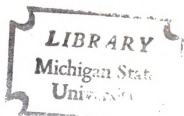


A MODEL TO FACILITATE
THE ASSESSMENT OF EPISTEMOLOGICAL
QUALITY IN ELEMENTARY
SCIENCE PROGRAMS

A Dissertation
for the Degree of Ph. D.
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Paul S. Knecht
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This is to certify that the

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A MODEL TO FACILITATE THE ASSESSMENT OF
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Paul S. Knecht

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ABSTRACT

A MODEL TO FACILITATE THE ASSESSMENT OF EPISTEMOLOGICAL QUALITY IN ELEMENTARY SCIENCE PROGRAMS

by
Paul S. Knecht

The Problem

In recent years for practical reasons, some science educators have called for an abrupt change of emphasis from what we know to how we know, thus directing attention to an often neglected issue: the meaning of what we claim to know depends heavily on how we arrive at the claim. The basic assumption of this study is that "knowing" in science is meaningful only as it is operationally defined. The NSTA Position Statement on "School Science Education for the 70's", out of which this study developed, is interpreted here as saying that by knowing how we know we acquire an awareness of some fundamental strengths and limitations of scientific knowledge that contributes greatly to our ability to use such knowledge more effectively in meeting human needs than we otherwise could. This perception of the nature of scientific knowledge is called "scientific literacy", and is put forward by the NSTA as the

comprehensive goal for science education. What then, are the characteristics of science programs most likely to contribute to the achievement of scientific literacy? This study is an attempt to develop a sound philosophical basis from which to derive those characteristics, and to build a model based on them for comparing the quality of elementary science programs against this stated goal for science education.

Further Assumptions and Methodology

The philosophical stance developed in the study incorporates these additional assumptions:

1. that meaning is derived from sensory experience and not from words, which serve by mutual agreement as labels for experiences we have shared.
2. that the distinction between physical objects and all other "things" that words can name is basic to the structure of scientific knowledge and must be maintained in the pursuit of scientific literacy.
3. that science education programs can be evaluated usefully by examining the materials used in them: text books, teacher guides, laboratory equipment, and supplies.
4. that the assessment of epistemological quality must be made at the level of specific knowledge claims intended for student instruction.
5. and finally, that children do seek meaning and that they have the capacity of independent reason.

Based on these assumptions, the argument is developed as follows: the emphasis in science programs should be on clarifying the basis for knowledge claims and, since knowledge claims are not all derived from the same basis, they must be distinguished in terms of how they may be "verified". Knowledge claims about word usage and meaning (analytic statements) are to be distinguished from those that may be verified by direct observation of natural phenomena (synthetic statements) and these in turn from those that inform as to our interpretations of such observations (theoretic statements). But knowledge claims must be extricated from the text and this becomes feasible only by devising a procedure for classifying all sentences according to the functions they perform, those identified above becoming then, sub-classifications of sentences whose function is to make knowledge claims. This procedure and procedures for sampling and recording data were worked out empirically using Concepts In Science as a referent program. Data from the sentence sorting procedure provide the input for a sample profile that is most revealing of its character and quality. After isolating the knowledge claims, a series of questions directs the investigation of how the program clarifies the basis on which each claim is made. Recognizing the problems inherent in the concept of verification, this basic model was chosen for implementation:

- 1) Discover what function a sentence is intended to perform.
- 2) Determine in advance what would constitute verification.
- 3) Examine the material to see if it has been provided.

Synthetic statements were singled out for examination in this study and data was gathered on five variables for each knowledge claim. After the model proved adequate to the analysis of the Concepts In Science program, its general applicability was tested on the SCIS program and only minor modifications were necessary. Data gathered with the aid of the model are in well defined categories and provide a very solid basis for making judgments about the epistemological quality of programs.

Results and Conclusions

In one sample examined, the data show that theoretic statements predominate, conditions are generally not specified, little evidence is provided, faulty logic is employed, examination of evidence is generally obviated, and techniques for prodding students to evaluate the quality of the knowledge claims are lacking. Extensive use is made of a literary device and picture combination that create an illusion of examining evidence, which is misleading and illegitimate. "The Sun is the Earth's chief source of radiant energy", is referred to as an "event" which has "attributes" and which could be "predicted" from "one signal, say a lump of coal." Thus words, in this sample, are used in strange ways, the approach is deductive and the epistemological quality was judged to be unacceptable.

In the other sample, analytic statements dominate, conditions are more frequently specified, direct observation of natural phenomena is characteristically the method of verification, the need to examine evidence was obviated in only one instance, and students are continually prodded to evaluate the quality of the knowledge claims. The approach is inductive and, the epistemological quality of this

sample, was judged to be good.

The model facilitated discovery of these differences in the epistemological quality of the two samples, and further research is now needed to establish efficient sampling methods and to assess the precision of results among different analysts using the sentence sorting procedure. Recommendations are included for expansion of the analytic statement portion of the model, which should prove especially applicable to early elementary materials, and for development of criteria to evaluate support provided for theoretic statements at upper levels. It is hoped that this functioning prototype may be further developed by concerned people to the point where research in this area can be replicated, and that this will result in significant curriculum improvement that may accelerate progress in the direction of scientific literacy.

A MODEL TO FACILITATE
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IN ELEMENTARY SCIENCE PROGRAMS

By

Paul S. Knecht ^{Stanley}

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CHAPTER I

PURPOSE AND OVERVIEW OF THE STUDY

This study is an attempt to develop a sound philosophical basis upon which to build a model for estimating the potential contribution of elementary science programs toward achieving the stated goals of science education, and to build such a model.

Background and Need for the Study

Leading science educators, facing the rapid pace of change and realizing that today's toddlers will spend their adulthood in the twenty first century, have moved to an emphasis on how scientific knowledge is acquired rather than what scientific knowledge has been acquired. This move is both practical and revolutionary: practical because it has already become impossible to select from the vast output of scientific knowledge what should be included in courses, and revolutionary because it moves the teaching of science into the realm of philosophy by raising the question of how things are known. This question belongs to the branch of philosophy known as epistemology and if it is to become a principal focus of science education, traditional goal statements must be abandoned in favor of the new goals reflecting this thinking. Berkheimer and the NSTA Committee on Curriculum Studies K-12, have formulated such

goals and summarized them in the NSTA position paper, School Science Education for the 70's.¹ In this study an attempt will be made to draw from the literature, information about the nature of knowledge that is relevant to the goals of science education, and to bring it to bear on the problems of program evaluation.

Some systematic method of evaluating the epistemological content and quality of programs is badly needed, i.e., a method is needed for looking at whether and in what ways programs make clear the basis on which knowledge is claimed. It is highly desirable further, that methods be developed that will allow comparisons, based on objective data in well defined categories so that independent researchers can replicate the findings of others and thereby develop substantial evidence of the comparative quality of science programs. Analytical techniques for this kind of evaluation involve a meaningful integration of the nature of language and the nature of scientific knowledge, organized into a workable format for examining programs. This is what the present study undertakes to develop.

Douglas A. Roberts of the Ontario Institute for Studies in Education describes this area of investigation as "highly

¹Preprinted from The Science Teacher Volume 38, Number 8, November 1971, by the National Science Teachers Association.

promising but relatively undeveloped.¹ He is an active researcher in this field and expresses his deep concern that science education "as ordinarily conducted is having a detrimental impact to which most science teachers have not been sensitized." The reason, he hypothesizes, is that "we lack well developed conceptual frame works by which to understand all of what we are doing to learners."² The model undertaken for development in this study is designed to bring to light certain program characteristics to which every child is exposed but which seldom receive any notice i.e., the ways that programs support scientific knowledge claims. An essential part of this study is the development of distinctions among analytic, synthetic, and theoretic statements, and Wilson's argument that authors must maintain such distinctions if we are to understand what they are saying. A number of other program qualities will come to light which are fully developed in Chapter II.

Assumptions, Argument, and Terms Used

This study assumes that:

1. the goals of science education as formulated by Berkheimer and the NSTA Committee, and subsumed under the rubric of

¹Douglas A. Roberts in Forward to Brent Kilbourne, Analyzing the Basis for Knowledge Claims in Science Text Books: A Method and a Case Study, The Explanatory Modes Project Background Paper No. 6 (Toronto, The Ontario Institute for Studies in Education) 1971, p. 1.

²Douglas A. Roberts, "About the Explanatory Modes Project," Bulletin #2. The Explanatory Modes Project. (Toronto, The Ontario Institute for Studies in Education) 1972.

"scientific literacy", are worthy goals to be used as the standard for evaluation of science programs K-12 throughout the nation.

2. science education programs can be usefully evaluated by examining the materials they require: textbooks, teacher guides, and laboratory equipment and supplies.
3. the investigation must be conducted at the level of specific knowledge claims which are content material for student instruction.
4. knowledge claims in science are meaningful only as they are operationally defined. This fundamental premise is the working principle of the entire model.
5. knowledge arises from experiences of the phenomena of nature and not from contemplation of the meaning of words, which serve only as labels arbitrarily assigned to identify experiences.
6. the distinction between physical objects and all other "things" that words can be used to name, is basic to the structure of scientific knowledge, consequently to scientific literacy.

The argument may be summarized as follows:

1. The emphasis in science education should be on clarifying the basis for knowledge claims.
2. Knowledge claims do not all rest on the same kind of basis.
3. Science programs must therefore distinguish between knowledge claims in terms of how they are "verified".

4. Since the meaning of a sentence depends heavily on the speaker's intent, the author is obligated to make his intentions clear.
5. Certain kinds of statements are believed on the basis of evidence: for such statements, provision of defensible evidence is a requirement of acceptable programs.
6. A knowledge claim and its evidential support must be such that the student might reasonably be expected to appreciate the force of the evidence as support for the knowledge claim. The argument is fully developed in Chapter II.

The following terms are used in this dissertation in the sense indicated.

Scientific literacy is a comprehensive expression that sums up the goals of science education as set forth in the NSTA Position Statement, School Science Education for the 70's.

Position Statement is the NSTA Position Statement referred to above.

Assertion refers to a sentence that has the quality of being either true or false, believed or not believed. It is used in this study as synonymous with knowledge claim, statement, or proposition.

Epistemology is "the division of philosophy that investigates the nature and origin of knowledge".¹ It is a comprehensive term covering studies in five broad areas: (1) the nature of knowledge (2) the kinds of things that can be known (3) the presuppositions and conditions of knowing (4) the basis on which knowledge is

¹The American Heritage Dictionary of the English Language, 1973.

claimed, and (5) the reliability or validity, the certainty or doubt we attach to what is claimed.¹ The assumption made earlier that "knowledge" is meaningful only as operationally defined, is an affirmation with respect to areas 1 and 2 above: the term "epistemology" as used in this dissertation will primarily focus on areas 4 and 5 with some attention to 3 as well as they apply to the subject matter of science. If information under consideration could be regarded as pertinent to the question, How do you know? it is described as epistemological.

Verification refers to whatever convinces a person that a given assertion is an accurate description of the state of affairs it purports to describe. This is why science programs are obliged to provide specific information about the grounds of knowledge claims.

Evidence refers ultimately to observations of states of affairs.

Theoretic statement means any statement that incorporates the name of any non-observable "thing" whose existence is only inferred. Atoms, forces, and species are examples of such "things".

Analytic statement is a non-theoretic statement whose truth value can be ascertained by analysis of the statement itself. The knowledge content of such statements is restricted to the meaning of words, hence can usually be obtained by consulting the dictionary.

¹This description is a composite of these two: Dr. W. Hamlyn, "Epistemology, History of," The Encyclopedia of Philosophy, 1967, III, p. 8. "Epistemology," The New Caxton Encyclopedia, 1969, VII, p. 2219.

Synthetic statement is a non-theoretic statement, such that, all its words being fully understood, some natural phenomenon must be observed in order to ascertain its truth value.

The Method and Limitations

The method to be implemented is developed around Wilson's three step model for finding out if a statement is true:

1. We must discover what the speaker is intending to communicate.
2. We must determine what would count as evidence.
3. We must examine for evidence and make a decision.¹

The first stage of investigation calls for extensive research into the nature and functions of language; the second, into the structure of science, and the third into the program under investigation. Since language serves many functions besides making knowledge claims, a method of sorting out the sentences is necessary. This need is met in the "Sentence Sort Scheme", developed specifically for this investigation. After isolating the various sorts of knowledge claims, the analyst is obliged to determine what would count as evidence. Procedures for preparing the sample for sentence sorting facilitate the examination for evidence as well. A referent program was selected and the basic argument and method as given above applied, working out procedural details empirically. Argument, method and procedures were then applied to a different type of program as a test of the generalizability of the method.

¹ John Wilson, Language and the Pursuit of Truth. Great Britain, Cambridge University Press. 1956. p. 51.

The method involves the use of simplistic models of the nature of words, the functions of language and the structure of scientific knowledge, and its general adequacy is yet to be established. The analyst must be competent to decide whether a statement contains theoretic terms, is consistent with scientific thought, and whether there is evidence in support of the statement and this support can be perceived and evaluated by the children. Many decisions are more or less subjective and agreement among analysts may be low but the purpose of the model is to identify decisions that must be made, not to make them. Analysis with the model is still tedious but it does work and experience with it greatly reduces the time required. As with most tools in their early development the quality of the product is largely dependent on the skill of the user. Further research could conceivably turn up correlations that would lead to a fast, efficient evaluation of program quality but that must remain in the future.

Organization and Evaluation

Chapter I is intended to provide an orientation to the study. Chapter II develops the basic argument from the literature. Chapter III provides a detailed description of the actual evolution of the model as it was shaped empirically in the analysis of the referent program, and of its adaptation to another program of a very different kind. Chapter IV presents the findings with respect to the two programs examined and translates them into an assessment of the strengths and weaknesses of the model. And Chapter V contains conclusions and recommendations for further research.

At the outset of this study the model was a bare notion of something that might be possible. At the conclusion it has emerged a functioning prototype, a guide for the careful analyst, designed to help him lay bare the epistemological character of elementary science programs. The purpose of the study was to develop such a prototype: its refinement will require further research and the input of other interested parties.

CHAPTER II

REVIEW OF RELATED LITERATURE

Part I Rationale for Study

Background

The literature reveals that by the sixties, leading science educators were well aware of profound changes taking place in science and society, and were hard at work in a massive effort at "Rethinking Science Education", as indicated by this title for the 50th Yearbook of the National Society for the Study of Education.¹ The pressures for reform were many and strong, the most immediate perhaps being the "information explosion" and the impossible situation it created for those most concerned about subject matter "coverage."² But some educators had already realized the far reaching consequences of this turn of events: children presently in elementary schools will spend their prime years in the 21st century, and the problems they will face then, we cannot possibly foresee. Paul DeHart Hurd expressed

¹Rethinking Science Education. Fifty-Ninth Yearbook. The National Society for the Study of Education Part I. (Chicago, Illinois, The University of Chicago Press, 1960).

²Haven Kolb, "Pressures on the Teaching-Learning Situation" Designs for Progress in Science Education ed. by David P. Butts (Washington, D. C., 1969) p. 23.

this concern to the Association for Supervision and Curriculum Development in 1962, calling for,

"...an education that will enable young people to live intelligently in a world in which they are going to live. What is taught must have value beyond the context in which it is learned. Learning in every course must be durable, counting for the rest of the students' life..."¹

This is the vision and the concern that sparked the flood of new programs in science, and that could lead to what Lee describes as "a genuine revolution" in science education.²

For very practical reasons it had become obvious that traditional subject matter could no longer provide the objectives in science education. But what new objectives have been defined? And by what practical means can programs in science education be examined to see if they are in line with them? The formidable task of defining new goals for science education was undertaken by Berkheimer in his pursuit of the science supervisor's role in selection and use of curriculum materials,³ and brought to the

¹Eugene C. Lee, New Developments in Science Teaching, ed. by Paul DeHart Hurd, Wadsworth Guides to Science Teaching (Belmont, California: Wadsworth Publishing Company, Inc., 1967) p. 4.

²Lee, New Developments, p. 3.

³Glenn David Berkheimer, "An Analysis of the Science Supervisor's Role in the Selection and Use of Science Curriculum Materials," (unpublished Doctoral dissertation, Michigan State University) 1966. pp. 30-65.

attention of science educators at national and international levels in the NSTA Position Statement which calls for "Further identification of criteria for making curriculum decisions that are based on these broad goals", so that they "can be translated into instructional programs."¹ The objectives of this dissertation are the identification of criteria and the development of a model that will provide a systematic method for evaluating programs to see if they are in line with these goals: to see if they hold some promise of "value beyond the context" in which learning occurs.

The Move to Philosophy

The stratagem adopted by science educators is a move from pursuing knowledge about the nature of the physical world to pursuing knowledge about the nature of knowledge. Such a break with tradition is in Lee's words, "a genuine revolution",² no mere shift in lateral direction but a vertical displacement to a significantly higher level of abstraction. In proposing that students and teachers become involved in the problem of how things are known, we are proposing to move them into the realm of philosophy in general and epistemology in particular. Science educators are saying that the general public must acquire an understanding of:

1. the diverse processes that are used to produce the conclusions of science.

¹Berkheimer, et al. NSTA Position Statement.

²Lee, New Developments, p. 3.

2. the theories, models, and generalizations that show the unity of science.
3. the "structure" of scientific knowledge.¹
4. the limitations of these methods.²

These goals are concerned with the nature of knowledge, and controversy has always surrounded this subject but knowledge is what education is about and educators must concern themselves with its problems. Educational decisions are surely influenced by the philosophical positions of those who make them--whether they have consciously structured these positions or not. So we must function in the realm of philosophy but we must not underestimate the difficulties involved. Bochenski says:

"Every simple solution to the problem of knowledge must be rejected as inadequate. Reality, and hence the thought which tries to take it in are obviously of enormous complexity. Any attempt to make this work simple,...springs from complete misunderstanding."

This complexity is illustrated in the age old problem of induction:

"The great work achieved by induction appears to the logician like the successful deciphering of a text in code, to which we still lack the key. That some things have been decoded seems certain: it is just what we do not know how this has happened."³

¹Joseph J. Schwab, "Structure of the Disciplines: Meanings and Significances: The Structure of Knowledge and the Curriculum, edited by G. W. Ford and Lawrence Pugno, Rand McNally Curriculum Series, (Chicago, Rand McNally and Company) 1964, pp. 1-49.

²Lee, New Developments, p. 5.

³J. M. Bochenski, The Methods of Contemporary Thought trans. by Peter Caws, (Dordrecht, Holland: Driedel Publishing Company, 1965) p. 125, 114.

Bochenski acknowledges the difficulties but is persistent in the notion of some enduring truth: to those who suppose that science need not be true, just useful, he argues that it is only useful to the extent that it corresponds to real states of affairs, and to that extent it is in some sense already "true". He sees successes of technology and the stability of certain ideas both over time and over a vast array of situations, as strong support for the claim to "know": yet he is unmistakably saying that if we do know, we cannot fully explain how we know. Considering the consequences of decisions man is now being forced to make because of recent advances in science and technology,¹ this weakness of not being able to fully explain how we know, prompts a closer look at what we mean when we claim to know, and this closer look must be a vital part of all science education. For as Wilson said, "The worst possible thing is to imagine that we know when we do not know".² Thus, the fact that we cannot fully explain how we know, casts a shadow on the certainty implied by our claims to know and creates a problem that is likely to be with us for some time to come. Noting that the problem of knowledge "has rarely been as eagerly worked at as in our time", and citing as great accomplishments, developments of the phenomenological method, linguistic

¹As presented in Leroy G. Augenstein, Come Let Us Play God, (New York, Harper and Row, 1969).

