.

12Bruner, Goodnow and Austin, "A Study of Thinking," p.83.

[13]Bruner, Jerome S., "Some Theorems on Instruction Illustrated With Reference to Mathematics," Theories of Learning and Instruction, The Sixty-third Yearbook of the National Society for the Study of Education, Ernest R. Hilgard, Editor, Chicago, Illinois, University of Chicago Press, 1964, 306-335.

[14]Bruner, Jerome S., "On Knowing: Essays for the Left Hand," Cambridge, Massachusetts, Harvard University Press, 1964, p.111.

[15]Bruner, Goodnow and Austin, "A Study of Thinking," p.6.

[16]Bruner, "On Knowing," p.82.

[17]I am indebted to my graduate curriculum class for this example.

[18]Senesh, Lawrence, "Organizing a Curriculum Around Social Science Concepts," Concepts and Structure in the New Social Science Curricula, Irving Morressett, Editor, 427 Wood Street, West Lafayette, Indiana, Social Science Education Consortium, Inc., 1966, 21-38.

[19]Senesh, Lawrence, "Economics", Social Science Education Consortium, Publication 105, 1966.

[20]Senesh, "Organizing a Curriculum Around Social Science Concepts", pp.25-26.

[21]Pimental, George C., Editor, "Chemistry: An Experimental Science", San Francisco, California, W.H. Freeman, 1963.

[22]Schwab, Joseph J., Biology Teachers Handbook, New York, New York, John Wiley and Sons, Inc., 1964, p.p.30-42.

[23]Schwab, Joseph J., "What Do Scientists Do?", Behavioral Science, V, 1960, 1-27

[24]Schwab, "Invitations to Investigate", Biology Teachers Handbook, pp.45. 226.

[25]The principles as described generally by Schwab are reported in Connelly, F. Michael, "Conceptual Structures in Ecology with Special Reference to an

Enquiry Curriculum in Ecology," Unpublished Doctoral Dissertation, University of Chicago, Department of Education, 1968.

[26]Connelly, "Conceptual Structures".

[27]Schwab, Joseph J., "The Teaching of Science as Enquiry", The Teaching of Science, Harvard University Press, Cambridge, Massachusetts, 1962, p.65.

[28]Connelly, "Conceptual Structures".

[29]"Recovery of meaning" is a term developed by Joseph Schwab in his book "College Curriculum and Student Protest," Chicago, Illinois, University of Chicago Press, 1969.