DOCUMENT RESUME

ED 129 559 SE 019 025

AUTHOR	Voelker, Alan M.
TITLE	Science Concept Learning: Needed Lines of Research.
PUB DATE	Mar 75
NOTE	30p.; Paper presented at the annual meeting of the National Association for Research in Science Teaching (48th, Los Angeles, California, March 17-20, 1975)
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS	*Concept Teaching; Curriculum; *Educational Research; Instruction; *Learning; Research; Research Methodology; *Research Needs; *Science Education; *Scientific Concepts
IDENTIFIERS	Research Reports

ABSTRACT

Six research areas are suggested and discussed as guidelines for the study of science concept learning. These areas are: (1) definition of a science concept, (2) a taxonomy of science concepts, (3) concept analysis, (4) diagnosis of science concept learning, (5) models for assessing science concept attainment, and (6) status assessment. The need for research in each area is explained in conjunction with comments on deficiencies in the current research in science concept learning. Also discussed are basic questions arising from the nature of science, the nature of learning, and the interactions which promote learning, and ways in which these questions can be built into a research framework. (MH)

SCIENCE CONCEPT LEARNING:
NEEDED LINES OF RESEARCH

By
Alan M. Voelker
Northern Illinois University

A paper presented at the 48th annual meeting of the National Association for Research in Science Teaching

Los Angeles
March, 1975

INTRODUCTION

The base for this paper is derived from many sources. They include personal study and research on science concept learning, affiliation with research projects in science education, perceived deficiencies in the development of school science programs, and the assessment of science concept learning. These concerns are not new.

It was the preparation of a paper on the status of research on science concept learning for ERIC which brought together a multitude of these concerns. During the preparation of that paper I realized why I had been so uneasy with research and development in science concept learning. In a nutshell, it was because we had not adequately done our homework and conducted enough basic research to provide theoretical structures to bring together our ongoing activities or, for that matter, to give direction to our future endeavors. These inadequacies were diluting the effectiveness of my own efforts and making it difficult for me to make sense out of others' work. The sum of all these involvements has necessitated the pursuit of organizational models and the specification of critical lines of research to guide research activity.

Another concern is an apparent down-grading of concept learning in science programs. On the surface it appears that dissatisfaction with science education program outcomes is taking science concept learning out of program design. This dilutes the conceptualization of science education, possibly placing science in the position of being a mere vehicle for research in educational psychology, etc. But science education is more than this.

Many difficulties are the result of forgetting, possibly never recognizing that science education and education in science are not identical. It is not my purpose to discuss that issue here, but to reaffirm that I believe that science education has a special domain. The absence of a satisfactory definition of that domain has detracted from developing models and related lines of research to guide our efforts.

THE RESEARCH REVIEW

In preparing the review of concept learning research the studies were categorized for convenience of discussion. The groupings were representative of the general nature of the studies. They provide a reasonable point of departure for organizing the balance of this paper.

Some pertinent points from each section, in abbreviated form, are presented here.

Cognitive Development

1. Some study of observation and classification.
2. Little evidence is provided about the quantity and quality of the experiences of students participating in studies.
3. Concepts are developmental--an obvious statement but often forgotten in planning and conducting relevant research.
4. Most factors affecting cognitive development reflect experiences.
5. Science is often a vehicle to study child development; little evidence of concern for the nature of the science stimulus.
6. All stages of development appear at all ages in the student population.

Factors Influencing Concept Formation

1. Factors related to experience and cognitive abilities are predominant.

2. There is no conclusive evidence about the role of I.Q. in concept formation.
3. Knowledge possessed is particularly influential.
4. The attributes and origins of the concept(s) under investigation are not usually considered.
5. Learners have little grasp about how knowledge is developed.
6. Assessment frameworks (Bloom, etc.) and development of concept attainment measures are largely ignored.

Level of Concept Attainment

1. Levels of concept attainment are influenced by interactions of experiences within and external to the school environment; criterial amounts and timing not really known.
2. Concept development is heavily associated with descriptions and the characteristics and properties of objects and phenomena; more concern for what than why.
3. Student's concept accuracy seems to be improving.
4. Older students develop multiple concept meanings, but understandings vary within all ages and all ability levels.
5. Interpretation of children's language development is inadequate; dependence on verbalization and concept definition penalizes children.
6. Available techniques for assessing concept attainment are unused and misused.
7. Experience and concrete stimuli are consistently the best vehicles for concept development and concept assessment.