²John Wilson, Language and the Pursuit of Truth, (Great Britain, Cambridge University Press, 1956) p. 74.

analysis, and the axiomatic approach, Bochenski is still not optimistic. Philosophers, he says, are committed to the defense of their particular method, and exponents of the various methods do not listen to each other. Yet the various methods are complementary and what is needed is a synthesis that incorporates the valid contributions of each into,

"a genuine philosophy bringing all available resources to bear on the search for knowledge... A remedy for this situation will not come...from simple systems committed to a single method... incapable of taking in the whole."¹

Berkheimer establishes that the goals of education must be revised from time to time as demanded by our best understanding of the character of our culture, the needs and potentials of the learner, and the nature of the subject matter. Since the general goals of education are developed around culture and learner, it is reasonable to bring these goals to bear on the structure of scientific knowledge and to derive from their combination specific goals for science education. The general goals as developed by the NEA Project on Instruction had just been updated and already reflected the aroused concern for "durable" learning, and so were accepted as valid for the purpose of Berkheimer's study, but he undertook an extensive and deliberate synthesis of the nature of scientific knowledge.

¹Bochenski, Contemporary Thought, p. 127

The Structure of Scientific Knowledge and the Values it Represents

Abstracting from numerous statements on the nature of science, Berkheimer identifies observation as the foundation of scientific knowledge, and the thought processes of the method of inquiry as its superstructure. Science is shown to have both an empirical and a rational aspect, which, fused necessarily with the medium of language, make up the 3 fundamental elements of scientific knowledge.¹ From the days of Aristotle, "reasoning" has been partitioned into "terms, propositions, and arguments"², and when the terms, propositions, and arguments are of the appropriate sort we have in this ancient analysis of the elements of reason, an analysis also of the elements of scientific knowledge. Robinson refers to the "semantical, logical, and pragmatic components" of scientific knowledge³, and Sears in his brief Forward to the SAPA Commentary for Teachers identifies the same three elements as the three essential educational processes: the use of the five senses, the accurate use of words, and learning to think about experiences.⁴

¹Berkheimer, Science Supervisor, pp. 18-60.

²John Stuart Mill, A System of Logic: Ratiocinative and Inductive 8th ed. (London, Longmans Green and Company, Lt'd.) 1724 (Impression 1965) p. 2.

³James T. Robinson, The Nature of Science and Science Teaching edited by Paul DeHart Hurd. Wadsworth Guides to Science Teaching (Belmont, California, Wadsworth Publishing Company, Inc.) 1968 p. 126.

⁴Paul B. Sears, Forward to Science A Process Approach: Commentary for Teachers (n.p. Commission on Science Education of American Association for the Advancement of Science/Xerox Corporation) 1970.

These then are the major areas with which we must be concerned: what is known to the senses, what is known by reasoning, and the role of language in the development of knowledge.

"Truths are known to us in two ways," says Mill, "Some are known directly...by immediate consciousness, (others) we know only by inference...What is known to us by consciousness is known beyond possibility of question...no science is required for the purpose of establishing such truths. There is no logic for this portion of our knowledge".¹

On the same point, Bochenski says,

"It is one of the most important insights of exact methodology that the truth of a sentence must be either apprehended directly, or inferred; there is not, and furthermore there cannot be, any other way."²

Thus it is maintained that there can only be two kinds of knowledge claims: claims made on the basis of having "apprehended directly", and claims made by the process of inference. Claims of the first sort are specific statements "referring to the content of a single experience" and verification of such statements is "the occurrence of the experience to which they uniquely refer". Such verification is, "incorrigible...it is impossible to be mistaken about it except in a verbal sense."³

The sense of "incorrigible" here seems to be precisely that of Mills "beyond possibility of question", i.e. when a credible person

¹ Mill, A System, p. 4.

² Bochenski, Contemporary Thought, p. 65.

³ Alfred Jules Ayer, Language, Truth and Logic. 2nd ed. (London, Victor Gollancz, Ltd.) 1948 p. 10.

declares he has experienced a specific happening, only under unusual circumstances can one with certainty deny it. If the speaker is using words in the same sense that the hearer understands them, then his report of a direct, sensory experience (i.e. observation) constitutes the strongest available verification. Carefully kept records of such experiences including date and time of observation, observer's name, etc., constitute "hard evidence". Bochenski calls such statements "protocol" ("original") statements, which, "from an epistemological point of view are the...foundation of the system: theoretical elements play a secondary role.... Protocol statements ultimately determine the admissibility of other elements to the system...", "Anything inconsistent with protocol statements must be set aside.... Anything which serves to explain these statements is admitted."¹

But for all of their certainty, protocol statements are of little consequence unless they can be generalized. Yet in the very act of formulating a generalization, we move from a statement that is certain, "known beyond possibility of question", to a statement that we know can not be certain. All generalizations go beyond evidence, describing not only what is, but what has been, and what shall be; and as stated by Hospers, "it is logically impossible to know the truth of any statement involving the future...We cannot know that any law of science is true".² Since then, the truth of

¹Bochenski, Contemporary Thought, pp. 98, 99.

²John Hospers, An Introduction to Philosophical Analysis, (New York, Prentice Hall, Inc.) 1969. p. 169.

a statement can only be known directly or inferred, and "there cannot be any other way", we cannot know that any scientific statements are true except protocol statements, and these are specific to the content of a single experience. But laws and theories of natural science infer beyond our experience to inaccessible sets of unknown and unknowable events and phenomena. This method of "thought-amplification" known as induction is not fully explainable and cannot be conclusive. As Berkheimer sums it up, "Empirical knowledge by its very nature is inconclusive because it is impossible to observe all possible cases."¹ Scientific statements then can be classified as (a) beyond possibility of question, or (b) beyond possibility of verification, and there is no in between!

The objective of scientists is the creation of such statements, which taken together constitute a body of knowledge about the world. Authors seem never to tire of saying this:

"...this much seems certain, that every science strives to establish true statements: that is the ultimate aim..."² "We cannot avoid the realization that science is a process of constructing bodies of knowledge..."³ "Science is a spectacularly successful way of knowing."⁴

Thus, scientific statements, and the processes by which they are

¹ Berkheimer, Science Supervisor, p. 41.

² Bochenski, Contemporary Thought, p. 7.

³ Schwab, Structure, p. 35.

⁴ D. J. O'Conner, An Introduction to Philosophy of Education, (London, Compton Printing, Lt'd.) 1957 p. 73.



generated constitute the sum and substance of what we mean by "science". So when we isolate scientific knowledge claims and seek to discover the basis on which they are made, we are probing the very structure of science, discovering the nature of scientific knowledge.

Finally, since science is a creative activity of the human intellect, it fully reflects the beliefs and values of its originators. Wilson suggests that scientists believe "...that every detailed occurrence can be correlated with its antecedents in a perfectly definite manner...It is this instinctive conviction... which is the motive power of research".¹ The search for laws does seem to presuppose that there is order in the universe and such presupposition is indeed, a kind of faith to which the scientist subscribes. Nor is science values free: one basic value of scientists with respect to the knowledge they create, is simplicity. "Elegance" it is sometimes called, and Bronowski says of it,

"William of Ockham first suggested to scientists that they should prefer that theory which uses in its explanation the smallest number of unknown agents. But is there indeed any ground for it other than a kind of aesthetic satisfaction much like that of sacrificing your queen at chess to mate with a knight?"²

Scientific knowledge then, is not sterile, objective, and absolute, but creative and therefore tentative, subject always to re-evaluation and correction, to accommodate more data, or to

¹Wilson, *Language*, p. 13.

²J. Bronowski, *The Common Sense of Science*, (Cambridge, Massachusetts, Howard University Press, 1967), p. 135.



find a new elegance of expression. These qualities of scientific knowledge must be revealed in science programs if they are to be in line with the objective of scientific literacy.

The Role of Language

We think with language. Mill says of language that it is, "by the admission of all philosophers...one of the principal instruments of thought"¹, and Black comments similarly that the influence of language on thought "has been a favorite theme of scholars throughout the ages."² It is not being suggested that we cannot think without language. No one would deny that catching a high fly ball on a windy day involves some complex mental activities that seem to take place without the need for language. And it seems that in many cases the attempt to express even simple operations in words renders them virtually unintelligible. Purely verbal instructions, for example, on how to tie a shoestring would probably be very difficult to understand. There is, then, knowledge that is "incapable of being formulated in language," knowledge how in contrast to knowledge that, but it is the latter to which attention is directed in this study: "The kind of knowledge which can be set forth in sentences."³ "Knowledge refers to states of affairs and these are represented first of all by propositions.

¹Mill, System, p. 11.

²Max Black, Critical Thinking: An Introduction to Logic and Scientific Method (Englewood Cliffs, New Jersey, Prentice Hall, Inc. 1946) p. 161.

³George Ferree, "The Body of Knowledge Unique to the Profession of Education" (unpublished paper, Michigan State University, n.d.) p. 2.

Propositions then are the first requirement for knowledge".¹ The tremendous significance of language in the pursuit of knowledge is perhaps best exemplified in the methodology of Semiotic which seeks knowledge through a system of operations upon symbols in a formalized, philosophical language. But the Semiotic methodology offers little at this point to those who wrestle with curriculum problems; and for all the imperfection of existing languages, they remain one of the basic tools of the scientist, in whose hands they are "strangely effective and powerful."²

Summing up then, "Science" is an expression of a consuming desire to know, pursued in a fundamental belief in the orderliness imposed on or found in the universe, kept functional by its insistence on simplicity, and reproducible by its effective use of language: a desire that constrains the whole of man, his body, his mind, and his spirit, to pursue understanding. It is small wonder that the product of a community so motivated should become at some point a "knowledge explosion", and that a great "gap" should have appeared between those so motivated to know and the rest of society. And it is this "gap" that has alarmed some science educators, and prompted them to draft strategies for effecting a revolution in their profession.

¹Bochenski, Contemporary Thought, p. 4.

²Berkheimer, Science Supervisor, p. 42.

Berkheimer details examples of the gap between science and "common sense", and Frank traces its origin and development from about the year 1600. The rift occurred when scientists despaired of finding ways to derive the practical truths of experience from the grand generalizations of philosophy, and began to put forward fragmentary generalizations instead, from which those practical truths could be derived.¹ Science ultimately found its function and its identity in a close relationship to technology, but in so doing, severed its ties with philosophy, and with the most general principles and concerns of society at large. And if the past is any guide to the future, the 21st century may well find the "gap" beyond remedy. From this perspective Berkheimer says: "One of the greatest challenges of our times is, then, to bridge the gap between science and common sense through science education".²

But in this day of specialization and expertise, must we really worry about scientists knowing too much about the world? This is obviously not the problem: the problem lies in the technological application of that knowledge and the God-like power it concentrates in the hands of those who have access to it. Conant warned that if democracy is to survive, the gap must be narrowed and it is the task of science educators to do this. This was

¹Philipp Frank, Philosophy of Science, ed. by Arthur E. Murphy. Prentice-Hall Philosophy Series (Englewood Cliffs, New Jersey, Prentice-Hall, Inc.) 1957 pp. 28, 29.

²Berkheimer, Science Supervisor, p. 42.

Conant's great burden as the awesome reality of the atomic bomb settled into his thinking. He undertook to direct educators away from the mass of scientific facts to the "tactics and strategies" of science, in the belief that an understanding of science is a matter of acquiring some feeling for what scientists can or cannot be expected to accomplish.¹ The present emphasis on the structure of scientific knowledge seems fully compatible with these early views of Conant. And this is what the "revolution in science education" is all about.

Berkheimer's Goals Epistemological

It was asserted at the outset that science education has moved into the realm of epistemology, that branch of philosophy that undertakes to examine the basis on which knowledge is claimed. Summarizing articles from several encyclopedias, epistemology may be divided into five general areas:

1. the nature of knowledge.
2. the kinds of things that can be known.
3. the presuppositions and conditions of knowing.
4. the basis on which knowledge is claimed: the senses, reason, (or other means), and the relationships between them.
5. the reliability or validity, the certainty or doubt we feel about claims made.

¹James B. Conant, On Understanding Science, A Mentor Book (New York, The New American Library, By arrangement with Yale University Press, 1951) p. 26.



The purpose of this section is to demonstrate the epistemological character of the goals of science education developed by Berkheimer. The first two categories of goals are headed "Observation", and "Rational Processes"¹, and the 15 specific objectives listed obviously belong under item 4 above. Other areas of epistemological nature are also involved as in this compound objective; "Observe those things that are relevant to the problem at hand". This calls for science programs that teach students to depend on direct sensory perception in acquiring knowledge but also to make decisions about what is "relevant to the problem at hand." Relevance may involve both presuppositions (item 3) and the scope or limits of things that can be known (item 2). If for example, one observes the behavior of isopods under controlled laboratory conditions in an effort to determine optimum temperatures for their survival in nature, he must presuppose that observed behavior is in response to the manipulated variable (and not to some other or combination), and that laboratory results can be generalized to the natural habitat. Another objective, "Understand the influence of the observer on what is being observed", is directly concerned with the presuppositions of knowing.

"understanding the distinction between induction and deduction" involves an awareness of the basis on which knowledge is claimed, the relationship between kinds of claims, relative certainty, etc.

¹Berkheimer, Science Supervisor, p. 54.

"Treat scientific data and conclusions in such a way that an understanding of the tentative nature of scientific conclusions is evident", falls under item 5 - "The reliability or validity, the certainty or doubt we feel about claims made." And "Understand when experimental conclusions are valid" is the whole gist of epistemology: passing judgement on the quality of knowledge claims by assessing as many of the factors that may affect them as we can recognize.

Other goals are that students should know what assumptions are being made, and understand that "the language used to transmit science is much different than the language used to transmit common sense". It has already been noted that "language is the principal instrument of thought," and that precision of language is essential to the reasoning processes by which inference is made. All of this is the subject matter of epistemology.

The student is to "understand sufficient facts, concepts, and principles in at least one field of science to see the underlying structure of the discipline". The "structure" of scientific knowledge is surely an aspect of the nature of scientific knowledge, the first and most comprehensive of the five general areas of epistemology. One of Berkheimer's objectives calls for students to "operationally define terms and concepts; to understand the impossibility of divorcing concepts from the operations through which they are generated." This single objective almost sums up the notion of epistemology as it applies to science. The relation

between the meaning of a statement and its method of verification is strongly developed by Wilson. But it is difficult to conceive of any stronger assertion of this point of view than the one already cited: Berkheimer's goal statement that calls for "understanding the impossibility of divorcing concepts from the operations through which they are generated." The meaning of a scientific statement can only be determined as one understands the processes and assumptions that produced it. "Knowing that" is then, ultimately a function of "knowing how" intellectually (not physically here), as knowing how one reasons to a conclusion based on an observation. And the whole notion of "knowing" is restricted to being operationally defined.¹

It is not necessary to further elaborate on the epistemological nature of the new goals for science education. They are primarily concerned with how we know what we claim to know, and call in traditional science subject matter as needed, to illustrate the processes of knowledge generation.² Berkheimer's objectives are reflected fully in the NSTA Position Statement, School Science Education for the 70's, which subsumes all these goals under the rubric, "Scientific Literacy". "Scientific literacy" also stresses the objective of using scientific knowledge in the best interests of society, but one's ability to do so is directly dependent upon

¹Berkheimer, "Science Supervisor", pp. 35-59.

²Lee, New Developments, p. 6.

his awareness of its nature and limitations. Of the team that created SCIS with its goal of scientific literacy, Karplus says that "scientific literacy" refers to one's ability to use scientific knowledge "as though he had obtained it himself."¹ Thier says it means having an understanding "not only of the basic structure, but also of the rationale, and ways of thinking that characterize modern day science...appreciating not only the accomplishments but also realizing the limitations of science and scientists".² Thus, the ability to use scientific knowledge wisely is dependent upon an understanding of the way it comes to be.

But Kolb justifiably expresses concern about how the goal of "Scientific Literacy" will be interpreted in the classroom where it really counts. Will educators grasp the vision of a radically new direction in science education?³ His fears are well founded. Thompson and Voelker, in their evaluation of the SCIS program, report that its objective is "an understanding of science principles".⁴ They certainly failed to see anything revolutionary, any

¹Robert Karplus, "Theoretical Backgrounds of the Science Curriculum Improvement Study", Journal of Research in Science Teaching (October, 1965) p. 8.

²Herbert D. Thier, "Science in Your Classroom," Science Curriculum Improvement Study 42 page Feature THE INSTRUCTOR (Berkeley, California, University of California, January 1965) p. 81.

³Kolb, Pressures, p. 21.

⁴Barbara S. Thompson and Alan M. Voelker, "Programs for Improving Science Instruction in the Elementary School, Part II, 'SCIS'". Reprinted from Science and Children Vol. 7, No. 8 May 1970, pp. 29-37.

significantly new departure from "the re-hash of old ideas." They saw no move away from the traditional goal of helping students acquire knowledge about the nature of the world, to a bold new objective of helping them acquire knowledge about the nature of knowledge. How could they have missed the "revolution"? And what is to keep countless others from doing so? Part of the problem lies in the lack of systematic procedures for examining the content of programs. The epistemological dimension must be identified deliberately and examined against specific criteria if programs are to be selected or evaluated against the objectives of scientific literacy. Without a systematic approach to the evaluation of the epistemological quality in science programs, the tremendous input of effort to chart a significantly new direction for science education will have been spent in vain.

Chapter II Part 2. Rational for the Model

Content Analysis

In her plea for content analysis, Ellen Campbell reminds us that the selection of educational programs is heavily influenced by lethargy, tradition, convenience, advertising, and bandwagon effect. Content analysis in social studies has turned up solid data on the presence of such undesirable characteristics as stereotypes of sex, race, and religion in children's readers and other books as part of the otherwise unnoticed treatment that children are subjected to in the process of education. The text, the pictures, the approach, or questions may all contribute "subtle biases of the textbook authors", which at times are "in contradiction to the stated goals of a particular program... Only by measuring texts against our goals can we be forewarned against such unforeseen results."¹ This argument is fully applicable in school science, where to date little of this kind of work has been done.

The Explanatory Modes Project of the Ontario Institute for Studies in Education has made a beginning under the leadership of Douglas A. Roberts who believes that, "science education, as ordinarily conducted, is having a detrimental impact to which most science teachers have not been sensitized." Roberts goes on to call for "an entirely new line of investigation in science

¹Ellen K. Campbell, "Content Analysis: A Tool for Choosing Texts". Evaluation and Measurement Newsletter No. 17 (Toronto, Canada, The Ontario Institute for Studies in Education) September 1973.

education,...(involving)...epistemology, philosophy of science, and philosophical analysis of teaching, and of other education concepts as well".¹ One of the project's papers is relevant and worthy of discussion here. The author, Brent Kilbourne, attempts an analysis of "The Basis for Knowledge Claims in Science Text Books". He offers a sample analysis of a portion of BSCS material but he backs away from any attempt to isolate the evidence for claims made, on the ground that: ..."most arguments depend on more than evidence if the term evidence is restricted to observation of states-of-affairs, making a treatment of evidence as such insufficient."² What he means by "insufficient" is not clear. But it seems that because text books are so very weak in providing evidence, he abandons the pursuit of evidence in deference to this failure and settles for "support" instead. Support includes not only evidence but also any reference to evidence, reference to authority as well. Such information, if classified and labeled, provides some measure of the epistemological quality of a program, but since laws and theories are themselves evidence dependent, if students are to understand the nature of scientific knowledge, they must also know the evidence on which these generalizations

¹Douglas A. Roberts, Explanatory Modes Project Bulletin #2, (Toronto, Canada. The Ontario Institute for Studies in Education) April, 1972.

²Brent Kilbourne, "Analyzing the Basis for Knowledge Claims in Science Text Books: A Method and a Case Study", The Explanatory Modes Project Background Paper #6. (Toronto, Canada, The Ontario Institute for Studies in Education) 1971, p. 13.



rest. From the days of Galileo, the basic issue in the history of science has been one of authority: are we to examine the evidence or believe the "experts"? Scientific literacy calls for examining the evidence and this must principally refer to evidence for inferred statements, especially laws, and theories. Therefore, programs must be examined especially for evidence in support of laws and theories. But Kilbourne's decision is due in part to the theoretical argument which he develops around the work of Scheffler and Ayer. Scheffler maintains the classical stance that one can claim to know if and only if what he claims to know, (a) is in fact true (b) is based on good evidence, and (c) is believed by the one who claims to know it.¹ For reasons to be further developed, these conditions are ill suited to scientific knowledge in general, being directly applicable only to statements about states of affairs that can be verified by direct observation. But scientific knowledge generalizes such certain statements into hypotheses, laws, and theories which are known to be non-verifiable, as a rule, and are not held as "beliefs" by scientists but recognized as tentative, and ever subject to revision. Kilbourne drastically alters the belief condition ("the individual believes the claim") to this distantly related question: "What is being believed that allows an argument for the claim to be plausible?"² This is a question about the presuppositions and assumptions one brings to the claim rather than a question of whether one believes the claim itself.

¹Kilbourne, Basis, p. 5.

²Ibid.

Kilbourne uses Ayer's classification of all statements as either "analytic" or "synthetic", but in doing so he ignores the ancient tradition of distinguishing statements that are verifiable by direct observation from statements that can only be inferred. It has already been shown that this distinction is seen as "one of the most important insights of exact methodology",¹ and one therefore that we can ill afford to discard. Kilbourne further argues that synthetic statements, (as he uses the term) "are empirically verifiable, on the ground that they depend in part, on observation for their truth".² But since every inference about the physical world, depends ultimately on observation, by this argument, they all, (hypotheses, laws, and theories) become, "empirical" statements. This violates the fundamental sense of the word "empirical" which means "derived from observation or experiment and not theory",³ and obliterates the distinction between what is verifiable directly by the senses, and what we are able to conclude, or infer by the processes of reason. Kilbourne's work, despite these weaknesses, is a valuable resource from which several important ideas will be incorporated into this model.

Statements and Verbal Symbols

It has already been shown that language is inextricably involved in making and supporting knowledge claims, and that in any sample of

¹Bochenski, Contemporary Thought, p. 65.

²Kilbourne, Basis, p. 8.

³The American Heritage Dictionary of the English Language. 1969.

discourse, many of the knowledge claims are statements that deal exclusively with the meaning of words. Such a statement is called "analytic" because its verification consists of analyzing the statement itself, i.e. examining the meaning of its words. Hospers provides as a simple example, "all black cats are black."¹ The statement is certainly true and one need only examine it to decide so. It does not call for any observation of cats, as observation could add nothing to the decision about its truth. Mill calls such statements "purely verbal"² propositions about the meaning of words. But the example just cited is deceptive in its simplicity as analytic statements can be very hard to recognize, and frequently appear (as Wilson says) "in disguise".³ They may seem to express profound truths or to announce great discoveries. In the statement, "Ice is really just frozen water", it is suggested that a new truth about the physical world is being put forward but the only truth it contains is about the equivalence of words. If anyone is fully apprised of the meaning of all words in this statement, it has no information to communicate. In the following case, an analytic statement may appear to explain a phenomenon of nature: "This medicine may cause you to feel drowsy because it contains a soporific ingredient". But "soporific" means "sleep causing", so this analytic statement is "disguised" to look like it gives a reason for the occurrence of an event in the natural world.

¹Hospers, An Introduction, p. 88

²Mill, System, p. 70.

³Wilson, Language, p. 60.

But the most troublesome statements are statements like, "matter takes up space". Assuming that the hearer has an intuitive notion of space, it sounds as though we are making an empirically verifiable statement about matter, and one needs only to point to several objects and show that they each require a certain amount of space to verify it. But if we raise the question, "How do you know that this particular object is matter?" i.e. if we require that "matter" be defined, it turns out that most often the statement is intended to be defining. When we say "matter takes up space", we actually mean that we shall use the verbal symbol "matter" to designate all that has the property of taking up space.

Analytic statements, "are used to show how we have agreed...to relate the meanings of verbal signs to one another."¹ They are, in Ayer's words, "tautologies",² giving no information about the world of sensory experience. Tautologies that are true are self evidently true and those that are not true are self contradictory, (e.g. "a triangle has three sides", or "this square is round.") A summarization of the properties of analytic statements is included in Appendix 1, but since their truth value and meaning rests exclusively on the way we have agreed to use words, it is practical in this kind of analysis to classify a statement as "analytic" if the information it conveys can be obtained by consulting the dictionary.

¹Wilson, Language, p. 60.

²Ayer, Language, p. 31.

Analytic statements as described by Hospers, present a "word-word" situation that shows word equivalence. This is in contrast to a "word-thing" situation that relates a verbal symbol with a physical object,¹ as when a mother holds a ball before her baby and repeats the word "ball". It is obvious that words have meaning only by association but since words are, in a very real sense, "things"-bits of ink, disturbances in the air, having a separate existence from the association that gives them meaning,² there is nothing to prevent their being circulated apart from their meaning. Words serve as "labels" for human experiences and there seem to be no limits to the kinds of experience they can identify. But there are some limits to their effective use: they communicate nothing "unless we actually share experiences of a kind which would make it useful for us to agree on an established meaning". "It is our agreement about its use and not the sign itself which enables us to communicate." "What exactly are we trying to describe or explain: what experiences are we grouping together when we use (a word)...for if we do not know...we cannot really know what we are talking about."³ Since words exist apart from their meanings, and can be exchanged for other words according to well defined rules, it is entirely possible that a person could know all of the synonyms for a given word without having any understanding of its meaning. If this were the case for a great

¹Hospers, An Introduction, p. 54.

²Bochenski, Contemporary Thought, p. 31.

³Wilson, Language, pp. 87, 45.

number of words, such a person might be "fluent" with language, pass examinations with high marks, and be considered an example of extraordinary "literacy", while his knowledge of the physical world was nil and the probability of his making wise choices in the public interest virtually zero. The objective of scientific literacy is clearly of a different sort and demands an educational process and evaluation that can distinguish between the ability to exchange words, and the ability to communicate meanings. How can we begin to attack this problem?

Since words are used to represent every kind of "thing"- "in the broad sense",¹ not only all physical phenomena but "everything of which the mind is conscious",² and since we usually recognize a difference between physical objects, and all other "things" (like ideas) that words can name, it seems advisable that at the outset, we should restrict our attention to words that name physical objects. What is the nature of such verbal symbols? In all the emphasis among science educators on the "processes" of science, little attention has been paid to the process of naming.³ Mill describes it as "haphazard", a verbal symbol becoming arbitrarily associated with a particular object, and then being applied to other objects on the basis of "some vague likeness". In time, it may be difficult to ascertain what that likeness was, and consequently just what objects

¹Hospers, An Introduction, p. 1.

²Mill, System, p. 49.

³Compare for example, Robert W. Burns and Gary D. Brooks article, "What Are Educational Processes." The Science Teacher, February 1970.

should be named by that symbol. "The meaning of the word must then be 'picked up' from its use or from enumeration of examples, leaving the hearer to infer, if and in what way these objects are related since they are called by the same name. This is generally referred to as giving the 'denotation' of a word, or as Bochenski speaks of it, as 'proceeding extensionally'. He further describes it as a method extensively employed in logic and natural science,...

"because denotation is much easier to handle than meaning. Ultimately it is only through the meaning that the denotation can be fixed but the advantage of the extensional process are so great in these fields that it has been made a general rule to proceed extensionally wherever possible".¹

It would seem at this point that we have turned up a striking similarity between the workings of science and of common sense, but Bochenski goes on to explain that scientists rely heavily on extension because they are not nearly so interested in clarifying terms as in understanding things.² If this is true, it seems especially important to stress that it is the scientists' great store of common experiences of things that makes it possible to talk about them with minimally developed word meanings. Words in this case function as they function best: they remind the hearer of experiences he has had before, and direct his attention immediately to them. The scientist has a wealth of carefully acquired experience that he can handle with a minimum of attention to words. By contrast, the student is usually confronted

¹Bochenski, Contemporary Thought, p. 51.

²Ibid., p. 86.

with a vast exposure to words that he is expected to handle with a minimal accumulation of experience.

Under these circumstances, Mill's challenge of the practice of trying to communicate meaning by providing the denotation of a word is very much in order, for, "those who know nothing about the names except that they were applicable to such and such objects, would be altogether ignorant of their meaning. I might even know every single individual to which a given name could properly be applied...and yet could not be said to know the meaning of the name."¹ "Meaning" then is being used in a restricted sense, and does not apply merely to the ability to interchange words correctly.

How then does one proceed to determine the meaning of the name? In saying above that, "we usually recognize a difference between physical objects and all other 'things'...that words can name," and in proceeding to focus attention on physical objects for the purpose of analyzing the nature of names, a subtle but fundamental assumption is involved: we assume that meaning resides in experiences of physical objects which are "real" and knowable in terms of what they look like, how much they weigh, etc., and that they are fit subjects around which to develop a model for analysis of the nature of names. As natural as such thoughts seem to us now, the Greeks had proceeded on the assumption that meaning resides in words, and had developed a totally different orientation to the world. And the impact of Greek thinking on Western Civilization was such that the above mentioned assumption in Mill's time represented a radical departure

¹ Mill, System, p. 27.

from established modes of thought. A departure which, as vital as it seems to our present way of perceiving the world, we frequently abandon, reverting to positions that are thoroughly Aristotelian.

To the Greeks, physical objects were but crude expressions of a reality knowable only to the mind. The physical world, Plato believed, could provide no knowledge of reality at all since it is in a state of constant flux, and since our perception of it is of necessity biased and relative. At best our sensory experiences of the world might be expected to remind the soul of similar experiences in previous existences, the aggregate of which might begin to approximate the ultimate "Reality" of Plato's "Ideal Forms".

Aristotle refined, renamed, and expanded Plato's philosophy but instead of "Ideal Forms", he spoke of "Universals", which are present in all material objects and make them what they "really" are. Any observations of a piece of gold for example, could not only never lead one to discover the real nature of gold but would constitute a hinderance to such discovery, as what is observable is material in nature and therefore "accidental"-not a part in any way of the "real" thing. The real properties of gold are to be found only in its "essence", by intellectual discernment, and they are synonymous with its name, "gold": all that is knowable about "gold" is contained in the name "gold". So the search for truth was a search for the meaning of this name - the "essence" of gold, and the ability to discover the essence was limited to someone truly "expert". Aristotle's philosophy - through the efforts of "one of the most voluminous writers of all time," Origin of Alexandria,

was to dominate the intellectual life of Western civilization for more than a dozen centuries.¹

In the Aristotelean tradition, a word does not name a physical object or phenomenon, but a Universal, and the consequences of this view to the pursuit of knowledge are described by Mill as follows:

"This notion:, says Mill, "seems to me one of the most fatal errors ever introduced into the philosophy of logic...It almost always tacitly implies ...that the investigation of truth consists in contemplating our ideas or conceptions of things instead of the things themselves."

Mill argues further that in the Aristotelean tradition,

"...objects are made what they are called. Gold for example is gold not because it has certain properties to which we have chosen to attach that name but because it participates in the nature of a certain general substance called gold in general, which with all of its properties inheres in every individual piece of gold. The properties of this general substance constitute the "essence" of gold: the rest of the properties belong to the specimen individually...When a question arises as to whether a particular object should be classified as gold, it is then as though there existed a master list of definite and known individuals and we have but to consult an expert who can read the list to see if that object is included under the heading "gold".²

In sharp contrast to this way of thinking Mill argues that material "things are self existent", that they are fully synonymous with their physical attributes, and that our sensory experiences of their attributes is the ultimate limit of what can be known about them. When a verbal symbol is associated with the object it is

¹D. W. Hamlyn, "Epistemology, History of," The Encyclopedia of Philosophy III, pp. 8-13. 1967.

²Mill, System, pp. 86-101.

something we do for convenience; its selection is arbitrary, the object is real and the verbal symbol "accidental". Thus, with Aristotle objects crudely represent words which embody realities: with Mill, words crudely represent objects which are in themselves, realities. Further Mill argues that we can use words to stand for all the properties of the object, (some of which may not as yet even be discovered), or we can specify that the word (i.e. name) shall stand for only the most obvious or important properties of the object. Then all objects that have those properties shall be called by this word for their name, and whatever is properly called by this name may be presumed to have these properties. Suppose for example, that an object is metallic, lustrous, yellow, unusually malleable and ductile, non-corrodible, and has specific gravity 19.3. Suppose further that whatever other properties it may have, any object having this set of properties is to be represented by the verbal symbol "gold". All substances that have this set of properties are then "gold", and any substance properly called by the name "gold" may be supposed to have these properties. To determine whether or not an object is "gold" is a simple matter of examining the object to see if it has the properties designated by the word "gold". This is Mill's model for the nature of a word.¹ Hospers describes the process of assigning a word to an object as a "word-thing" process, and the "obvious or important properties" the name is to symbolize as the "designation" of the name.² And it is in the designation of

¹ Mill, System, pp. 86-101.

² Hospers, An Introduction, p. 25.

the name that the problem of meaning is resolved. To define what we mean by "gold" is to state what properties have been designated by this word: e.g. "gold" means all objects having properties A, B, C...N. But the word "gold" does not designate any of the other properties of the objects it names; only those outstanding and important ones specially selected to be designated by the name. The full definition of "gold" is then a complete list of these properties, and constitutes its "essence" - i.e. all that the word "gold" means, or is intended to mean or to convey.

A discussion of the process of naming leads naturally to the reverse process of defining, but it is important to point out that defining is not simply the reverse of naming: in the process of naming the referent is an object, and in defining, the referent is a verbal symbol. The first is concrete, the second entirely abstract. Some of the problems arising from word-word situations have already been mentioned but one in particular has occasioned a long history of philosophical confusion. The use of various forms of the verb "to be", as, for example, in "Gold is a yellow metal", and "Gold is lustrous and dense", has led to the recurrent phenomenon of someone "discovering" a separate independent existence for gold: "Gold is!" That is, they infer an Aristotelean existence of "gold" apart from its properties. For those without the experience of gold, and of naming it "gold", whose only exposure is to words and word-word rules of exchange, this is a natural pitfall. For they are at the mercy of their own imagination to develop "experiences" of the words, which are indeed things in their own right.

The tendency to revert to Aristotelean thinking is very strong, even among some scientific methodologists, who have proposed that we can bridge the gap between induction and deduction, by definition!

Bochenski illustrates their fallacy as follows:

"Take diamond and suppose it to have been defined hitherto by three properties A, B, and C; now suppose somebody burns one or two diamonds, as Lavoisier did, and finds that carbon monoxide is obtained from the combustion, and therefore claims that all diamonds are made of carbon. How can this be justified? Simply by adding the newly discovered property, 'being made of carbon', to the previously known qualities; 'Diamond' according to the new definition will now mean everything which has the properties A, B, C, and also the newly discovered property of being made of carbon. If this is agreed upon it follows deductively that a diamond must always be made of carbon."

"But it is obvious", continues Bochenski, "that a convention of language is not a natural law, and science requires more serious foundations".¹

In Mill's system, names name things, provide their primary analysis, supply a rule for deciding what things shall be so named, denote all things which have the properties they represent, and inform of what we believe about them. They are in no way mysterious, contain no "deep" meanings, and offer no understanding of "reality" in return for contemplation. The entire meaning of any name is, "The sum of all the essential propositions which can be framed with that name for their subject."² And this set of "essential propositions" is precisely what we mean when we classify a statement as "analytic". It is a word-word

¹Bochenski, Contemporary Thought, p. 111.

²Mill, System, p. 87.

statement that contains information about the way words are to be used. Every statement in which some or all of the designation of a term is asserted about that term is by definition, analytic. It is "true" if what is predicated of the subject is indeed part of the designation of the subject, but its truth value is in a certain sense "trivial": when we say that, "gold is a yellow metal", we are only stating explicitly, part of what we mean when we use the word "gold" and verification of the statement is simply a matter of discovering what people mean when they speak of "gold".

Synthetic Statements

Consider now the statement, "Gold dissolves readily in aqua regia". Nothing in the designation of the word gives any clue as to whether this statement is true or false. Knowing the designation of the word however, enables us to positively identify an object of nature as gold, and having done so, to put the statement to a conclusive test. If the piece of gold upon being placed into the specified solution does "readily dissolve", the statement is true. If it does not, the statement is false. Assuming that the gold does quickly dissolve, the statement may be said to have been empirically verified and the person who performed the experiment can be expected to say that he knows the statement is true because he saw the gold dissolve. Synthetic statements, as their name suggests, "put together" a subject and a predicate, each of which has an independently established meaning. They are statements about the physical world and their verification requires observation of the phenomena of nature. But they too are dependent upon the idea of the designation of words.



The following dialogue illustrates this dependence:

- A. "Good political leaders are law abiding."
- B. "Not so: I know a good political leader who does not abide by the law."
- C. "Then he is not a good political leader."

The problem obviously lies in the fact that each speaker has a different designation for "good political leader" and in such a situation there is no way to verify or refute. This statement appears to be synthetic but is in fact analytic. The first speaker in referring to "Good political leaders" means those who abide by the law.

The idea of the designation of a word has figured prominently in the classification of statements so far: statements that give information which is part of the designation of a word are analytic, while those that give information beyond its designation are synthetic. Only synthetic statements are empirically verifiable and their verifiability is largely dependent upon the way we approach analytic statements. Unfortunately, the designation of most words has not been precisely established and dictionaries to some extent continue to rely on denotation for communicating meaning. But to the extent that they do provide the designation of terms they can be used for classifying statements. If the content of a statement can be obtained from the dictionary, that statement can be classified as analytic.

Thus for any objects (or other observable physical phenomena) if they have been named and the designation of the name specified, all statements about them, can be classified as analytic or synthetic. But what about statements using words that name non-observable

"things" like "knowledge", "species", or "atoms"? Is there an analytic/synthetic distinction to be made among them? Both Mill and Bochenski provide grounds for arguing that there is not: that they must be regarded as fundamentally different from either of these and maintained in a category of their own.