Methodological Effects

1. Children's inability to generalize hinders the development of physical science concepts. Reasonable success begins to occur at the upper limit of the elementary school.
2. The nature of a concept influences whether it is best learned through school or non-school situations.
3. Children can and will learn what they consider to be low priority items.
4. Laboratory work is of little value unless the "investigator" has the necessary processing skills and is expected to process.
5. Awareness of the historical development of concepts might aid learners see how concepts develop and better develop those concepts themselves.

Methodological Comparisons

1. Children are not prepared to learn concepts inductively as the concepts evolved over time.
2. Programs designed for a specific purpose are superior in achieving their objectives than programs not designed for that purpose.
3. Students capable of abstract thinking can learn new concepts through abstract modes such as modeling and simulation.
4. Inadequate diagnosis of the pre-instructional situation continues to confound the results of studies; i.e., methods are inconsequential unless more is known about the learning environment and the entering disposition of the learner.

Curricular Content

1. Studies suffer from the failure to distinguish between conceptual knowledge, conceptual ideas, concepts, generalizations, and principles, etc. Completed studies both help and hinder us.
2. Researchers do not appear to consider replication necessary.
3. The emphasis is on the subject rather than the learner.

Instrument Development

1. One of the weakest areas in science concept learning.
2. General taxonomies of objectives, etc. are being indiscriminately applied in concept assessment without adequate consideration of the nature of concepts and their interrelationships.
3. Children's ability to communicate "their" way does not get a fair shake.

Reviews and Models

1. There are weaknesses in the conceptual frameworks underpinning research on science concept learning.
2. Science educators are in turmoil about who they are and what their mission is.
3. We are hide-bound to singular and aged perceptions on the nature of science and the nature of the learner.

Certainly these findings do not constitute a complete base for continuation activity, but they reveal much about the present state of the art, making it obvious that there are several inadequately explored areas.

The balance of the paper will focus on things that must be done in order to have any viability for theory generation and model testing. Without developing these areas it is not possible to raise appropriate research questions and determine the relative priorities of these questions. I will discuss some areas that need to be established or restructured as lines of research and in some instances make suggestions concerning research design. For some lines of research, pertinent questions will be included as an indication of the parts of a network to use in guiding future work on science concept learning.

NEEDED LINES OF RESEARCH

Based on the results of the aforementioned research analysis and subsequent study, it appears that at minimum the following lines of research on science concept learning need to be defined and followed--primarily as areas of basic research with only minimal concern about the implications for school programs and instructional material development. New knowledge and diagnosis should be the priorities.

1. Definition of a science concept
2. A taxonomy of science concepts
3. Concept analysis
4. Diagnosis of science concept learning
5. Models for assessing science concept attainment.
6. Status assessment

DEFINITION OF A SCIENCE CONCEPT

It may appear ridiculous to single out the definition of a science concept as a major line of research. But you need do only the most casual examination of the literature to give credibility to this position. There are many definitions of concepts in various writings. This is expected and tolerable in light of the nature of concepts, but the examples of science concepts eminating from use of these definitions are unacceptably wide and diverse. To allow the continuation of such capricious behavior is to suggest that science education has no character or structure.

To further emphasize this need, survey the concept definitions used in various methods books, research reports, and other pieces of science education literature. Examples are not often compatible with the definition and there is no discernible character to the various groups of examples. The lack of serious, scholarly study of this area conveys too many unintended messages and misconceptions to all science educators and the research quality is diluted.

If each of you were asked to list one basic science concept, I contend that most responses given would not share common attributes. Or if you were asked to pick concepts from the same sources, the lists would be widely varied. Even those who conduct research on science concept learning would not behave in predictable or identifiable manners.

We need to research the definition of a science concept to evolve a system by which all science educators, no matter what role they play, use common language and guidelines in a uniform manner. Without this, there is little usable research nor will there be quality developmental products.

The current status of the science concept definition has a further limitation of equal magnitude. That being the omission of the "process" concepts from the definition. Observation, classification, inference, experiment, model, prediction, etc. are themselves major science concepts which need to be incorporated into our definition of a science concept.