Theoretic Statements

"It is extremely difficult to avoid making mistakes about words," says Wilson who argues that one of the greatest mistakes is the failure to distinguish words that name ideas from words that name material things. "Gravity and electrons are not things in the same way that billiard balls are things".¹ "We invent concepts such as "force" in physics and the "bond" in chemistry...".²

Yet verbal symbols give no clues as to whether they name ideas or objects, and people often act as though an abstraction such as "knowledge", were a thing like a lost ball for which we must search until we find it. Wilson even argues that only proper nouns name things and that class names have already become generalizations that name not things but ideas. Of the word "elephant" for example, he says, "we cannot say what it names because it does not name anything". In moving from specific objects to classes of objects we have already begun to generalize: we have begun the search of the Greek

¹Wilson, Language, pp. 46, 24.

²J. S. Bruner, quoted in Arno A. Bellack, "Knowledge, Structure and the Curriculum", Education and the Structure of Knowledge edited by Othanel Smith, Fifth Annual Phi Delta Kappa Symposium on Educational Research College of Education, University of Illinois (Chicago, Illinois: McNally and Company 1964), p. 264.

³Wilson, Language, p. 19.



philosophers for that "reality knowable only to the mind." The process of reductive inference, (generalization of protocol statements to laws, and of laws to theories,) is the old search for "Universals" in a more sophisticated form, and from the opposite direction, but as Aristotle insisted, it is a search presided over by "experts" - a Darwin here, a Newton there, and despite the modern phenomenon of "big science" and compulsory education the number of experts in the world is infinitesimally small.

Furthermore the name of an idea (like "atom"), in true Aristotelean fashion must be treated as representing all that is knowable about "atoms" for it is not possible to examine an "atom" to set the designation of the name. It is therefore not possible to formulate any empirically verifiable statements about "atoms" and the question "How do we know that such "things" exist demands first, a denial that they are "things" as that word is normally understood, and then a reconstruction of the sensory experiences and thought processes that led eventually to the idea that we have named "atom". There is no other way to answer the question. We can evade it by appealing to the Aristotelean "expert" but this is precisely what scientific literacy is determined to overcome. If then the student is not prepared to engage in the thought processes requisite to the development of an idea, the task of education is, in Gagne fashion, to build a conceptual "staircase" that may lead him to it, which is simply a way of saying that theories ought not to be introduced as "explanations" when the terms they use are more mysterious than the phenomena they are supposed to explain. Scientific literacy calls

for developing in students the demand for evidence, but,

"to have adequate evidence is not simply a matter of having evidence which is adequate to support an appropriate argument; it is to have such an argument as well...when we judge that some one has adequate evidence, we are judging that he has an evidential argument which he understands...that he has proper credentials for his belief, the force of which he himself appreciates".¹

Such a position has deep implications for curriculum leaders in their examination of the content of science programs.

The distinction between empirically verifiable and theoretic statements is not made by those who classify all statements as either analytic or synthetic: hence this limited scheme is inadequate for revealing the structure of scientific knowledge. It has already been shown that there exists a fundamental difference between statements that can be verified by direct observation and statements that are inferences, derived from observation. The latter of those make up the class of theoretic statements, which together with empirically verifiable statements, and statements about words complete the set of kinds of statements that may contain scientific knowledge claims. Theoretic statements from every perspective are the most interesting and the kind without which what we know as "science" would not exist. The masses of carefully acquired observational data would be an unstructured and meaningless confusion and the chances that anyone would be interested in adding to that confusion seem very small. Theoretic statements in the field of science are described by Bochenski as statements of "reductive inference", that arise in this way: when

¹ Israel Scheffler, Conditions of Knowledge: An Introduction to Epistemology and Education quoted in Kilbourne, Basis, p. 12.



some regularity is observed among natural phenomena, we undertake to describe the regularity in a general statement such that any specific instance of this phenomenon is an example of the general statement. If the statement proves widely applicable, without known exception, it may become recognized as a natural law. Any observable regularity in the operation of natural laws calls for further generalization such that the manifestation of this regularity in the operation of a given law is but an example of the more comprehensive generalization which we may eventually call a scientific theory. If fundamental similarities become evident in the nature of theories, they too may be further "reduced" to still more comprehensive new theories.

The logic of theoretical statements is as follows: events in the world do not happen capriciously but as a result of certain conditions. When the event occurs, then those conditions must have been present. We have but to figure out what they must be in order to formulate a general statement that will account for all events of this type: symbolically, if A (the conditions), then B (the event). B (the event occurs) therefore, A (the conditions must have been present). This is called "regressive reduction"¹ or "explanation". The term "explanation" has several meanings but it is applied here in the sense that laws integrate specific events into a regular pattern and theories do the same for specific laws. "Explanation" then in science, is a matter of showing a specific event to be part of a recognized and predictable pattern. But the logic of scientific

¹Bochenski, Contemporary Thought, p. 92.



explanation is obviously faulty. From the basic premise, if A then B, we can correctly conclude, A, therefore B: but the conclusion B therefore A, is the well known logical error, "assertion of the consequent". It is for this reason that all laws and theories of science must be held tentative: "A" is a possible explanation of B, which can never be verified but it can only be hoped that it will escape falsification in repeated trials.

But laws and theories in addition to their function of explanation, also identify fundamental similarities among innumerable observations, and predict the occurrence of phenomena in the future.¹ Like class names, laws and theories are very useful models of nature. They can be readily distinguished since laws are stated in the language of observation and theories incorporate new terms not found in the laws they explain (e.g. "electron", "species", "gravity", etc.) Laws and theories are both in the group of non-verifiable statements of science and must be evaluated in terms of how useful they are: how much information they relate, how satisfactorily they explain, and what success they have gendered in predicting potentially observable phenomena not previously discovered. Clearly, theoretical statements belong in a class by themselves.

Epistemological Statements

One further class of statements must be mentioned briefly. These are statements that assert a relationship between a set of observations and the statements that interpret them or a set of laws and the theory that explains them. These form a special class of

¹O'Conner, Introduction, p. 81.



"rules of correspondence" that are called for want of a better name, "epistemological statements". How are such statements to be supported? One either "sees" the relationship when it is asserted or he does not: he may suddenly "see" it some time later, or he may never see it and deny its validity. These statements, like axioms of logic, "are verified by an intellectual insight".¹

Verification and Meaning

Returning briefly to the classical conditions for knowing a statement to be true, the very first requires that the statement in fact be true. It seems to call for a purely Aristotelean stance, that there is a "thing" out there called "truth", and that we have found it. We have already indicated that those statements of whose truth we are most certain are specific experiences of little consequence until they are generalized, and that there is no way we can know if a general statement is true. We ought to ask rather what one means by "true", and what are the characteristics of the set of experiences to which he is willing to attach the label "knowledge". In asking the question "how do you know?" we are asking both of these questions as simply and directly as language will allow: we are asking for both the verification and the meaning of the statement, as these are inseparable, complementary qualities.

"Verification is a guide to meaning because the meaning of a statement depends largely on its method of verification...If there is no possible method of verification, there is no meaning".² And

¹Bochenski, Contemporary Thought, p. 58.

²Wilson, Language, pp. 52, 53.



because "verification" is a term "beset with serious difficulties"¹, we can only know what weight to attach to a statement if the speaker tells us the grounds on which he makes the claim, i.e. what he did and what he experienced that led him to the conclusion he reached. This is not necessarily an argument against an Aristotelean stance: just an insistence that such a stance does not relieve one of the obligation to declare how he knows. "Knowing" has meaning only as it is operationally defined.

Modern science is truly a marriage of empiricism and rationalism in a matrix of language and any analysis of programs in science must begin by identifying the kinds of statements just described. Once they have been identified it is a relatively simple matter to further examine the program to determine whether these statements are presented to the student in an epistemologically defensible way- i.e. does the program give attention to the evidential basis on which they rest? But as has been constantly stressed, the problem of knowledge is never simple. Even after one can identify these types of statements readily, he is still not able to pick up a science program and proceed with the intended analysis. For as Wilson stresses, "It is people that mean, not words that mean", and the meaning we must attach to words depends to a very large extent on what the author is attempting to achieve. The uses of language are virtually without limit. It is used to arouse and express emotions, attitudes, desires, and beliefs: to question,

¹Bochenski, Contemporary Thought, p. 55.



assert, command, and request. It provides social, cultural, religious, political and economic identification, besides its use in ritual, slogan, taboo, and social formula. Perhaps the greatest mistake one can make with respect to language is the supposition of "one word, one meaning".¹ Not only do words and statements serve multiple purposes, they frequently do so simultaneously, and the final criterion for interpretation is the total context in which an utterance is made.

"All intelligent response to language...must begin with an understanding of the motives and purposes of the speaker in that situation".² And an interpretation or response is appropriate when it is in keeping with the speaker's intention. This is not to say that precision of language is unimportant but rather that even the most precise language must be interpreted in the light of the speaker's intention. The rhetorical question for example, is not put forward to elicit an answer but to prepare the hearer for what the speaker wishes to state next. And assertions of factual knowledge are used in many ways other than to simply convey their information content. In an effort to cope with the functions of statements, the "Sentence Sort Scheme" has been developed from Wilson's analysis of the functions of language, and modified empirically until it seems adequate to the analysis of the referent program, Concepts in Science. The scheme is a series of questions designed to isolate those statements whose primary function seems

¹Conner, Introduction, p. 75.

²Black, Critical Thinking, p. 151.

to be the assertion of a scientific knowledge claim. When these statements have been identified the program can be examined to see what evidence it provides in support of the claim.

Chapter 11 Part 3. Wilson's Conditions for Verification

Wilson identifies three conditions that must be met if we are to find out whether a statement is true. Note the great dissimilarity between these conditions and the classical conditions of Scheffler's approach referred to above.

1. We must discover the meaning of the statement: i.e. what its use is, what it is intended to communicate.
2. We must agree before hand about what we would accept as verification.
3. We must consider the evidence and make a decision.¹

The first two conditions are almost invariably overlooked but this model develops all three, the Sentence Sort Scheme assisting with the first. Wilson classifies all language as poetic or prosaic in function, poetic referring to any speech that is emotion arousing, prosaic to speech intended for the intellect. Five functions of prosaic speech are described: the empirical, the analytic, the imperative/attitude, the value, and the metaphysical. These categories were helpful in getting the Sentence Sort Scheme started but in its adaptation to the overall objectives of this study they were extensively revised, retaining of course the basic notion that language must be interpreted in the light of what the author intends to communicate.

The Sentence Sort Scheme is an ordered series of questions applied to each sentence in the sample in an effort to determine

¹Wilson, Language, p. 51.

what it is intended to communicate, i.e. its function. The question sequence is fixed and when the function of a sentence is pinpointed by a question, that sentence has been classified, or "filtered out." Sentences that pass through the entire sequence without being "filtered out" are studied carefully until their function is discovered and they can be classified in existing categories, or in new categories that must be created for them. The rationale for each question is provided below along with clarification of how it is to be applied. To provide consistency in the use of symbols some questions are stated negatively. This is a source of confusion but it is less confusing than other alternatives tried. The description of the Sentence Sort Scheme could have been placed in Chapter III but is included here since some justification is presented for each of the questions.

The Sentence Sort Scheme

Question 1 Is this sentence in the form of an assertion?

Assertion is the form of language used to make a knowledge claim. To assert is to state as true, "to affirm that something is the case."¹ Assertions are to be distinguished from questions and directives, exclamations, wishes, imperatives, etc., as they contain the knowledge content, the subject matter of the course. Schwab, in this connection remarks, "Of the four topics of education - the learner, the teacher, the milieu, and the subject matter...none has

¹Ferree, Body of Knowledge, p. 3.

been so thoroughly neglected in the past half century as the last."¹
This question then goes to the heart of the area of greatest neglect.

Kilbourne points out however, that the assertions of a program are usually "overwhelmed by the context."² Locating them is a difficult and time consuming job calling for special procedures as outlined in Chapter III. "Sugar is a solid substance" is a simple example of assertion.

Question 2 Is this sentence in the cognitive domain?

If it is, it will appeal directly to one's sense of reason and logic in contrast to his emotions and feelings. The distinction here is crucial and while both are integral parts of all learning situations it is imperative that we at all times be able to identify which is which. Language intended to arouse feelings need not be taken literally. That is, it is not liable to the demand for verification as is language in the cognitive domain. When domains are mixed Wilson describes the situation as "dangerous, for we may easily allow their poetic force to blind us to the prose meaning."³ It is imperative to make this analysis in science programs suspected of being "mixed" to determine whether poetic force is being substituted for the weight of evidence.

¹Schwab, "Problems, Topics and Issues", Education and the Structure of Knowledge ed. by Othanel Smith, loc. cit., p. 4.

²Kilbourne, Basis, p. 37.

³Wilson, Language, p. 56.

Some non-cognitive sentences are difficult to recognize but in general they fall into two subclasses. Either they do not make logical sense internally, or they do not make logical sense in the context where they appear. "You've known that all along, of course",¹ is an example of the first for there is no logical sense in informing a person of what he knows. "Substance is a word that scientists use",² exemplifies the second in that it is extraneous to the discussion and seems to have been included to "strengthen" an argument by using the word "scientists." Any sentence in the form of an assertion, whose logical function is not to inform may be considered non-cognitive as well.

Question 3 Is the content of the statement science subject matter?

This question is viewed from the perspective of subject matter disciplines - biology, physics, chemistry, in contrast to history, geography, and math. Statements about the program, or student characteristics are also encountered. Here are two examples: "For many years the people in a little village in India baked their bread in open fire places"(40)³ and, "You will learn about these parts soon" (107).

¹Paul F. Brandwein et al. Concepts in Science, Level Three, 3rd ed.; (New York, Harcourt Brace Jovanovich, Inc.) 1972. p. 94.

²Brandwein, Concepts, p. 106.

³All examples are taken from Paul F. Brandwein, et al. Concepts in Science, Level Three, 3rd ed. New York, Harcourt Brace Jovanovich, Inc. 1972. Numbers in parentheses are page numbers in the student text.

Question 4 Is the statement fully explicit?

A statement is fully explicit when it is more likely to elicit a request for verification than for clarification. Statements that are very general or suggestive are not fully explicit. They may serve to introduce, or to join other statements, or to stimulate to infer, or they may serve no purpose at all. Some examples are:

- (a) "Air and water are alike in two ways".(126)
- (b) "Some rivers were once clear and clean".(131)
- (c) "There are many ways of separating mixtures".(117)
- (d) "Here is what a class in Ohio saw on the third day".(111)

Sentences "a" and "c" are followed up with specific information but "b" is not. Sentence "d" is obviously intended to elicit an inference.

Question 5 Is the statement non-subjective?

This question is intended to "filter" out overtly subjective statements where the author is very much in evidence, as in the following: "This is not surprising" (105) and, "We have made drawn models of molecules...just to show how they get around".(105) This example is more subtle: "Now we can see that the Earth's air and water are not endless."(132) "We" is very general but the author's intention that the students "see" this is evident. In both senses it is subjective.

Question 6 Is the wording consistent with scientific thought?

Imprecise language is confusing and non-verifiable. Statements that are anthropomorphic, inaccurate, misleading, that contain strained or forced word usage, or in any other way fail to represent

scientific thought accurately should be identified here. Some examples are:

(a) "Water can change its form" (94). (anthropomorphic)

(b) "...water vapor that cools and turns back into water" (98)

This is a poor choice of words in a discussion intended to show that phase changes do not alter the composition of substances.

(c) "The water in the pan weighed less after boiling." (98)

This is self contradictory. There was less water in the pan after boiling, or the pan of water weighed less after boiling, would be more appropriate.

(d) "Molecules make sugar disappear in water." (110)

Here is a case of strained usage: Molecules do not make colored solutes (like potassium permanganate) disappear in water. This wording suggests a very false magical concept of the solution process.

(e) "The sugar molecules were left behind in the pan." (112)

This is strained word usage.

Question 7 Is the statement without theoretic terms?

The distinction between theoretic, analytic, synthetic, and epistemological statements has been developed at length above. Theoretic statements are identified by their inclusion of theoretic words: words that name "things" whose existence and properties can only be inferred, such as "atom", "species", and "gravity". Some examples are: "These tiny bits are called molecules." (104) and, "An element is made up of just one kind of atom." (122) The distinction between inference and observation may become very difficult in some cases but some strong arguments could probably be raised against including very many situations of this kind in an elementary science program.

Question 8 Is this statement non-epistemological?

Claims to know, explicit or implied, are not epistemological statements. But statements declaring what can be known, what cannot be known, or identifying the grounds for claiming to know, or the degree of certainty to be attached to a statement, are epistemological. In the example below, statements a, b, and c are epistemological, d and e are not.

- (a) "Many experiments have shown the same thing." (96)
- (b) "We cannot see molecules." (105)
- (c) "You have evidence of molecules from using your nose." (105)
- (d) "You know what happens." (118)
- (e) "We know that Earth's air and water are not endless."

Question 9 Is the statement not identified analytic?

Analytic statements, verifiable by analysis of the statement itself, have been described in detail above. They provide information only about how we have agreed to use words and it is the author's responsibility to inform the reader that this is his intention when he makes an analytic statement. This is easily done by using expressions like "means", "is called", "is another word for", etc. If we say, for example, the word "matter" means anything that takes up space and has weight, we have identified this statement analytic, making its meaning and method of verification perfectly clear. If an author fails to do this,

"We may feel inclined to say that (his) statement does not really give information...The onus of giving an account of the meaning and verification

of a statement which purports to give information lies on the person who makes the statement."¹

This requirement probes the author's sensitivity to epistemological concerns and could possibly provide the best single index of program quality. This hypothesis of course must be tested by further research.

Question 10 Is the statement not verifiable by the dictionary?

Analytic statements often "pass for" synthetic statements until they are carefully investigated. If all the information in the statement can be obtained by consulting the dictionary, the statement is clearly analytic. For example, "water is a liquid" is analytic because the dictionary defines water as a "clear, colorless, odorless and nearly tasteless liquid."² "Sand is a solid" is analytic because sand is defined as "loose, granular, gritty particles of worn or disintegrated rock finer than gravel and coarser than dust"³ making it clear that we are talking about a solid. The content of the statement can be learned from the dictionary. Both of these statements are used in Concepts in Science, in fact, to provide examples of what we mean by "liquid", and "solid".

Occasionally a statement seems clearly analytic but it cannot be verified satisfactorily by the dictionary. An example of this is found in the statement, "This kind of change is a chemical change." No dictionary consulted has a listing under "chemical change", the meaning of which is to be found perhaps, only in science text books.

¹Wilson, Language, p. 58.

²The American Heritage Dictionary.

³The American Heritage Dictionary.

This is a stipulated definition of limited circulation and should be identified analytic.

Statements not "filtered" out should include the synthetic statements, and problem statements. For synthetic statements the program is to be analyzed for evidential support, and the problem statements further analyzed to determine their function.

These ten questions are intended to identify the knowledge claims of the program and to identify them as analytic, synthetic, and theoretic, but in the process a number of incidental categories were developed, each providing additional data on the quality of the program. With the exception of statements "inconsistent with scientific thought", and unidentified analytic statements, those in any of the other categories could either enhance or detract from the program's overall quality. The analyst must make these decisions. A flow chart of the Sentence Sort Scheme (final form) is included in Appendix 2 for reference.

All of this preliminary work was necessary to comply with Wilson's first step toward finding out whether a statement is true: we have to discover its use, what it is intended to communicate. Assertion is the function of interest in this study, statements intended to communicate information about words, or about observable phenomena of nature, or about abstractions, i.e. theories. Having classified the statements according to their use, we can proceed to Wilson's second step:

"Agree about how to discover whether it is true or not".
The intimate relation between meaning and verification has already

been introduced but a few more ideas are in order. Wilson points out that "we can logically compel someone that what passes the verification tests for being red is actually red. But we cannot logically compel him to agree to accept the verification tests themselves."¹

Bochenski says of verification, "one should as far as possible, make use only of such expressions and formulate only such statements as are relatively easy for others to verify", and "...there shall be some method or other by means of which it can be ascertained whether a statement is to some extent correct or in-correct."²

Carnap: "...everyone is free to decide what kind of verification he intends to allow...", but he makes clear that in the sciences, statements must be "ultimately verified by sense experience".³ Many volumes have been written on the subject of verification but little is said about what makes verification tests acceptable to their users. Wilson says: "He will accept them if he has the same experiences and desires as other men". And, "we agree (about tests for verification) because we find such agreement useful or advantageous." Two very generally accepted tests are the test of prediction and that of application: statements are useful "primarily because they

¹Wilson, Language, p. 89.

²Bochenski, Contemporary Thought, pp. 55, 56.

³Ibid. p. 56. Carnap's position described by Bochenski. No reference to the work provided.

enable us to predict, ...they are verifiable because they work".¹

The call for scientific literacy is a call for the student to have "an evidential argument which he understands, ...and proper credentials for (his)...belief, the force of which he himself appreciates".² He must therefore understand that "evidence" is what we are willing to accept as evidence. And whether a science program presents evidence that supports its claims must to a very substantial degree be decided by those who are going to use it. The teachers must appreciate the force of the evidence. The point is that Wilson's item 2 - "Agree about how to discover whether it is true or not" is finally a classroom activity. It follows that programs that make knowledge claims, the evidence for which is beyond the students' ability to appreciate, should under no circumstances be selected for that group, and that those who make curriculum decisions must have a very realistic perception of the kinds of things their students could be expected to understand.

Wilson's third step is to "consider the evidence and make a decision". And while agreement as to what constitutes evidence for any specific statement is necessary,³ this is not to say that it is capricious. The "structure of scientific knowledge" concept is built upon the idea that there are several well defined types of verification, each of which gives rise to a well defined type of

¹Wilson, Language, pp. 85-89.

²Scheffler. Quoted in Kilbourne, Basis p. 12.

³Wilson, Language, p. 51.

statement. It is therefore appropriate to review the concept of verification as it applies to each type of statement.

In the case of analytic statements, "evidence" would refer to whatever might convince unbiased parties that words are legitimately used as the author has used them. And, while this is occasionally a problem it can usually be resolved by consulting an appropriate dictionary. The more common problem with analytic statements is that the author fails to indicate that he is making one.

Synthetic statements are subdivided into two groups as follows:

1. Statements relating to a single event or sequence of events:

The best evidence is to have witnessed it yourself along with others who can also testify. The next best is a first person report (a protocol statement) that includes the date, time, circumstances, name of observer, and specific authenticating details. Second and third hand reports become more convincing as they include specific relevant details.

2. General statements summarizing the observation of many

instances: For generalizations of observation, the number of instances on which the generalization is based is significant. It is not reasonable to suppose that the program should provide all the evidence needed to establish the generalization, but the method for doing so should be clearly developed. Evidence looked for then would include the conditions under which the statement is held true, observation of specific instances of the phenomenon, quantifying and gathering data, organizing and interpreting the data,

making and checking predictions. But as Robinson points out, prediction should provide more data than those which formed the original observation as the scientist seeks "deductive fertility and a non-trivial return". Such prediction is, perhaps "the most searching criterion of understanding",¹ the most convincing evidence of the validity of a generalization.

As used in this paper, the term "theoretic statement" describes a statement, derived by reductive inference, of what is common and significant to the operation of scientific laws. It can be identified by its inclusion of words that are not part of the language of observation: words that name "mechanisms" that would account for the behavior we observe if indeed such "mechanisms" having such and such properties were to exist. Evidence for theoretic statements involves a clear and historically accurate development of where they came from and why they are held. This includes identification of the protocol statements that led to the laws that the theory was invented to explain. The assumptions should be identified, the reasoning elucidated, the utility of the theory demonstrated, and its "elegance" made evident. By utility we mean its power to interrelate many pieces of apparently unrelated information, and by "elegance" its ability to make it all seem simple. This description is included in the interests of future research as theoretic statements will not be pursued further in this study.

¹Robinson, Nature of Science, p. 117.

If knowledge claims are to rest on evidence, it is important that programs be developed in such a way that students have full access to the evidence, and that they are truly dependent on it in reaching their conclusions. If there are "answers" easily accessible from the text or teacher, even good evidence may become mere illustration and the origin of scientific knowledge remain a mystery to the student.

Teaching for scientific literacy is the most demanding kind, requiring the most alert teachers and the most carefully prepared materials. It is not enough that science programs distinguish between types of knowledge claims and provide good evidence and arguments: they must also incorporate techniques conducive to students' becoming personally involved in the evaluation of the quality and meaning of evidence. Unqualified assertion militates against this and has no part in any science program. Different classes of science statements vary in the certainty with which we are justified in holding them, and it is imperative that the author provide, in context, some indication of this. Even a cursory examination of source materials shows that scientists display a characteristic tendency to carefully qualified speech: "data are limited", "a firm and certain assumption", "according to our present conceptions", "it has seemed to me", and so on.¹ It is one of the aims of

¹Henry M. Leicester and Herbert S. Klickstein, A Source Book in Chemistry: 1400-1900 ed. by Edward H. Madden. Source Books in the History of the Sciences (Cambridge. Harvard University Press) 1952. pp. 439, 453, 460.

scientific literacy that this tentative quality of scientific knowledge be clearly perceived by the student, and programs must be evaluated to see how they convey this information. The following question sequence was developed in an effort to gather data on these important characteristics of science programs.

The Examination for Evidence

- (A) What is the knowledge claim?
- (B) Under what conditions is it held to be true?
- (C) What evidence and argument would (or did) establish this claim?
- (D) What evidence and argument is provided in the program?
- (E) Does the program obviate the necessity for examining the phenomena of nature?
- (F) What techniques in the program might be expected to promote individual evaluation of the evidence?

The first question has been extensively treated above. The second is important in order that the statement be accurate, but also so that the phenomenon may be successfully demonstrated or observed by the reader. "C" and "D" have been discussed at length and "E" is included to differentiate programs that stress first hand experience of the evidence from those that minimize its importance even though they may indicate how it could be done. "F" is perhaps the most crucial test of all. Scientific literacy is not a matter of arming the student with arguments and supplying him with evidence to back them up, but of engaging his mind in the process of considering what

constitutes good evidence. It is therefore imperative that this matter pervade the curriculum. Whatever devices or techniques seem likely to encourage this will be catalogued.

Summary of Chapter II

The information explosion and the rapidly accelerating rate of change have led many educators to realize that the subject matter of today's science will hardly be useful to today's children who will spend most of their lives in the twenty first century. The move in science education then, is toward an emphasis on how we know rather than what we know, and specific goals for effecting this kind of education have been carefully drawn up. The present need is for a procedure by which to examine curricular materials to see if they hold some potential for meeting these goals.

Philosophers have long recognized that knowledge is of several kinds: we have knowledge about physical phenomena via our sensory perceptions, such knowledge being the foundation on which science is built. We may also claim to know things on the basis of inferences drawn from these observations, such knowledge being the laws and theories of science, its superstructure. And all of science is expressed in language of one sort or another so we must have knowledge about language. These three elements in the structure of scientific knowledge are integrated in the curriculum evaluation model: a sentence sorting scheme that facilitates identification of the function of sentences, and a procedure for examining the appropriate statements to see how they are supported. The analyst is left to decide whether the support is adequate or not. Data

must also be gathered on program safeguards against obviating the necessity to examine evidence, and on techniques for promoting individual involvement in interpreting the meaning and quality of evidence provided. The philosophical justification for this model is developed mainly from the works of Mill, Wilson, and Bochenski.

CHAPTER III

METHOD: DEVELOPMENT AND APPLICATION OF THE MODEL

Overview

The strategy for developing the model was to (a) identify the epistemological character of the NSTA goals statement, (b) describe from the literature the elements of an epistemological approach to knowledge, (c) empirically develop procedures for identifying these elements in a carefully selected referent program, and (d) test these procedures by applying them to a contrasting science program. Having fully developed "a" and "b" above in Chapter II, this chapter will principally describe the empirical development and testing of the model.

With the various types of knowledge claims identifiable and the conditions for verification specified, the problem was to find the knowledge claims, "embedded" as they are within the program. Hit and miss efforts at spotting them proved thoroughly frustrating and inadequate. To cope with this problem a Sentence Sorting Scheme was created that facilitates discovering the function of all sentences in the sample and sorting them on this basis, providing much additional information about the program. Synthetic statements were chosen as the principal target in this

investigation because (a) they are most directly and conclusively verifiable, (b) they constitute the foundation upon which science rests, (c) theoretic statements cannot be verified but only traced logically back to synthetic statements, and (d) for pre-formal operational children, they are pedagogically sound, the kind one might reasonably expect to find extensively in elementary programs. It was supposed initially that it would suffice to simply note whether analytic statements were so identified, and this proved to be a significant variable in the two programs examined-so significant that several recommendations for future research are aimed at analytic statements.

But even after classifying statements on the basis of their general mode of verification, Wilson, Mill, and others agree that each statement has its own "proper" verification,¹ some generalizations for example being acceptably verified by very few observations while masses of data are insufficient for others.² It is therefore necessary to specify the evidence and argument required to verify each individual knowledge claim. This responsibility falls on the analyst who must work out an appropriate sequence of verification procedures that would be defensible to most interested parties, and then examine the program to see if they, or equally valid procedures are present.

The highly specific nature of verification makes data summaries difficult but some progress has been made in this direction as will

¹Wilson, Language, p. 51.

²Mill, System, p. 156

be seen in Chapter IV. The content of the findings is intended to be informative primarily about the model rather than the programs analyzed but this distinction is hard to maintain. What is reported on each program must be interpreted to mean that the model would be helpful in determining the presence or absence of such characteristics in other programs.

Developing the Sentence Sort Scheme

With some background in the nature of both science and language developed in Chapter II, a referent program was needed around which to build empirically a functional procedure for isolating science knowledge claims within a text. The qualities looked for in a referent program were these:

that it be a science program for elementary students.

that it contain explicit knowledge claims for them to learn.

that it be in current wide use.

that it be well established, through at least one revision.

that it be challenging so that a model equal to its analysis would hold substantial promise for use in analysis of other programs.

Concepts in Science meets all of these criteria and was selected after examining materials from most major publishers. The third grade level was chosen as optimum for this study in anticipation of many kinds of difficulties, a choice that has proved very wise. The examination began with a careful reading of the introductory material to Part One, CONCEPTS IN SCIENCE-THE PROGRAM. This initial investigation provided a strong internal criterion against

which to evaluate the results obtained by using the model. A strong similarity between the epistemological character discovered in the introduction, and that found in the text gives support to the notion that the epistemological quality of a program is a fundamental characteristic and that a relatively small sample has broad implications for an entire elementary school science program.

The first efforts at developing a technique for sorting sentences were with single pages taken at random from all units in the text, and sentences were simply identified as assertions or non-assertions. Then ten pages were selected for intense study, using a table of random numbers. The language in Concepts in Science is simulated conversation, with one word questions, one word statements, and all the usual and unusual modes of expression mixed in a very unconventional way. "You break a stick." Break a candy bar in half. Cut up an apple."¹ Sentences like these provide a real challenge to this type of analysis. By isolating the more familiar types and continually working to discover the function and describe the characteristics of the difficult ones it was finally possible to classify most of the sentences in the sample selected. Sentences in the teacher notes and background material were also classified and the experience was very frustrating. As a result, in subsequent analyses, only the student text was examined for knowledge claims and the rest of the program for evidence in their support. This was not out of harmony with

¹Brandwein, Concepts, p. 126.

the design of the program and greatly simplified the task. Several explorations were undertaken of various ways of numbering and grouping sentences in this attempt.

For the next phase of development a whole unit was selected in an area of my own expertise and all aspects of the model tested. The question sequence was revised extensively, eventually coupled with a data sheet and used to collect data on more than 250 sentences. Several new methods of numbering and grouping sentences were tried along with attempts at keeping track of repetitions and rewordings. The numbering and grouping was successfully worked out but the rewording and repetition proved too complicated. A new data sheet was developed and used for the analysis of the more than 550 sentences in the unit chosen for intense analysis. A sample of this data sheet and its subsequent revisions is included in Appendix 3.

The next task was to gather all the sentences of a given type together for comparison and further description. This procedure resulted in the reclassification of a number of sentences and several significant revisions in the sentence sort scheme. All sentences were then re-examined, some reclassified, and subclassification within groups worked out providing additional identifying features of sentences and making the sorting procedure much easier. The resulting question sequence is the one described in Chapter II. The complete set of classified sentences from the sample is included in Appendix 4 to provide maximum clarification of the terms used in the Sentence Sort Scheme. This "Scheme" is not presented as a

finished product; but it did prove adequate to the analysis of the two (very diverse) programs investigated. It is a matter of great interest and further research at this point to see just how comprehensive the presently defined categories are. In any case the method may be expanded and modified to suit new situations as they arise.

Using the Sentence Sort Scheme

1. The introduction to any program should be carefully studied at the outset as it may provide sufficient cause to reject a program without further analysis, but no program should be accepted without further analysis simply on the claims its authors make in such passages.
2. Procedures for sampling are yet to be established by further research but based on the author's limited experience it seems that single topic selections, i.e. the presentation of a single knowledge claim, is the most reasonable approach to the problem. These are usually short sections of 1-3 pages and should be selected from several different subject areas or disciplines, at least one of them an area of the analyst's expertise.
3. The sample should be prepared as follows:
 - (a) Photocopy the pages to be examined, preferably from the student text as the page is less crowded and the print larger.
 - (b) Determine what is to be omitted: review questions, enrichment experiences, etc.

- (c) Number every sentence on one page (or under one heading) from 1 to n. Accuracy is essential as the data sheet identifies sentences only by page or topic heading and number, and trace back is essential for many reasons including the examination for evidence. Keeping the number sequences small protects against errors in numbering as there is little space for writing them.
4. Read the sample material several times to gain a feel for the style and development of ideas.
 5. Be sure that you are familiar with all the features of the program: required lab manuals, teacher guides, equipment, etc. and the way they are to be used.
 6. Complete the information needed at the top of the data sheet.¹
 7. Enter the number "1" in the first row to the right of "Sentence #." All data on sentence "1" will be recorded in the first column under this number except for notes which may be made on the lower part of the page. The abbreviated questions are given in full in Chapter 11.
 8. If the answer to a question is "yes", a plus (+) is marked to the right in column one and the next question is asked.
 9. If the answer is "no", a minus (-) is entered and classification for that sentence has been completed. Non-assertions

¹Sample data sheets are provided in Appendix 3.

may be further identified "Q" and "D" (question and directive, respectively) but there are other types of non-assertions as well.

10. If the category for any sentence is immediately obvious it may not be necessary to ask each question before classifying it. However, a sentence is removed (classified) at the first question for which the answer is "no". To indicate that even if all the questions had been asked the sentence would still belong in this category, a wavy line is drawn down through the column to the minus.
11. When a question seems awkward with respect to a certain sentence but does not really call for a "no" answer, this can be indicated by an arrow () and the next question raised.
12. If none of these options seems appropriate a question mark should be entered and this sentence put in the "Problem" category. On further study it may be classified or it may call for the addition of a new category in the scheme.

The Sentence Sort Scheme is a set of questions designed to "filter" the text with sentences passing through when the answer is "yes", but being "filtered out" when the answer is "no". At the first question, "Is it an assertion?", all sentences that are not assertions are identified by the minus sign and stopped, and only assertions pass through. By filtering out successively, various classes of non-verifiable and analytic statements, the synthetic

statements should pass through and be easier to separate from whatever else escaped classification. The program can then be examined for evidence in support of the statements of interest and data on the distribution of other sentence types in the sample is an interesting by-product. It should be noted that this Sorting Scheme classifies without overlap, not because the categories are mutually exclusive but because a sentence is removed at the first question for which the answer is "no". Thus, a change of question sequence could redistribute the statements and caution must be used in interpreting the distribution.

Restructuring the Material

For the purpose of sorting it is frequently necessary to "restructure" a sentence, i.e. to break a sentence into several parts or to join short sentences together. This may be done as illustrated in the following example.

1. "Have you ever jumped into water and hit hard? 2. If you have you know that water is pretty solid stuff. 3. But try this." Sentence #1 is a question and is "filtered out" at the first stage by marking a Q or - sign under #1 on the data sheet. Sentence #2 has two distinct clauses serving two different functions: "Water is pretty solid stuff", appears to be an assertion about the nature of water, while, "If you have, you know that...", informs of how the assertion can be verified. It has proved workable to sort such sentences by drawing a slant mark between the two clauses and identifying the first as 2a, the second as 2b and completing a

separate column on the data sheet for each. In this case the first would be filtered out at "not epistemological?" because it is epistemological, and the second at, "Wording consistent?" because the wording is not consistent with scientific thought. Sentence #3 would be identified as a directive, with a 'D', or simply as not an assertion, with a (-) sign. Some sentences are more complex but all can be sorted by these simple techniques. The process of breaking or joining the original sentences, referred to as "restructuring" the material, is crucial to the completion of the analysis. The more carefully it is done, the easier will be the examination for evidence. This seems to be a practical consequence of the intimate relationship between meaning and verification.

The Examination for Evidence

Data on analytic statements is taken directly from the data sheet and theoretic statements are not further pursued so the "Examination for Evidence" refers exclusively to specific synthetic statements identified in the sample. What would count as evidence is so specific to a given knowledge claim and so variable in length that a special form for this portion of the analysis did not seem warranted. There are no special procedures at this point: the analyst must simply search the program to see how the specific knowledge claims in the sample are supported. Six questions are raised to direct the search:

- A. What is the knowledge claim? One of the recurrent problems in this study is rewordings and repetition. Before beginning the search for evidence, all of the restructured material

classified "synthetic" should be gathered together in one place, and redundancy eliminated. The assertions that remain are the knowledge claims for which the program must be examined for evidence. Closely related statements may be grouped in the examination for evidence.

- B. Under what conditions is it held to be true? The primary concern here is that an interested person should have enough information to enable him to witness the phenomenon if he wishes. Further, of course, this information is part of the requirement for making a true statement. If no conditions are given, the statement may be set forth as a universal, the conditions may be met in the way instructions are provided for a demonstration, or the author may have been careless. Some assessment of the situation should be noted.
- C. What evidence and argument would or did establish this claim? It is the analyst's responsibility to determine in his own mind what it would take to verify the claim. The procedure and the argument should be written down step by step. If the analyst can not come up with a method, he can resort to the history of this discovery. If he can not find any method of verification the statement is to him, at least, metaphysical¹ and does not belong in the science program.