A TAXONOMY OF SCIENCE CONCEPTS

Once a definition of science concepts has been established we will have the base for generating the initial members of the universe of science concepts and recognizing new members of this set. It then behooves us to categorize these concepts. Concepts have attributes (properties and characteristics) which must be carefully identified before <u>any</u> research can be launched.

An examination of literature by scientists, psychologists, and science educators hints that some thought has been given to this need. However, much of what is written has not been conceived from the unique character of science education and all of the work has suffered from the lack of a definition which can generate a set of concepts with criterial attributes. Therefore, the work has remained at the level of generalization.

An examination of the historical development of science and child development shows some interesting parallels. There are parallels in the kinds of questions asked (What, How, Why), and the relative proportion of each kind of question asked as more concepts develop and as the respective concepts and their interrelationships become better known in number and sophistication. For example, in both endeavors an early activity focuses on the identification of properties and characteristics. A major outcome is a knowledge and perceptual base on which to build science concepts. Some science concepts relate primarily to the existing knowledge in science and others deal with how knowledge is initially developed and how its credibility is subsequently established.

Some concept development activity is based primarily on manipulation of attributes while other activities are oriented toward recognizing and seeking relations and forming abstractions. Each is successively less dependent on physical objects and things. And, whereas initial activity uses attributes much in the manner of classifying, in later instances specific instances of property or characteristic presence becomes less important as a single entity. Rather they are clues to ideas representing larger sets.

If one considers these general notions from the standpoint formation of a taxonomy, it appears that concepts could be classified into sets with common characteristics. With such a structure available, researchers and research users would have a solid base for their activities.

Initial examination of previous efforts indicates that some work already completed could become a base for this line of research. The superstructure of the taxonomy might approximate the following.

SCIENCE CONCEPTS

PRODUCT	PROCESS	OTHER
Classificatory		
Relational		
Theoretical		

Whether this or something else be the framework, a taxonomy of science concepts is needed to give order to what we have done and more importantly give direction to what we might and will do.

CONCEPT ANALYSIS

Following the formulation of a definition for science concepts and the development of a taxonomy of science concepts, it will be possible to establish a line of research to complete detailed analyses of the individual concepts. (Certain aspects of task analysis will be useful in this area, but will be only a part of a more comprehensive system.) This is necessary because there are differences between the acceptance and utilization of concepts in the discipline, and student's development and learning of science concepts are acquired by students in much the same manner as they evolved within the scientific community. But we have not determined what these might be. There are other science concepts that learners have little hope of learning in the way they were created in science. At best, we can give them samples of the types of activities which played a role in the historical development of a concept so they can perceive some association of the role of time, experience, and human intellect in concept formation.

There are concepts which students will have to acquire through teacher directed mechanisms. They can "visualize" inputs which aided the evolution of these concepts, which will in part illustrate how concepts have variations in development, sophistication, and application. Concepts of this nature will be learned in the form they are currently used in the scientific community. Not all science concepts can be "learned" in the inductive sense. But students can learn how concepts are developed, changes they undergo with time, and see applications of some concepts. Some classificatory concepts can be learned in approximately the manner they were developed in the scientific community while abstract and theoretical concepts will be acquired in terms of their current existence and their means of application.

For example, classificatory concepts such as plant and animal can be learned in an inductive fashion and concepts such as physical change and chemical change can be learned in a classifying mode. But these latter concepts have limitations in the learner's world. There is a limit on the degree of sophistication that can be attained for these concepts in relation to their association with concrete phenomena. And without an analysis of the character of these concepts there is no base for making research plans on what the students did learn, can learn or when, where, and how that learning occurred.

Then there are concepts such as ionic bond and covalent bond which are predominantly theoretical in nature. True, they have origins in and associations with physical phenomena, but with the limitations on the processing ability of the learner and the nature of the instructional process, we can expect learners to experience difficulty with formulating these concepts. It will be difficult to provide more than a few samples of the types of phenomena and situations from which the concepts were derived (after the fact). In this instance, the learner processes inputs in a different way than with plants or animals and the expectation for use of the "learned" concepts is markedly different. There is more emphasis on using the concept to account for phenomena in the existing environment than trying to formulate the concept as the scientist did.

Without analysis of concept categories sense as implied in a taxonomy of science concepts there is no basis for research on science concept learning or the application of research knowledge in the development or assessment of science programs.