¹Wilson, Language, p. 99.

- D. What evidence and argument is provided in the program?
Whatever seems intended to support a knowledge claim should be noted and matched against the procedure in "C" above. Illustrations, analogies, etc., should be so identified (they are not evidence), and a judgement passed as to whether the claim is verified or the method that would verify it clearly presented.
- E. Does the program obviate the necessity for examining the phenomena of nature? Any indication that evidence as available to the student is not the ultimate basis upon which the statement rests should be noted. Failure to provide evidence, unqualified assertion, presentation of the "results" before doing the experiment, or any other method that minimizes the significance of observation puts scientific knowledge on an authoritarian basis. This question should be answered "yes" or "no" and reasons noted.
- F. What techniques in the program might be expected to promote individual evaluation of the evidence? This is closely related to "D" above but calls for specific identification of methods employed in the program that might stimulate students to individual rational skepticism. Any technique thought to have potential in this area should be listed.

Sample Analysis of Synthetic Statements from Concepts in Science.

Examination for Evidence

- A. Knowledge Claim 4 "When water changes from solid to liquid form it does not change weight. 5 The same is true when water changes from liquid to solid form. 6 No water is lost or gained"... 13 "No water is lost or gained as a result of changing it from liquid to gas and back to liquid."¹ Sentence #13 is the comprehensive statement and in this case all of these assertions were treated as a unit in one evidence search. It is very tedious to do each assertion individually when they are intimately related but when difficulties arise they can usually be resolved by making the breakdown to simple assertions.
- B. Under what conditions is it true? No conditions are given: Variables listed that might influence the outcome of the suggested demonstration include evaporation, condensation, and scale reading error.
- C. What evidence and argument would or did establish this claim?
1. Each type of phase change should be examined.
 2. Multiple samples should be examined for each.
 3. Precision of the scale should be established.
 4. Data (before and after weight difference) compiled.

¹Brandwein, Concepts, pp. 96; 100. The numbers before the sentences refer to the sentence numbers on the page.

5. Data show that within the limits imposed by the precision of the balance, no weight changes occur.

Argument: If the balance were as precise as we could make and if this continued to be the result every time a determination was run, we would be justified in making this knowledge claim.

D. What evidence and argument is provided in the program?

C-1 Change from solid to liquid is examined.

Reverse change suggested as student take home project. Liquid to gas and back to liquid is pictured, anecdotally described and mildly suggested as a demonstration: "You can easily set up a coffee pot still as suggested on this page."¹

Only one phase change is treated as integral to the program.

C-2 Only one sample is examined.

C-3 No mention of behavior of scale. Teacher instruction:

"results this time should agree." Any difference in reading to be accounted for as an error in weighing, spillage, evaporation or condensation.

C-4 Only one datum taken.

C-5 Statement and "verification" treated as absolutes.

"The scales (pictured) all show the same weight because no water is gained or lost when an amount of ice is changed to liquid form."²

¹Brandwein, Concepts. teacher edition, p. T119.

²Ibid., p. T116.

The proposition is deduced: the observation is a consequence of the truth of the proposition.

- E. Does text book obviate the necessity for examining the actual phenomena? Yes. All investigations are accompanied by photographs which are entered as "the results of one trial." The outcome is not only pictured but confirmed by the teacher's prescribed (categorical) answers to questions, and reiterated several times in the text as well. For example, question: "was any water lost when the water changed from solid to liquid?" Answer in teacher note: "(no) Children's responses should be based on their findings in the investigation. When the water was frozen again and changed from liquid to solid, was any water lost? (no)." The investigation was a demonstration and the refreezing was suggested as something "a child might do...at home and report results the next day."¹ The introduction to the Concepts In Science program makes it clear that in the author's mind the text and pictures constitute a sufficient program, but the suggested activities "confirm the predictions."² Materials needed for doing the activities are listed merely as "useful materials."³

¹ Brandwein, Concepts. teacher edition, p. 115.

² Ibid., p. F12.

³ Ibid., p. T112.

- F. What devices in the text might be expected to promote individual evaluation of evidence?

None. Teacher instructions in this section include:

- a. "Let them justify their response." (T112)
- b. "...ask children to make a prediction (hypothesis)."
(T114)
- c. "Ask also: What did you see forming at the bottom of the pan? What evidence did you get that water left the pan? What did you see in the air above the pan? Now children may read the page to confirm or change their responses." (T118)

The reference in "a" is to the child's answer to a riddle posed by the teacher. The prediction called for in "b" is in the form of a "yes" or "no" guess, at the start of the unit and the passage under "c" shows that even what the child may have observed or counted as evidence during the demonstration, he is expected to change or "confirm" in accord with what is written in the text. The text several times asks, "How could you get some evidence?" but the teacher is instructed in one case as follows: "After suggestions have been made and considered, let the children read the rest of the page and examine the picture carefully." (T119) The "evidence" is supplied by the picture, (a drawing of a coffee pot still and an account of what a twelve year old boy did with it.) But no data are given and several statements are hard to believe.

Careful study of the program treatment of this knowledge claim reveals a categorical, deductive approach, that leaves no room for evidence or student participation in the generation of knowledge. Complete results of the analysis of this program is presented in Chapter IV.

CHAPTER IV

FINDINGS

Organization of the Chapter: Efficiency in reporting the results of this kind of investigation is not easily achieved. The findings are simply described in the order of the investigation as follows:

Part 1 Concepts in Science

Examination of Introductory Material

Sentence Sorting of Sample

Examination of Synthetic Statements for Evidence

Summary and Interpretation of Findings

Part 2 SCIS

The findings in the application of the model to SCIS are presented in essentially the same way as for Concepts in Science, and while each program is analyzed in some detail, the data on specific details are not directly comparable since the order of the questions in the Sentence Sort Scheme was revised after the first program was analyzed. (Compare Appendix 3A and 3B). This could have resulted in slight differences in the way sentences were classified in the two programs, but could hardly have any effect on the overall character of the sentence profile or on the general epistemological character of the programs as brought to light by the model. It must be reiterated that the main thrust of this effort is the development of the

model, and not comparison of the two programs involved: a fundamental difference in their epistemological quality does become apparent though, and this fact becomes a measure of the model's usefulness.

Part 1 Concepts in Science

Examination of Introductory Material

A number of statements in the introductory material seem to contain significant implications as to the epistemological quality of the program. Some of these have been included below and are followed by a brief statement making explicit what they seem to imply. These implications, if properly perceived, should be supported by the data gathered in using the model, so final evaluation of these introductory statements is reserved until the data has been presented, and is included in the last section of Part 1 of this chapter. These statements seem to be especially epistemologically significant:

- 1) "Children verify the data obtained from observations."
(F-9)¹
- 2) "Lesson clusters are organized in a sequence in which situations are created whereby children come to associate an entire set of attributes of this event: The Sun is the Earth's chief source of radiant energy." (F-12)

¹"(F-9)" means page 9 in the introductory section of the teacher's edition which is called "Part One: Concepts in Science-The Program"

- 3) "Even if children were to undertake analysis of just the problem-picture situations visualized they would be engaging in selecting the essential attributes of the event. Such selection would enable them in turn to predict the event from one signal, say a lump of coal. But the children's text book suggests many activities to confirm the prediction."

What these statements seem to imply:

The first, by referring to verifying data obtained from observations implies that in this program observation is not the strongest available verification, hence that protocol statements are not the foundation of the system of scientific knowledge. In this program then, verification must come from inferred statements-theories, and laws, by deduction.

Bizarre word usage is encountered in 2 and 3 above, where a proposition, "The Sun is the Earth's chief source of radiant energy" is called an "event". No dictionary consulted, nor any of this author's past experience would allow this meaning for the word "event": yet no stipulation of new meaning was found in the examination of the program. And this word usage seems to play a key role in this program's approach to the structure of scientific knowledge. "The Sun is the Earth's chief source of radiant energy" is said to have "attributes", and children are supposed to be able to select its "essential attributes", and to predict that "The Sun is the Earth's chief source of radiant energy" from a picture

of a lump of coal. They can then "confirm" their prediction by noting that a plastic bag filled with air is warmed by sunlight!

Aside from this strange method of confirmation, it seems that common words with well established meanings in the context of scientific investigation, are being used in this program with new meanings: and the reader is left to infer just what the new meanings might be. For this reason, it is especially important to analyze the sample to determine precisely how words are used by its authors in making and supporting knowledge claims.

Finally, it would appear from these introductory statements that the authors regard the text book and its pictures as the primary focus of their program, student experiences with natural phenomena being relegated to a place of secondary importance. Careful examination of data from the sample should show whether or not these inferences may be validly drawn from the statements in the introduction.

Sentence Sorting Scheme Data Summary

Program: Concepts in Science

Sample: Unit Three, "Planet Earth-Changing Form" pp. 92-135

Student's text (except "On your own," "Before you go on", and "Using what you know.")

Number of sentences sorted: 552.¹

Method of reporting results: Two breakdowns are used, the percentage of assertions in the whole sample (552 sentences = 100%), and the percentage of sentences in each category of assertions (314 assertions = 100%). For convenience of computation, results are reported to a tenth of one percent.

Categories:

1. Non-assertion: 238 of the 552 sentences examined (=43%)

The following % is based on 314, the number of assertions in the sample.

	<u>No</u>	<u>%</u>
2. Non-cognitive	21	6.7
a. do not make logical sense (17)		
b. do not contribute logically to the context (4)		
3. Not science subject matter	4	1.3
a. about the disciplines (2)		
b. about the program (2)		
4. Not Fully Explicit	24	7.6
a. introductory/conjunctive (8)		
b. generality (11)		
c. inference to be drawn (5)		

¹All sentences sorted are listed by categories in Appendix 4 for reference.

	<u>No</u>	<u>%</u>
5. Overtly Subjective	2	.6
6. Wording not consistent with scientific thought	23	7.3
a. anthropomorphic (4)		
b. inaccurate/misleading (14)		
c. forced word usage (5)		
7. Theoretic Terms	63	20.0
a. epistemological (10)		
b. word usage (4)		
c. purporting to explain (47)		
d. postulating existence (2)		
8. Epistemological (non-theoretic)	13	4.0
a. verification explicit (5)		
b. assurance of evidence (4)		
c. ways we cannot know (4)		
9. Identified Analytic (11)	11	3.0
10. Analytic, not so identified	33	10.0
a. verifiable by dictionary (32)		
b. thing-word relationship (1)		
<u>OTHER STATEMENTS</u>	125	40.0
11. Synthetic	46	14.6
a. refer to single event (16)		
b. general (30)		
12. How to do (8)	8	2.4

	<u>No</u>	<u>%</u>
13.* Pseudo-protocol (28)	28	9.0
14.** Make-believe (28)	28	9.0
15. Problems	15	4.8

*These statements are worded as first hand observations of unique classroom events, i.e. as protocol statements, but are in fact deduced from generalizations, hence are in this context, non-verifiable, misleading, and illegitimate. See the full list, of such statements included for reference in Appendix 4, and the discussion under pseudo-protocol statements in "Interpretation of the Profile", below.

**These statements refer to pictures in the text as though they were the things they represent. They are non-verifiable and misleading, also. See the full list of these statements in Appendix 4 and the discussion under "Make-believe statements", below.

Concepts in Science Sample Profile

Theoretic	20%	Wording not consistent	7%
Synthetic	15%	Non-cognitive	7%
Analytic	13%	Problems	5%
Pseudo-protocol	9%	Epistemological (non-theoretic)	4%
Make-Believe	9%	How to do	3%
Not Fully Explicit	8%	Not Science	1%
		Overtly Subjective	1%

Interpretation of the Profile

Theoretic statements. Theoretic statements top the list accounting for a full 20% of the sample, but this might have been expected with the unit concept objective entitled, "Matter consists of atoms and molecules." The further breakdown shows that 75% of these theoretic statements seem intended to explain, but since they are injected without evidence, their origin and validity is itself a great

mystery. It is certainly illogical to suppose that obscurity about natural phenomena can be lessened by simply positing notions still more obscure.

Synthetic statements. The number of synthetic statements is greatly inflated by an anecdotal account about a 12 year old boy in Texas. It is not a first person report, it lacks authenticating detail, and it accounts for more than 1/3 of the synthetic statement total. This leaves less than 10% of the sample in the synthetic category, compared to 20% theoretic and 13% analytic.

Analytic statements. Only 11 of the 44 analytic statements were so identified, leaving the student to guess whether the other 33 are about word meanings or natural phenomena. This low figure is a program weakness and evidence of poor epistemological quality in this category.

Pseudo-protocol statements. The existence and high incidence of this phenomenon is regarded as program disqualifying because it destroys the most basic distinction in the structure of scientific knowledge, i.e. the difference between observation and inference, and it tends to create an illusion of providing direct observation of natural phenomena without actually having done so.

Make-believe statements. Make-believe statements are assertions about pictures as though pictures were what they represent. Walton, in 'Pictures and Make-believe' talks about the 'immense attractiveness' of the idea that pictures 'look like' what they represent, but argues rather that the picture is a complex of

symbols that instructs us to imagine; to engage in a game of make believe. "I propose," says Walton, "regarding pictures as props in the game of make-believe: truths about picture objects are fictional and necessarily so."¹ He goes on to establish some rules for playing the "pictorial game of make-believe," the most important of which is that players understand that all statements they make about pictured things are only "make-believedly true."² Here is an example of a make-believe statement accompanied by a picture from Concepts In Science: "But look again at this solid water. What is happening to it? Yes, the ice is melting."³ There is in fact no ice and no melting to look at. This is clearly a game of make-believe, played in violation of the rules. These statements, adjunct to pseudo-protocol statements and the "problem picture situations" are, from an epistemological viewpoint, program disqualifying.

Not fully explicit. A number of these statements intended to elicit an inference are also part of the game of make-believe. "Here is what one class observed in about an hour." (picture referent), is an example. (103)

¹Kendall L. Walton, "Pictures and Make-Believe", The Philosophical Review LXXXII, Number 3. Whole Number 443 July, 1973. p. 300.

²Ibid., p. 305.

³Brandwein, Concepts, p. 94 (Examples from the sample are followed by the page number in parentheses.)

Wording not consistent. The most serious criticism must be directed toward the forced word usage used in connection with some theoretic terms, e.g., "The sugar molecules were left behind in the pan." (112) Other examples in this category tend to be technicalities of lesser consequence.

Non-cognitive. Many of these (item "2a" on the Data Summary) involve picture referents, and their forceful wording tends to increase the vicarious experience aspect of this program. Those under "2b" tend to lend credence by word association: "Substance is a word that scientists use." is attached to the context of a statement that all substances are made of molecules.

Problems. Most of these seem to have legitimate pedagogical uses and no further sorting was necessary.

Epistemological (non-theoretic). The 4.0% is inflated as the breakdown within the category shows, with verification-explicit statements accounting for just 1.5% of the sample.

How to do. This category escaped notice in formulating the sentence sort scheme even though it was identified in Chapter II. It belongs in the scheme and is now included.

Not science. This area is poorly represented in terms of the comprehensive goals of science education in the NSTA statement and in terms of the requirement that authors should be very explicit about what they are intending to do.

Overtly subjective. This category was created for statements that give information directly about the author (in contrast to those that indicate what he is trying to do.) It may not prove generally useful.

Caution must be maintained in drawing conclusions about the distribution of sentence types at this point; and how well this profile actually describes other portions of this program is a matter for further research. But my feeling is that it is representative. The Sentence Sort Scheme contributed significantly to the discovery of pseudo-protocol and make-believe statements by providing a means of classifying and removing more easily recognized sentence types. The overall significance of this profile is discussed at the conclusion of the next section.

Examination of Synthetic Statements for Evidence

Concepts In Science

1. A. What is the knowledge claim?

"When sugar is put in water the sugar comes apart. The tiny lumps come apart into the smallest bits."¹ 110 (4,5)

B. Under what conditions is it held to be true?

Conditions not specified: instructions for amount of warm water and sugar given.

C. What evidence and argument would or did establish this claim?

Historically the idea of indivisible particles with well defined properties was helpful in explaining the law of

¹"110 (4,5)" means page 110 and sentence parts 4 and 5 as numbered in preparation for analysis.



definite proportions and the law of conservation of matter but neither of these have been developed here. The existence of "smallest bits" is an assumption that has never been established and so far as we know, cannot be.

D. What evidence and argument is provided in the program?

The existence of "smallest bits" is assumed and the smallest bits are called "molecules." The "evidence" consists of dissolving sugar in water and then tasting the solution.

"...the sugar disappears. Yet the molecules are there. How do we know? The taste of sugar is still there!" 110 (8,9,10)

A sugar solution is allowed to evaporate. "The sugar molecules were left behind in the pan." 112 (7)

The first situation is a case of irrelevant conclusion: the sweet taste of a sugar solution, while it provides evidence that sugar is still there, in no way provides evidence for its structure or form, i.e., for the existence of "smallest bits." The second is the fallacy of equivocation, that is, using the same word in two different senses. What is left behind in the pan is recrystallized sugar, not "smallest bits."

E. Does the program obviate the necessity for examining the phenomena of nature?

Yes, even though examination of the phenomena referred to could not establish the claim that is made. A picture sequence accompanies these sentences: "Put some sugar in water. Stir. Has it disappeared?" The text informs the

student that the sugar is still there because "the taste of sugar is still there." A similar sequence accompanies the evaporation procedure.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Students are to measure the sugar before dissolving and after evaporation. The question is then asked, "How will the amount of sugar put in compare with the amount got back?" The teacher note says, "Each child or group should make its own prediction and test it. (The amount recovered should equal two level teaspoonfuls...)" They are instructed to take two tablespoonfuls but this is obviously a typographical error. There is some potential for individual evaluation of evidence here but no instruction for follow up or discussion of their findings, which are treated as an exercise of confirmation.

A teacher note is included about a picture of a molecular model of sugar. "Remind them that this was only a model of a real molecule." T130. No distinction is made between theoretic "things" and observable things, i.e. the distinction between observation and inference is not maintained in this sample.

2. A. What is the knowledge claim?

"When water is evaporated from a sugar solution, the sugar has not changed nor has the water." 113 (7)

B. Under what conditions is it held to be true?

None found.

C. What evidence and argument would or did establish this claim?

Properties of sugar and of water should be established before mixing them. Water vapor condensed and examined, sugar examined, before and after, properties compared. Since this is a general statement, more than one example is needed.

D. What evidence and argument is provided in the program?

Children examine a solid and "satisfy themselves that the solid is sugar." (no discussion of its properties.) They measure the amount dissolved, and watch the formation of crystals with a magnifier during the evaporation. They measure the amount of sugar recovered. "How did you know the sugar did not change? (tasted the same)." T133 The appearance of granulated table sugar is changed very notably in the process of recrystallization and the children would be sure to see it, yet no mention is made of this.

"How did you know the water did not change? It did change in form but it was still water. We started with sugar and recovered the sugar so the water must have evaporated." This is an example of the logical fallacy of irrelevant conclusion. The proposition is, the water did not change. The assertion about sugar is intended (presumably) to mean that the sugar did not change. The "conclusion" is, "so the water must have evaporated." This makes no sense at all.

- E. Does the program obviate the necessity for examining the phenomena of nature?

Yes. It appears that this knowledge claim is really included to illustrate the meaning of the word "mixture." The follow up is, "Sugar and water make a mixture. In a mixture, substances do not change." The fact that the sugar and water both change in observable ways is ignored. The conclusion has been reached deductively even in the face of observable evidence to the contrary!

- F. What techniques in the program might be expected to promote individual evaluation of the evidence?

None found.

3. A. What is the knowledge claim?

"Stir some pennies and sugar in a pan. No matter how hard you stir, the pennies do not change. The sugar does not change. It's easy to separate the pennies and the sugar."

113 (10-13)

- B. Under what conditions is it held to be true?

None found.

- C. What evidence and argument would or did establish this claim?

Examine the pennies and examine the sugar with a hand lense. Put them into a pan and stir vigorously. Re-examine. Any changes observed would falsify the argument. Many failures to falsify would count as evidence in support.

D. What evidence and argument is provided in the program?

The teacher instruction is: "Present a mixture of sugar and pennies (or any other solid such as marbles). Who can separate these two solids? Of course it was easy!"

The text says, "No matter how hard you stir, the pennies do not change. The sugar does not change." Students are not invited to try this nor is it recommended as a demonstration. The claim is arrived at deductively and must be accepted on authority. Hard stirring does in fact cause observable changes: 1. some sugar is pulverized. 2. some sugar sticks to the penny. 3. In several investigations it did not fall off or even wipe off with a dry cloth. It had to be washed off. 4. The aluminum pan was scratched. 5. Some odor was noticeable. The knowledge claim in this case is not true. Any appearance that the lesson provides evidence for this knowledge claim is misleading.

E. Does the program obviate the necessity for examining the phenomena of nature?

It does. Observation is not seriously pursued: the proposition is deductively arrived at.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

None found.

4. A. What is the knowledge claim?

"Heat sugar and it becomes a black substance. Tests show that this black stuff is not sugar...That black substance left when sugar is heated is carbon." 120 (1), 121 (2,13)

B. Under what conditions is it held to be true?

A later repetition adds, "Heat sugar enough and...".

Conditions will be met if instructions are followed.

C. What evidence and argument would or did establish this claim?

120 (1.) This is a "not fully explicit" knowledge claim but since almost any heat source greater than a birthday candle will char sugar in a pan, the conditions are not hard to meet. Outside experience could be sufficient, especially if coupled with a demonstration.

121 (2) Simple observation shows that this is not sugar.

121 (13) The properties of carbon must be known and the black residue from heating sugar examined to see if it has these properties.

D. What evidence and argument is provided in the program?

1. A single demonstration of charring sugar.

2. Children are asked, "Is this black stuff still sugar?"

120 (2) Whatever they respond, the teacher note says "they will need more evidence." So they taste it, feel it, observe it with a magnifier, and try to dissolve a bit. These activities are done in groups which then reassemble to consider the question. "The group will report negatively; the substance doesn't act like sugar."



A picture of a ball and stick model of a sugar molecule is introduced. The balls are said to stand for atoms. "How many kinds of colored balls are there in the model? (three)" A red, a yellow, and a black ball are to be drawn on the board and labeled oxygen, hydrogen, and carbon respectively. "From the color code, children may infer the answer to: What is the black substance left after sugar has been heated? (carbon)"

The first statement is illustrated, and a single demonstration provided but this may be sufficient. The second is used to illustrate acceptable procedures for verification but the situation does not require it: the kids know the black residue is not sugar. The third statement is not evidence supported at all, and the children are led to make a wholly unfounded inference. This is sometimes referred to as a fallacy of circumstances-the fallacy going undetected only because of the vulnerability of the audience.¹

E. Does the program obviate the necessity for examining the phenomena of nature?

No. Examination of natural phenomena is called for but the data gathered are irrelevant to the method used for identifying the black residue. It is identified (illogically) from theory.

¹Black, Critical Thinking, p. 212.

6. A. What is the knowledge claim?

"But around big cities the air is changing. Sometimes it stings people's eyes. Sometimes it is hard for people to breathe. Plants cannot grow well in it." 129 (2-5)

"Smoke and invisible gases go into the air. They mix with the gases in the air...Earth's air store is becoming more and more polluted." 129 (12,13,15)

B. Under what conditions is it held to be true?

The text says, "There are places on Earth where the air is clear and pure." Big cities and automobiles are mentioned and may be considered "conditions" for changing air.

C. What evidence and argument would or did establish this claim?

A description of air: (What properties of air are changing?)
Data over time showing these changes for at least several big cities. Data on eye irritation and breathing problems that can be correlated with data on air composition. Data on plant growth for same periods and places.

D. What evidence and argument is provided in the program?

The teacher is to, "Suggest that after school, the children observe how many automobiles have smoky exhausts." T149
The teacher demonstrates that a cold plate held in the tip of a candle flame collects black soot from the smoke given off. People have always known that burning produces smoke and gases. There is nothing here to establish the claims made.



- F. What techniques in the program might be expected to promote individual evaluation of the evidence?

In the examination of the black residue, the teacher note says, "Any child or group that can think of another test should try it." (But it adds, "These tests too, should be negative.")
T140 This lesson would strongly discourage individual evaluation of evidence.

5. A. What is the knowledge claim?

"We could not live without air for more than a few moments. We depend on air." 128 (7,8)

- B. Under what conditions is it held to be true?

None mentioned.

- C. What evidence and argument would or did establish this claim?

Any actual accounts of suffocation, drownings, etc.

- D. What evidence and argument is provided in the program?

Children hold their breath for a slow count to twenty. "How long do you think you could live without air?" The experience is probably convincing but is not actually evidence of the truth of the proposition.

- E. Does the program obviate the necessity for examining the phenomena of nature?

Yes, but in this case justifiably.

- F. What techniques in the program might be expected to promote individual evaluation of the evidence?

None found.

- E. Does the program obviate the necessity for examining the phenomena of nature?

Probably not but neither does it provide any information as to how the claim of increasing pollution can be established. Students would probably be more alert to news about pollution-caused problems.

- F. What techniques in the program might be expected to promote individual evaluation of the evidence?

None found.

7. A. What is the knowledge claim?

"Much the same thing (as modeled) is happening to the Earth's clean water. It is becoming more and more polluted. For we are putting more and more waste materials into the Earth's water...And we are making more and more waste. 131 (2,3,4) 132 (8)

- B. Under what conditions is it held to be true?

None identified.

- C. What evidence and argument would or did establish this claim?

Identification of specific pollutants (and why they are considered pollutants) and data on their concentrations over a given period along with supposed effects.

- D. What evidence and argument is provided in the program?

None. The class builds a "model of polluted water," adding small quantities of household materials to a pan of clear water. The exercise is an attempt to illustrate the meaning of "pollution" but provides no evidence for the proposition.



E. Does the program obviate the necessity for examining the phenomena of nature?

Yes. No attempt is made at supporting this claim. It is simply posited.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

None found.

Two other knowledge claims are part of this sample but they are of a different sort: (If you spread butter on hot toast)" the butter melts." 126 (3,4) and, "Scientists often use a filter." 115 (9). These hardly call for evidence.

The synthetic statements were grouped into nine closely related sets of sentences, seven of which are provided an appearance of support in the program. The support was examined in detail above and the findings are summarized in the following table, a sample of the epistemological quality of this program.

<u>KC</u>	<u>Conditions</u>	<u>Evidence/Argument</u>	<u>Exper. Obviated?</u>	<u>Technique</u>
1	Not Spec.	None, logical fallacy	Yes	None
2	Not Spec.	Yes, contradicts knowledge claim	Yes	None
3	Not Spec.	None, claim is not true	Yes	None
4	Not Spec.	Partial, false argument	No	None
5	Not Spec.	None, false argument	Yes (justifiably)	None
6	Specified	None, misleading demonstration	No	None
7	Not Spec.	None, analogy	Yes	None



Summary and Interpretation of the Data
Concepts in Science

The profile shows that 20% of this sample (the highest single category) is made up of theoretic statements, but it also shows a nearly equal emphasis on the combined pseudo-protocol/make-believe statement system, a literary device which introduces a strong element of vicarious experience, and reinforces it by obliterating the distinction between physical phenomena and their symbolic representations. The ultimate basis for knowing in this program is theory, from which (pseudo-protocol) statements are deduced, and integrated into the text so that they sound like direct observations being made on the situations pictured. By talking about pictures as though they were the phenomena they depict an illusion of having witnessed an event in nature is created that is very strong. This illusion is probably strong enough to satisfy many students, and many teachers will be less likely to go to the trouble of providing experiences of actual natural phenomena as a result. In any case the basis on which the theory was developed is not included, the student must accept the theory by faith, and the program is seen to be deductive. The epistemological approach called for in the NSTA position paper moves in the opposite direction, beginning with observations on natural phenomena and showing how laws and theories are successively generated from them.

This analysis is fully supported in the examination of synthetic statements for evidence. No evidence is provided for the existence of "smallest bits": their existence is assumed, and they are named



"molecules." The claim is made that we know there are molecules because sugar water tastes sweet! Four of the seven synthetic knowledge claims contained in this sample are deduced from theory. The other three, concerned with pollution, are simply posited (without evidence) there being no theory from which they could be deduced. Of these seven knowledge claims, conditions were specified in only one instance, evidence was presented in only two instances (in one of which the evidence contradicted the claim), false argument was presented in three instances, another of the claims is not true, one claim is dramatized by a somewhat misleading demonstration, and another by a model. Experience of natural phenomena is obviated in five of the seven cases (one justifiably), and no techniques for promoting individual evaluation of the evidence was found in the sample.

The inferences drawn at the beginning of this chapter from statements in the introduction seem fully warranted. Observation of natural phenomena is not the ultimate method of verification in this program, and great liberties are taken with words (as seen in the invention of the pseudo-protocol/make-believe device, and the numerous instances of forced word usage). But the most significant instance of libertine word usage may well prove to be this one: in the introduction to Concepts in Science the impression is created that this program exemplifies the basic outlook of James Bryant Conant as expressed in his book, On Understanding Science (F-9). Conant's terms are freely used but their meanings have been



interchanged so that they represent the very opposite view to that put forward by Conant. In Concepts in Science, the atomic theory is referred to as a concept and is introduced in grade three to help the student to infer, in later years, the law of conservation of matter which is described as a "conceptual scheme." One sentence from Conant will show that he used these terms in just the opposite way:

"Of course the concept of the function of an animal organ such as the heart is far less general and abstract than the concept of a sea of air: and both are much nearer common sense ideas than such a conceptual scheme as the atomic theory."¹

Conant described concepts as leading to conceptual schemes but with Conant "concepts" is to be associated with lower level abstractions such as laws, and "conceptual schemes" with theories. This is the epistemological order described in chapter II and called for in the NSTA position statement. By using the terms "concept" and "conceptual scheme", the Concepts in Science program sounds like it reflects the stance of great leaders who are calling for an epistemological approach to science education. But by interchanging the meaning of these terms, Concepts in Science remains deductive, authoritarian, and traditional. When we finally understand that in this program, "concepts" means theories, this program position and emphasis are clearly set forth in its title, Theories in Science.

¹James B. Conant, Science and Common Sense, New Haven, Yale University Press, 1951 p. 212.

Part 2 SCIS

Examination of Introductory Material: The epistemological stance of the SCIS program is explained in its introduction, "The SCIS Conceptual Framework." The key term is "interaction" which is described as a "view" that is central to modern science, and therefore to this program,

"...that changes do not occur because they are preordained or because a spirit or other power within objects influences them capriciously but ...changes take place because objects interact in reproducible ways under similar conditions. Interaction refers to the relation among objects or organisms that do something to one another, thereby bringing about a change...The observed change itself is evidence of interaction."¹

The word "interaction" names whatever brings about changes and may be treated like any other reductive inference: $A \rightarrow B$, $B \therefore A$. Change requires something to bring it about. We see change; therefore something brought it about. The something that brought it about in this program is named, "interaction." All observation of change is treated as "evidence" of interaction. "Interaction" then, is a very general term that points in the direction of laws and theories, but does not rush the student into them. Thus, attention is heavily focused on observation, treating any observation of change as "evidence" that the changed objects "did something to each other," and just enough of a theoretical element is introduced to provide a meaningful frame of reference for making observations. In the structure of scientific knowledge, in the SCIS

¹Robert Karplus, et al., "Subsystems and Variables," The Science Curriculum Improvement Study, (Chicago, Rand McNally and Company, 1971) p. 8

program the notion of interaction lies immediately above observation and incorporates both laws and theories:

theories

laws

interaction

observation

It captures the basic assumption and reasoning process of science without getting involved in technical specifics. And since, all observations of change are evidence of interaction, the problem of sorting out what is "important" to observe is completely eliminated. This is a significant achievement.

The SCIS sample was also taken from grade three material and was "matched" to the Concepts in Science sample by treating three of the same topics, phase changes, mixtures, and solutions. Twelve of the thirteen chapters in parts 2, 3, and 4 of "Subsystems and Variables" were analyzed, generating more than 800 sentences to be classified. But the SCIS program has no text book: the student's manual is primarily for recording and summarizing his own observation. The knowledge claims of the program are to be found in the Teacher's Guide, which is addressed to educated adults and in this respect differs greatly from the Concepts in Science sample. This sample provided a good test for the model with its generally longer and more complex sentences and adult level of communication. Most of the knowledge claims are concentrated in the "Background information" but all sentences in the sample were examined in order to discover its profile, except for those in sections headed,



"Overview", "Equipment", "Optional Activities", and "Clean Up."

As in the Concepts in Science program, these sentences also were "restructured" for the purposes of analysis, and all data are reported in terms of this restructured material, i.e., in terms of single propositions, rather than the original sentences. The author is careful to indicate his intentions with frequent use of expressions like, "for example", "to illustrate", etc., and paragraph structure is good so that the function of many sentences can readily be inferred from the context. Many of these advantages accrue, no doubt, from the fact that it is addressed to adults rather than to third graders.

The subcategories generated in the referent program were much less useful in the analysis of SCIS for which reason a breakdown to subcategories was not pursued except for synthetic statements. For precise program comparisons, the breakdown to subcategories should be developed as it seems likely that subtle but important distinctions may come to light as a result.



Sentence Sorting Scheme Data Summary

Program: SCIS

Sample: "Subsystems and Variables", (Grade 3) Teacher's Guide, pp. 34-43 and 50-89 except sections titled 'Overview', 'Equipment', 'Teaching Materials', 'Clean Up', and 'Optional Activities.'

Number of sentences sorted - 845.¹

Method of reporting results. Two breakdowns are used, the percentage of assertions in the whole sample (845 sentences = 100%), and the percentage of sentences in each category of assertions (324 assertions = 100%). For convenience of computation the results are reported to a tenth of one percent.

Categories

1. Non-assertion: 522 out of 845 sentences examined (=62%)

The following percentages are based on 323 = 100%, the number of assertions in the sample.

	<u>No.</u>	<u>%</u>
2. <u>Non-Cognitive</u>	1	1.0
a. do not make logical sense.		
b. do not contribute logically to context.		
3. Not science subject matter	93	28.7
a. about program.		
b. from other disciplines.		

¹Only those sentences that came through the filter are listed by categories in Appendix 5 for reference.

	<u>No.</u>	<u>%</u>
4. Not fully explicit	12	3.7
a. introductory/conjunctive.		
b. generality.		
c. inference to be drawn.		
5. Overtly subjective	8	2.5
6. Wording not consistent	1	1.0
a. anthropomorphic.		
b. inaccurate/misleading.		
c. forced word usage.		
7. Theoretic terms	5	2.0
a. epistemological		
b. word usage.		
c. purporting to explain.		
d. postulating existence.		
8. Epistemological (non-theoretic)	59	18.3
a. verification explicit.		
b. assurance of evidence.		
c. ways we can <u>not</u> know.		
9. Identified Analytic	37	11.4
a. word-word.		
b. thing-word.		
10. Analytic-not so identified	91	28.0
a. word-word.		
b. thing-word.		
11. Knowledge how to do	13	4.0

	<u>No.</u>	<u>%</u>
12. Synthetic	40	12.3
a. refer to a single event (0)		
b. general statement (24)		
c. specific to this program (8)		
13. Look like pseudo-protocol statements (8)		
14. Make-believe statements (0)		

The SCIS Profile

Non-assertion accounts for 62% of the total sample. The remaining categories are rank ordered by percentage of the rest of the sample. The percent shown is the number of sentences in the category over the number of assertions in the sample (323), to the nearest whole percent.

Not science subject matter	29%	Not fully explicit	4%
Analytic	28%	Subjective	3%
Epistemological	18%	Theoretic	2%
Synthetic	12%	Non-Cognitive	0% ¹
Knowledge how to do	4%	Wording not consistent	0% ¹

Interpretation of the Profile

The high percentage of non-assertion comes from the extensive instructions to teachers. A significant number of hypothetical statements are included in this group in which possible student reactions are anticipated. The next largest group, ('Not Science Subject Matter') is mainly information about the program and about how students have reacted to it. The heavy emphasis on analytic

¹(One statement was found in each category.)



statements is very significant as the program reflects a strong commitment to John Stuart Mill's argument for the meaning of a word. Key words are operationally developed and defined, and much of the reasoning employed in the program is reasoning about their proper application. The high proportion of epistemological statements is also significant, especially when compared to the very low percentage of theoretic statements. Synthetic statements seem to be employed as much for the purpose of illustrating meanings and techniques as for their factual content. The focus of the SCIS program in short, is strongly on precision of language rather than on propositional knowledge, and uses the latter to illustrate the processes of knowledge generation just as described by Lee as the philosophy of the "revolution"-the new era in science education.¹

A word is in order about some of those statements accounting for the small percentages before returning to synthetic statements: All "not fully explicit" statements were actually used to introduce and the "subjective" group indicated the author's intention for various aspects of the program in a decidedly helpful way.

The 40 statements that came through the sentence sort scheme were further classified as called for by the model with these results:

No statements were found referring to a single event.

24 statements were classified as generalizations.

¹Lee, New Developments, p. 5.



8 statements refer to specific phenomena and events in the program and are not generalized beyond.

8 statements look, in isolation, like pseudo-protocol statements but were found on examination of the context to be part of the suggested discussion of experiences already past.

All problem statements were eventually classified in existing categories, some types of epistemological statements being hardest to recognize. Despite its complex sentence structure and the subtlety of some of its epistemological statements, this sample turned up no surprises (such as pseudo-protocol and make-believe statements) and was basically easier to work with than the other program. The reader is again directed to Appendix 5 for reference.

Examination of Synthetic Statements for Evidence

SCIS

1. A. What is the knowledge claim?

(1) "One characteristic phenomenon you see as liquid solutions form is a wavy pattern that distorts the background when you look through the liquid."¹

B. Under what conditions is it held to be true?

Intimate mixing of materials that differ slightly.

C. What evidence and argument would or did establish this claim?

Examination of many solutions and types of solutions in the process of formation, for this effect.

¹In the SCIS program sentences were numbered consecutively beginning with each subheading: 52 "Schlieren" (1) means page 52, subheading "Schlieren", sentence 1.