DIAGNOSIS OF SCIENCE CONCEPT LEARNING

I'll preface this section with a statement of personal belief. An inordinate amount of emphasis has been devoted to program development under the guise of research. The investigative activities of our community have focused on developing and evaluating materials, programs, etc. with only minimal consideration for the underpinning nature of the discipline of science or the inherent characteristics and skills of the learner. Curricular content and related instruction have been constructed from the perspective of the developer and then the learner is manipulated to achieve prescribed outcomes. (How can we get him to respond rather than How can we respond to him.) We should have been concentrating on the nature of the learner and then manipulating the discipline to maximize the probability that a student learns something consistent with his capabilities; studying how this relates to our idealized structures. We should be about creating structures which are responsive to students rather than using research in child development and learning to manipulate the learner to our own ends.

The researcher in science concept learning should probably forget about the development of programs and materials. Rather he should concentrate on developing diagnosis structures to use in judging the potential of materials and programs in both the preparatory form and the utilization mode. Emphasis should be placed on developing new knowledge about science concept learning rather than evaluating the temporary impact of sets of existing materials. Materials used in such research should be discarded soon after they are used (except in the case of replication) for the structure of the materials is the more important factor.

Consider the child development research related to stages of cognitive development. Our task should be to research systems for assessing where students "are" so that those selecting curricular content and planning instructional strategies have a base for deciding the kinds of lateral experiences from which children might benefit. "Grade placement" from this approach would be far more powerful than the imposition of an instructional sequence that is severely limited to conditions of the moment. Determining an exact structure for a vertical program is inconsequential in relation to finding ways to determine how the child is progressing, either vertically or laterally.

We should also be extremely cautious about postulations on the use of science materials and inquiry based science programs in advancing stages of intellectual development. At best, what such programs might do is provide opportunities for a youngster to more readily demonstrate his existing stages.

Once we have accepted the research role to be the development of new knowledge about the nature of and the learning of science concepts, we can give diagnosis its due. For it is determining what children learned and possibly can learn, and how they attack the learning situation--conceptually, operationally, etc. that gives us planning clues for some related development and evaluation activities.

For example, is it important to find that children use the concept label "plant" after reading prose material or playing with plants in the classroom? Or is it more important to find that when a child is asked to "tell about" a plant or a group of plants that he does not operate on those plants at all, and that his verbalization about the plant deals exclusively with gross physical properties of single plants, that he treats each plant as a separate entity revealing nothing about the character of the set. In the sense of the discussion, it would be the latter. And until we know such things from basic research sense does it really make any difference what form of instruction we provide?

Such work would eliminate much research as presently conceived. What would be accomplished is to determine how we might respond to where the child is in terms of what we desire for students to learn rather than predetermining the structure of what to learn and how to learn it and then see how the student copes with our structured framework.

MODELS FOR ASSESSING SCIENCE CONCEPT ATTAINMENT

From the framework of definitions, taxonomies, analyses, and diagnosis, it follows that models can be developed to assess science concept attainment, models which can account for much of what we already have available. If they are good models we should be able to make and test predictions about science concept learning. In addition to the models which might evolve from the existing state of research on science concept learning, there is a necessity for formulating many new models.

In formulating models factors which must be considered include the following:

The nature of the concept(s) under consideration

Attributes of concepts deemed important in science education

The pre-assessed nature of the learner(s) involved--gross generalizations such as the need for concrete experiences are inadequate.

The nature of the situation in which the research is to be conducted.

The means for obtaining data about the learning

Structure for evolving the content of curriculum and determining the potentially better instructional mechanisms.

A structure for learning that is a compromise between the nature of the discipline (our imposed philosophy) and the nature of the learner; one that favors the learner in all instances of debate.

When these factors are considered there logically follows the need to start carefully manipulating the variables so that we have control over the interaction results.

STATUS ASSESSMENT

We are all fully aware that the input for concept development comes from sources internal and external to school environments. Further, inputs from both these sources aid and inhibit the initial formation of concepts and their later refinement and comprehensiveness. Because we know these things it is surprising that we continue to place so much dependence on the school inputs; attributing cause to these inputs. This is especially surprising when we acknowledge the evolution of concepts in the discipline and in the learner. It is the accumulation of all inputs over time that is the source of concept development, school inputs being only one of many inputs and in many instances being presented in conflict to what we know about the development of concepts and find we didn't find out about the learner.

Thus, we should develop and maintain a line of research expressly for the status assessment of concept development. Its sole purpose, at least its major one, would be to establish the data base for calculating general shifts in concept development across populations, ultimately a help to curriculum developers and materials makers. The concern would be for the development of concepts by persons found at various points in schooling situations; attributes that have been learned, might be learned, are being learned sooner, and general changes in learning support systems. Less emphasis would be given to specificity of the nature and diversity of inputs but to the general progress in development of concepts and their attributes and their relationships within various segments of populations.

There should be little concern for the applied aspects of this line of research. The investigators should not be concerned whether program developers will use the results in a few months. The task should be solely to study the status of concept development.

The results of such work could be the research data base for continuing other types of research on science concept learning, particularly in the are of curriculum structures and general instructional strategies. Of equal importance to the field would be the development of models and techniques for measuring concept attainment through the multimethod--which we don't currently use (have).

We would also derive from this line of research theoretical ideas on helping students in school extend their learning through using all inputs: learning how to learn concepts, learning how concepts are developed, and learning the concepts themselves. We spend too much time "assessing" small, fragmented, school restricted, biased inputs. We should look for what overall payoffs might be coming from an accumulation of many pieces, some known and others not.

Such research will be enhanced by obtaining large amounts of data about the participants. Longitudinal studies with smaller N are certainly in order. Data should include:

1. Non-school experiences
2. Cognitive abilities
3. General knowledge
4. Perceptual abilities
5. Language development
6. Personal perceptions on important inputs
7. Self-esteem
8. Interests
9. Any data which will give us an indication of existing knowledge, ability to process that knowledge and new inputs; ideas about former opportunities to process and learn how to process. Information about school environments would be only one subset of this total information gathering activity.

Establishing lines of research on science concept learning necessitates re-examining the questions we need to ask. Hints as to these questions can be found in several sources, but usually they are treated in isolation from a total framework. To place a semblance of order on our research it is necessary to put these fragments together in a comprehensive whole so that we pursue answers to singular questions in the total perspective.

Researchable questions on science concept learning can be lumped into a limited number of categories which delineate the main thrusts of the science educator. Major categories are the nature of science, the learner, curriculum, and instruction. And, there are replication and longitudinal studies.

Nature of science

There are many unanswered questions related to the nature of science and the science concept learning. Such deficiencies continue to dilute our research efforts and, if allowed to persist, will cause all efforts in this area to be of questionable value to the research community and other consumers of research products. Some of the pertinent questions are these:

1. What is a concept? We have yet to answer this question in a way that communicates the same thing to all users of science concepts. We are unable to differentiate between concepts, principles, generalizations, etc. in ways to improve research or develop instructional products. The character of a science concept must be clarified and illustrated with concrete examples.
2. What are the science concepts? Systematic study must be made to identify and specify what the science concepts are. Without this identification we have no structures for guiding research or even communicating among our members.
3. What are the characteristics and attributes of the concepts identified in (2) above? What similarities and differences exist between and among the various kinds of science concepts? Without pursuit of these questions we have no base for conducting research or using the results of our inquiry.

4. How are concepts related and interrelated, from the historical and current perspectives of the discipline and particularly from the perspectives of learners? All the talk about concept complexity, sophistication, hierarchies, etc. has a weak structural base from research. There is high level jargonese, but this will do little to facilitate research until it passes beyond hypothetical and definitional levels.
5. What are the clues to the historical development of concepts? How do aspects of the historical evolution and development of science concepts relate to the learner's stages of development and learning characteristics?
6. What kinds of concepts and conceptual structures do we <u>want</u> in the science curriculum--from the perspective of science, society, and learner <u>interaction</u>? We need both general and specific structures from each point of entry to make judgments about priority areas for pursuing research.

<u>The Learner</u>

Much research on science concept learning has been too oriented toward producing predetermined outcomes in <u>the</u> learning situation rather than providing a situation where learning might take place. We pay little attention to the predisposition of the learner except to make broad generalizations such as, "the child is in the concrete operations stage." We should show concern for materials to help students learn selected concepts, but we should shift the priority toward finding out what he knows, how he can use what he knows and, especially, how he processes existing and encountered experiences in new and novel situations. Our consideration should then be for defining situations from which the learner, in his given state, might benefit primarily in the lateral sense and maybe acquire breadth of input and process to eventually foster vertical progression as potential and circumstance permit.

Some priority questions in this category are these:

1. What does the learner know? Does he possess multiple interpretations of concepts and their relationships?
2. What intellectual and cognitive skills does he possess which might enhance the probability of learning selected concepts and their attributes?
3. Given the existing state of the learner's potential for learning, what types of similar concepts and structures might he be able to learn? Can we generalize across types of concepts and skills? What is the learner's degree of readiness--concept types, levels of concept sophistication, etc.?
4. How does and is the learner able to communicate the state of his existing conceptual knowledge? How does he act on materials- under guidance? in "free" situations?
5. How does a learner process information and in what situations? How many variables can be handled at once? Is the number constant or situational?
6. What is the learner's perception of how knowledge is developed in science as well as by himself?
7. What are the sources of input that the learner uses in formulating concepts? from his perspective? from the researcher's perspective? What new inputs are critical cues to action?

8. What are the learner's personal characteristics--cognitive ability, educational set, perceptions of himself and the learning environment?

Curriculum

Research on conceptually oriented curricula needs to take a 180 degree phase shift. No matter what we say, our curricula have been developed from the standpoint of the discipline. There has been some consideration of child development and learning in the preparatory stages. But in the final analysis the focus has been on making the science "interesting for" and "compatible with" the students instead of evolving programs from student interest and ability.

We need to refine the structure of the discipline in light of the goals of science education. From that point forward, however, the discipline should be a guiding framework against which we assess what children are learning and might learn rather than using it to determine what children should learn. (Of course, the real position is somewhere in between, but we must give the learner more than token consideration.) The learner must become our point of entry.

Some priority lines of research on curriculum are these:

1. What general categories of science concepts can be placed at "general" points in the curriculum? Category and attribute placement is more important than determining where any one concept might be taught. Concepts have multiple variations, both horizontal and vertical; what facets of concepts that children can learn, "should be" included in curricula? Further, much of the symbolism and communication mechanisms in science have little relevance to the learner world.

2. What models can be evolved and tested to keep abreast of the changing nature of the learner, concept development and refinement in science, and changes in the society? What systems can be evolved to determine what should be deleted, what deserves retention and what should be added for new knowledge development and new societal applications?
3. What science concepts and their applications actually have a connection to the world of the learner and the citizen? Which of these concepts really give the possessor any better control over his situation and survival? What science concepts do citizens apply, consciously and/or subconsciously, in their world?
4. What science concepts do citizens utilize in decision-making about science and technology? When, where, and how do they apply them?

Instruction

Each of the earlier frameworks needs substantial refinement before we can do productive work in this area; an area including the development of learning situations and instructional materials for both school and nonschool science education programs.

1. Under what conditions are students learning concepts and their attributes, emphasizing what they learn from the situation more than determining what they should learn and stating that they did or did not. What students profit from moving laterally and/or vertically? Are vertical gains better derived from an accumulation of varied lateral experiences than narrowed, prescribed vertical experiences?

2. What kinds of materials benefit students with preassessed learner characteristics? What benefits students with certain learning styles and preferences for learning modes?
3. What effect does closure have on concept learning? Are the effects of reinforcement, cueing, advance organizers, questions specific to kinds of concepts and learning situations?

Replication

Replication is one of the most neglected areas of research in science concept learning. The sweeping generalizations which arise from the single study are atrocious. We have little idea whether the results of our studies are reproducible and what degree of predictability exists in the learning situations we contrive. Do we get consistent results when we change a single variable? One area where we are especially derelict is the determination of the degree of learner readiness for kinds of concepts and the relationships. To replicate the same study many times would be especially valuable compared to the research we are doing now. This is particularly true when we use so little information about the nonschool experiences students bring to the learning situation and the learner's personal characteristics.

Longitudinal Studies

I can think of only an instance or two where research on science concept learning has been concerned with longitudinal study. Our reason is that few science educators are engaged in basic research. Also, the members of our community with established lines of research are few in number. There have been some longitudinal studies related to general achievement but these are only peripherally related to the requirements for research on science concept learning.

Studies that should be pursued include these:

1. What concept types and concept attributes do students learn over time? Are these predominantly biological, earth, or physical science concepts? How do the proportions of concepts and concept attributes change with time and stages of development?
2. How does students' ability to process science information and contextual situations change with time? and other variables?
3. Does concept sophistication change continually and gradually or does it take quantum jumps? How much lateral refinement of a concept occurs before vertical development of that concept and others is exhibited?
4. How does the contextual application of certain concepts evolve over time?
5. What influences do school <u>and</u> nonschool experiences have on concept development? Are there dramatic shifts in school learning that coincide with cultural happenings and historical events of the broader society? Are there key interactions of school and nonschool experience that coincide with student advances in learning?
6. What relationships exist between developmental stages, self-esteem and the ability to learn specific concepts and process information?

SUMMARY

As you read this paper, it may appear that I have said nothing new. This is true if one considers only the pieces However, if one examines the whole rather than any one of the parts, at least one major point has been made. We are approaching research on science concept learning from a reductionist approach before we have grasped the big picture. Absent is the overarching structure and the critical lines of research which must be pursued first, or at least given equal time in thought and activity, before we can cut through the morass.

This is one time when a deductive approach takes preference over an inductive approach. Only by taking a deductive approach can we derive an adequate guiding framework to check hypotheses on children's learning of concepts and arrive at some general postulations about science concept learning. As an initial step in that endeavor I have tried to identify some priority lines of research and provide clues as to the research questions and research designs. These areas have not been sufficiently explored that we could proceed with productive research on science concept learning.

Further, I have stressed that we need to be more concerned with basic research that is less bound to packaged programs and manipulations of students under school learning conditions. Rather than trying to prove that programs can "advance" concept learning and stages of development, we should be trying to find out how various programs, materials, situations, etc. give students opportunities to process the information he already has with that of the new situation. We should be looking at the potential for school learning as much as trying to attribute Herculean outputs to it.

We spend a disproportionate amount of time on applied, mission-oriented research. We chase fool's gold and try to prove things that we can't prove. And if we didn't prove what we wanted to prove, we rationalize how the study got messed up. We should devote more time to producing data and structures that can be used to demonstrate why things shouldn't or can't be done in school programs, instead of chasing after data which has no pertinence other than in the frame of the single study. Let's pursue research which gives us better understanding of concepts learned, inputs that might have influenced the learning, how children think in and about science related areas, how learners process information, and logic used.

We should emphasize what has been learned from and what might be learned from various situations instead of pushing the learning of specific things under specific conditions. We should seek evidence to help establish learning situations and learning possibilities rather than insisting on definite outcomes. In the long run we'll better maximize opportunities for learners to acquire the concepts we'd "like him to learn" or those concepts he'd "like to learn." We should seek information about the development of science concepts <u>in</u> people and how they learn them as much as teaching concepts to people; some of no relevance and others which they cannot learn or do not have the necessary base for learning.

Further intimated in my discussion is that more research must be conducted by the old-timers; i.e., those who have their license and have had ample opportunity to develop one or more lines of research. We cannot afford to have the bulk of the research done by doctoral students who are not part of research teams, nor to have studies done essentially as an adjunct to a developmental project. This may even mean that the choice of a research project for an individual student is determined by the lines of research in existence at the institution; i.e., there are ample choices to conduct one of several studies fitting the framework of an existing line of research. (I do not believe that this is an infringement on the rights of the individual. In fact, to continue to adhere to the "free" choice routine is an infringement on the rights and responsibilities of the research community.)

Above all, I have tried to emphasize that we need to seek guiding frameworks for our research. Certainly, there are theoretical notions and models in other fields that need verification in science education, but if there is nothing unique to science education, then we should cease to use the label. Without criterial attributes, we don't exist.

We should seek that which is repeatable and consistent and eliminate those things which are not. But such searches cannot be conducted without an overarching framework for those searches. Our work to date has provided hints and suggestions about research, a clue to possible structures, but the general framework is missing. Individual researchers might sense a piece of the puzzle but the dimensions are not refined or clearly communicated. To continue this hodgepodge is embarrassing, and even more so, it leads us to chase low priority questions. We need to start thinking like researchers and less as program developers and package evaluators.

The needed lines of research in science concept learning are focused around a small number of basic questions stemming from the nature of science, the nature of the learner, and the interactions which promote learning. Responding to the nature of the learner with the nature of science concepts as a guiding frame to what might and can be learned is the appropriate direction. To conduct research on science concept learning from a lesser frame is suspect.

REFERENCES

Anderson, R. and Kulhary, R. "Learning Concepts from Definitions." AMERICAN EDUCATIONAL RESEARCH JOURNAL. Vol. 9, No. 3, 385-390; Summer 1972.

Barber, B. SCIENCE AND THE SOCIAL ORDER. Collier.

Clark, C. and McDonald, F. "Selection of Defining Properties in Concept Attainment." JOURNAL OF EDUCATIONAL PSYCHOLOGY. Vol. 59, No. 5, 328-333; October 1968.

Fowler, W. "Concept Learning in Early Childhood." YOUNG CHILDREN. Vol. 21, No. 2, 81-91; November 1965.

Frayer, A., Ghatala, E., and Klausmeier, H. "Levels of Concept Mastery: Implication for Instruction." EDUCATIONAL TECHNOLOGY. Vol. 12, 23-29; 1972.

Gagne, R. THE CONDITIONS OF LEARNING (2nd Ed.) Holt, Rinehart, and Winston.

Jacobson, L., Dickinson, T., Fleishman and Haraguchi and Stone, R. "Relationship of Intelligence and Mediating Processes to Concept Learning." JOURNAL OF EDUCATIONAL PSYCHOLOGY. Vol. 60, No. 2, 109-112; April 1969.

Johnson, P., Curran, T., and Cox, D. "A Model for Knowledge of Concepts in Science." JOURNAL OF RESEARCH IN SCIENCE TEACHING. Vol. 8, No. 1, 91-95; 1971.

Kemeny. A PHILOSOPHER LOOKS AT SCIENCE. Van Nostrand.

Koran, J. "Concepts and Concept-Formation in the Teaching of Biology." THE AMERICAN BIOLOGY TEACHER. October 1971.

Kuhn, T. THE STRUCTURE OF SCIENTIFIC REVOLUTIONS (2nd Ed.) University of Chicago Press.

Nagel, E. THE STRUCTURE OF SCIENCE. Harcourt, Brace and World.

Nash, L. THE NATURE OF THE NATURAL SCIENCES. Little Brown.

Nelson, K. "The Relation of Form Recognition to Concept Development." CHILD DEVELOPMENT. Vol. 43, No. 1, 67-74; March 1972.

Novak, J. "A Model for the Interpretation and Analysis of Concept Formation." JOURNAL OF RESEARCH IN SCIENCE TEACHING. Vol. 3, No. 1, 72-83; 1965.

Pella, M. "Concept Learning in Science." SCIENCE TEACHER. 33, 31-34; 1966.

Raven, R. "A Multivariate Analysis of Task Dimensions Related to Science Concept Learning Difficulties in Preschool Children." JOURNAL OF RESEARCH IN SCIENCE TEACHING. Vol. 9, No. 3, 207-212; September 1972.

Rowe, M. TEACHING SCIENCE AS CONTINUOUS INQUIRY. McGraw-Hill.

Russell, D. CHILDREN'S THINKING. Blaisdell.

Voelker, A. "Concept Learning in Science." Unpublished working paper. Wisconsin R & D Center.

Voelker, A. "Concept Learning in the Science Curriculum, K-12." In Martorella, P. CONCEPT LEARNING: DESIGNS FOR INSTRUCTION. Intext.

Voelker, A. "Concept Teaching and the Nature of the Scientific Enterprise." SCHOOL SCIENCE AND MATHEMATICS. Vol. 69, No. 1, 3-8; 1969.

Voelker, A. "Research on Concept Learning: An Analysis." Occasional Paper #11. ERIC/SMEAC.

Voelker, A. "Teaching the Concepts Physical Change and Chemical Change to Elementary School Children--A Replication." JOURNAL OF RESEARCH IN SCIENCE TEACHING. In Press.

Vygotsky, L. THOUGHT AND LANGUAGE. Wiley.

Walker, M. THE NATURE OF SCIENTIFIC THOUGHT. Spectrum.

Wilson, J. "Processes of Scientific Inquiry: A Model for Teaching and Learning Science." SCIENCE EDUCATION. Vol. 58, No. 1, 127-133; 1974.