D. What evidence and argument is provided in the program?

Every student prepares a salt solution and examines for the Schlieren effect. This experience is repeated in another exercise involving a more complex system.

E. Does the program obviate the necessity for examining the phenomena of nature?

No. Even though there is an excellent photo of the Schlieren effect in the Teacher's Guide, the student manual contains only diagrams of how to prepare the tea bag and where to look for the effect. Only one type of solution is worked with.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Every student prepares two salt solutions, each providing two tea bags loaded with salt. The Schlieren effect is observable below each tea bag. Each student describes what he observes in his student manual. Students are asked to provide examples of Schlieren from their experience. Two common experiences are suggested for the teacher; warm air and cold air mixing over a hot radiator or over a hot highway.

2. A. What is the knowledge claim?

"A colored liquid renders invisible a dot of very similar color that is viewed through the liquid." 54 Background information (5)

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B. Under what conditions is it held to be true?

The dot and the solution must be nearly the same color and the concentration of solution controlled to let light through. Students must discover this.

C. What evidence and argument would or did establish this claim?

Viewing many dots of various colors through colored solutions, some of which were the right color and concentration.

D. What evidence and argument is provided in the program?

Four different colored solutions and non-solutions of controlled maximum concentration are available and all children look at their own colored dots through them. Students are provided droppers for mixing solutions, and colored plastic light "filters" as well. Children are encouraged to compare and discuss results. The purpose of this exercise is to direct students attention to the properties of their mixture in preparation for several lessons to follow.

E. Does the program obviate the necessity for examining the phenomena of nature?

No. There is no way to obtain the needed information except by working with the solutions.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Student discussion and comparison of their results.

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3. A. What is the knowledge claim?

"The changes occur without the addition, removal, or substitution of material." 70 Background Information (2)
(The subject is phase changes but reference is made to the more general expression, "conservation of matter.")

B. Under what conditions is it held to be true?

(None identified).

C. What evidence and argument would or did establish this claim?

This statement would require performing phase changes in a closed system, as observing that there is no gain or loss of weight does not preclude a substitution of material. Multiple instances of changes from solid to liquid to gas and back again should be examined.

D. What evidence and argument is provided in the program?

Students (in teams of four) evacuate the air and seal a quantity of liquid Freon into a large plastic bag. The bag is warmed and the Freon vaporizes; cooled with ice and the Freon condenses again. Properties of the liquid (condensate) are examined and the argument, elicited from the students, that the Freon - bag system has not changed. (The law of conservation of matter is not introduced here.)

E. Does the program obviate the necessity for examining the phenomena of nature?

No.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Discussion is engaged before equipment is dismantled.

Disagreements are to be resolved by observation and experiment. Students are to propose ways of identifying the condensate, and then identify it. And to interpret the whole phenomenon.

4. A. What is the knowledge claim?

"Actually of course water and other liquids can change¹ slowly from a liquid to a gas at temperatures lower than their boiling temperature." 71 Boiling temperature (2)

B. Under what conditions is it held to be true?

Lower than boiling temperature.

C. What evidence and argument would or did establish this claim?

1. Boiling point of several liquids should be known.
2. Some awareness of how long it takes to vaporize a given amount of each at its boiling point.
3. Some liquids should be examined to see if-and under what conditions-they change from liquid to gas at temperatures below their boiling point.

D. What evidence and argument is provided in the program?

1. All students work with water and Freon. They determine the boiling point of Freon by plotting temperatures of

¹This wording is anthropomorphic and the statement should have been filtered out at "wording not consistent". Since it was not noticed until after its analysis here, it has not been deleted, but an entry has been added under the appropriate heading above.



Freon systems on a histogram. They determine temperatures of warm water, water-Freon, and melting ice systems.

2. All students observe the evaporation of fixed small quantities of Freon at room temperature a number of times.
3. They vaporize the same small quantity at the boiling point. Evaporation of water at room temperature is part of a previous lesson. No discussion of pressure is provided, (even though the students vaporize Freon in a plastic bag.)

E. Does the program obviate the necessity for examining the phenomena of nature?

No. All students take and contribute data that generates the concept of "boiling point" and "melting point."

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

The histogram is introduced in this study providing each student with a look at his own data as compared with that of all other class members.

5. A. What is the knowledge claim?

"At higher than usual pressures, as in a pressure cooker, boiling takes place at a temperature higher than the usual boiling temperature." 71 Boiling temperature (4)

B. Under what conditions is it held to be true?

Higher than usual pressures.

C. What evidence and argument would or did establish this claim?

1. Boiling points of a number of liquids should be established for known "usual" pressures.
2. Boiling points should then be determined at known higher pressures.

D. What evidence and argument is provided in the program?

None found. This statement is included in the Background Information on Boiling Temperature, and no evidence is provided for it.

E. Does the program obviate the necessity for examining the phenomena of nature?

No. There is nothing to suggest that the source of information is not observation, the statement is carefully qualified, and the pressure cooker cited as an observable example of the phenomenon. The failure to actually provide evidence was noted above.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Not applicable in absence of evidence.

6. A. What is the knowledge claim?

"At reduced pressure such as mountain altitudes, boiling occurs at a lower temperature." 71 Boiling temperature (5)

B. Under what conditions is it held to be true?

Reduced pressure.

C. What evidence and argument would or did establish the claim?

Boiling points of a number of liquids should be established at known normal pressures, and determined at lower pressures.



- D. What evidence and argument is provided in the program?

None found. The reference to mountain altitudes might be meaningful to a very few.

- E. Does the program obviate the necessity for examining the phenomena of nature?

No. Compare 5E above. The same argument applies.

- F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Not applicable in absence of evidence.

7. A. What is the knowledge claim?

'All Freons are non-toxic substances.' 71 Freon (1)

- B. Under what conditions is it held to be true?

A caution is included to avoid inhaling Freon as it replaces air in the lungs, depriving of oxygen.

- C. What evidence and argument would or did establish this claim?

If among children who have worked extensively with Freons there have been no ill effects, this would provide some basis for this claim. A statement from the Merck Index that Freons are non-toxic would provide further assurance. However, it can not be known that Freons would not prove toxic to some individual some where in the world.

- D. What evidence and argument is provided in the program?

None. Children and teachers work extensively with Freon. If none suffer from it, they have some basis for believing it is generally non-toxic.



- E. Does the program obviate the necessity for examining the phenomena of nature?

Yes. The program obviates any necessity to inquire further into the question of the toxicity of Freons.

- F. What techniques in the program might be expected to promote individual evaluation of the evidence?

None specially in this connection.

8. A. What is the knowledge claim?

"(Freon) evaporates much faster than water." 71 Freon (6)

- B. Under what conditions is it held to be true?

None found.

- C. What evidence and argument would or did establish this claim?

Time evaporation of equal quantities of the two liquids under similar conditions.

- D. What evidence and argument is provided in the program?

Droppers are used to squirt liquids on a paper towel and observe and describe what happens. The difference in evaporation rate is treated as obvious enough without timing, to distinguish Freon from water.

- E. Does the program obviate the necessity for examining the phenomena of nature?

No.

- F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Every child gathers his own evidence. The properties of Freon are listed on the board, all children participating.

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9. A. What is the knowledge claim?

"(Freon) feels cold on the skin." 71 Freon (6)

B. Under what conditions is it held to be true?

None found.

C. What evidence and argument would or did establish this claim?

A number of people to apply Freon under different conditions to various skin areas and describe independently the effects.

D. What evidence and argument is provided in the program?

All children explore the properties of Freon on their own and pool their findings in the discussion follow up. They are instructed specifically to explore the Freon with their fingers.

E. Does the program obviate the necessity for examining the phenomena of nature?

No.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Individual observations, pooling and discussing data.

10. A. What is the knowledge claim?

"(Freon) does not form a solution with food coloring."

71 Freon (6)

B. Under what conditions is it held to be true?

None found.

C. What evidence and argument would or did establish this claim?

A number of samples of Freon mixed with all types of food coloring under different conditions.

D. What evidence and argument is provided in the program?

All students engage in exploring the properties of Freon. The food color addition is to be suggested if students do not think of it first. One bottle of food coloring is provided: varying conditions is not suggested. The objective is to acquaint students with the idea that liquids also have identifying properties-not to provide in depth information about Freon.

E. Does the program obviate the necessity for examining the phenomena of nature?

No.

F. What techniques in the program might be expected to promote individual evaluation of the evidence?

Individual observations, pooling, and discussing data.



Summary of Findings

Examination for Evidence, SCIS

<u>KC</u>	<u>Conditions</u>	<u>Evidence/Argument</u>	<u>Exper. Obviated</u>	<u>Techniques</u>
1	Partial	Direct Observation	No	Individual observation, description
2	Partial	Direct Observation	No	Individual observation, Group discussion
3	Not Spec.	Direct Observation	No	Individual observation, Group discussion, Re-exam. of evidence
4	Partial	Direct Observation	No	Data from all students plotted on histograms
5	Specified	None found	No	N.A.
6	Specified	None found	No	N.A.
7	Specified	Direct experience	Yes	None
8	Not Spec.	Direct Observation	No	Data gathered, pooled, discussed
9	Not Spec.	Direct Observation	No	Data gathered, pooled, discussed
10	Not Spec.	Direct Observation	No	Data gathered, pooled, discussed

Summary and Interpretation of the Data:

SCIS

The relative percentages of analytic, epistemological, synthetic, and theoretic statements, in this order, and the very low incidence of non-cognitive and unacceptably worded statements, provide the initial evidence that this program is epistemologically sound. Data gathered in the examination for evidence further confirm this conclusion. Conditions are specified fully or in part in six out of ten cases, and first hand observation of natural phenomena provide the basis for eight of the ten claims. In only one instance was the need to examine natural phenomena obviated, and specific techniques to promote individual evaluation of evidence are used in seven of the ten cases examined. This program provides extensive experience of the foundation level processes of creating scientific knowledge, and minimizes its inferential superstructure. For grade three, this is both epistemologically and pedagogically sound. Words are introduced as labels for experiences provided, and they are carefully defined so that children can apply them correctly in new situations. In this program too, the epistemological stance as presented in the introduction is fully consistent with the way knowledge claims are developed in the classroom.

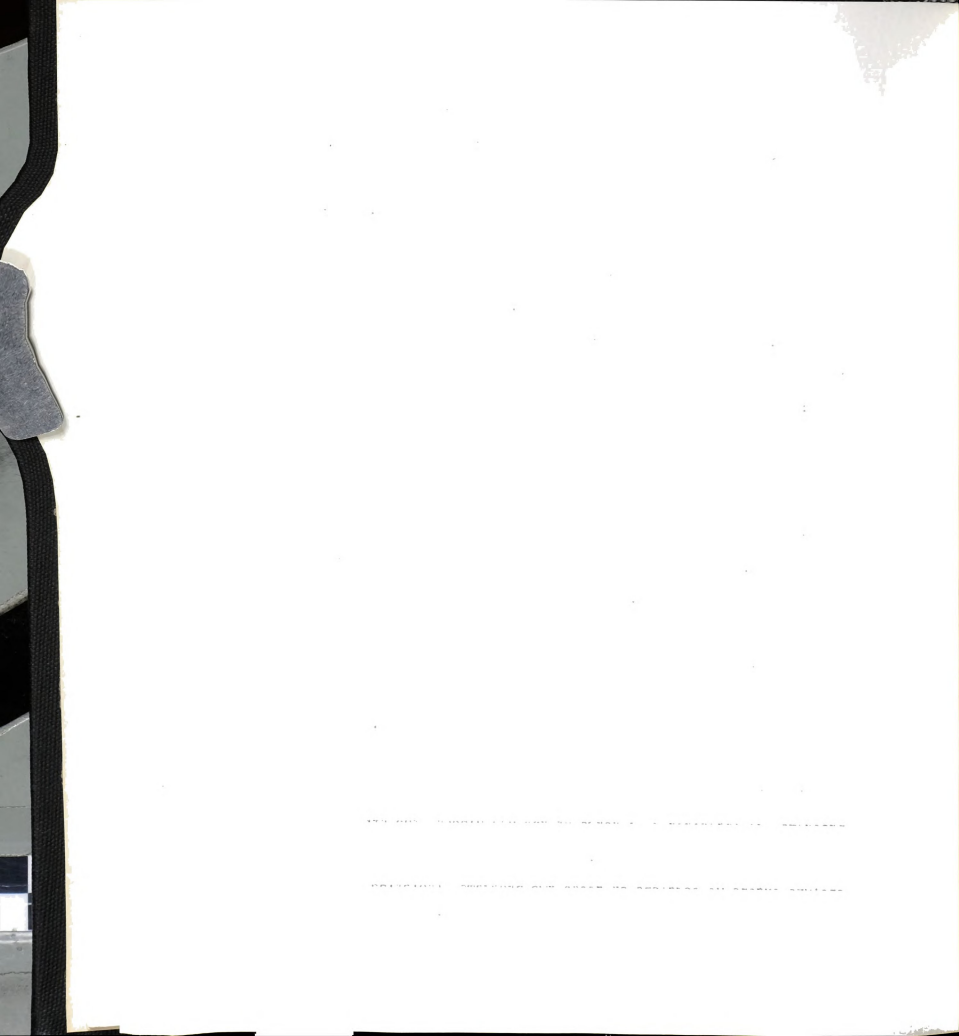
One difficult problem in developing the model has been the awareness that every synthetic statement does not need to be supported by evidence, but there was not always a clear basis for deciding which ones to exempt. The careful style discovered in the



SCIS sample, however, shows that an author can indicate directly which synthetic statements he proffers for their knowledge content per se, and which ones he introduces to perform some auxiliary function, such as illustrating by citing a concrete example. This consideration is as important to the reader as the identification of analytic statements in keeping with Wilson's insistence that to understand a statement, we must know the author's intent in making it. We must add, then another question in developing sub-categories for synthetic statements in future applications of the model: Does the author indicate that this statement is to perform an auxiliary function? Twelve examples of auxiliary-function synthetic statements were found in this sample and are included for reference in Appendix 6. Twenty other assertions are included in this appendix that refer to specific events not generalized beyond this program. Eight of these appear out of context (only), to be pseudo-protocol statements: all twenty are verifiable by experience as they describe what to expect when you follow the directions in the program. The evidence from all quarters, the introduction, the statement profile, the examination for evidence, and the careful style, shows SCIS to be an epistemologically sound program.

Summary of Chapter IV

In this summary, discoveries made in the analysis of the two programs are interpreted in terms of the usefulness, the strengths and the weaknesses of the model. The fact that it was possible to analyze extensive portions of these two programs, isolating their knowledge content and gathering data in a systematic fashion on



the way they support these claims is offered as evidence that the model is functional. Completed analyses of samples from the two programs are provided above with notes and data summaries, and extensive lists of statements from all categories are included in Appendix 4, 5, and 6, for reference. The data show conclusively that one program is theoretical and deductive with activities that tend to be confirmations, while the other is empirical and inductive, with activities that tend to generate protocol statements. These are fundamental differences in the approach to knowledge and the model provides a systematic procedure for discovering these differences within programs.

In both programs, introductions provide strong clues to their epistemological quality as found in the analysis of the text itself. This consistency between introduction and text strengthens the notion that epistemological quality is a fundamental property of science programs: if science really is a way of knowing, then the degree to which a science program concerns itself with how things are known is a fundamental measure of its worth to science education.

A real triumph for the model was the discovery and description of the pseudo-protocol/make-believe device that is so effective in creating an illusion of having evidence. And though somewhat less dramatic, the discovery that the frequency of the four basic types of statements is inverted in the two programs is probably more generally significant. A high percentage of analytic and a low percentage of theoretic statements with synthetic and epistemological percentages intermediate should be one characteristic of



good epistemological quality at this level. The Sentence Sorting Scheme is what made possible these discoveries and its value as a result, is greatly enhanced. The profound significance of words, discussed in Chapter II, emerged as one of the crucial factors in the differences discovered between the two programs. This strengthens the philosophical foundation developed in Chapter II and inspires the principal recommendation for further research in Chapter V.

In two cases, failure to completely isolate distinct knowledge claims led to problems in the examination for evidence. Since verification is specific to each knowledge claim, it is imperative that each discrete proposition be identified in preparing the sample for analysis. This is a crucial procedure for successful analysis and it must be thoroughly done.

Finally, Concepts in Science was a good choice for the basic referent program because of its wide variety of sentence types and the special problems it presented. Once the model was adequate for analysis of this program, it was readily adapted to the analysis of SCIS. It remains a matter of further research to determine how generally applicable it might be.

CHAPTER V

SUMMARY AND CONCLUSIONS

Recommendations for Further Research

Prior to doing this study, the author's attempts at evaluating curricular materials in science ended in some frustration because it always seemed that some basic issue had not fully surfaced. The NSTA Position Statement confirmed this suspicion and led to the research that is summarized in Chapter II: the basic issue is that one really does not know what a statement means until he knows how it is to be verified. Put another way, knowledge claims in science are meaningful only as they are operationally defined. Thus "content" programs that "explain" many natural phenomena by laws and theories, still lack meaning unless the method of verification of the laws and theories has been made clear. By making the methods clear as called for in the Position Statement, it is hoped that laws and theories really will explain, but also that students will achieve some insight into the strengths and limitations of scientific knowledge that will enable them to wisely use such knowledge as it continues to be generated. This is the ultimate goal of science education, called in the Position Statement, "scientific literacy". And it has been the objective of this study to develop a model to facilitate the evaluation of science program potential for contributing to the achievement of this goal.

Having identified the basic issue, that the meaning of a scientific statement is dependent upon how we know it, the next step in building the model was to set up procedures for classifying statements on the basis of what it would take to verify them. Based on the distinction between observation and inference, and the difference between verbal symbols and the things we use them to represent, three major classes of scientific statements were identified:

- 1) statements that clarify what we mean by, or how we use verbal symbols ("analytic" statements),
- 2) statements that inform as to what we have observed in nature, ("synthetic" statements),
- 3) and statements that inform as to our interpretations of such observations ("theoretic" statements).

These three types seem to be all the kinds of statements used to make science knowledge claims. Epistemological statements must also be identified but their function is different: they relate the knowledge claims of science to their evidential basis.

Making knowledge claims is only one of several functions sentences may serve, and unless the functions of the other sentences are also recognizable, isolating knowledge claims from the text of a program becomes very difficult. Wilson's description of the function of sentences was used as a basis for a classification scheme which was developed empirically in sorting the sentences of a referent program.¹ Analytic, synthetic, and theoretic statements then,

¹For extensive lists of sentences classified by this sorting scheme see Appendix 4,5,6.



are subcategories of sentences whose function is to make science knowledge claims. Procedures for sampling and sorting, and recording data were also worked out empirically and it was at last possible to precisely determine the knowledge content of the sample. By sorting all sentences, we obtain the actual count of sentences performing each legitimate function as well as those of questionable or unacceptable function. Some statements discovered in one program create an illusion that evidence is being examined: from an epistemological perspective the literary device that performs this function is deceptive and illegitimate. Data obtained by sentence sorting can be used to develop a frequency distribution profile that is most revealing of the sample character and quality.

After the knowledge claims have been isolated, a new series of questions leads the investigator in the search for evidence provided for their support.¹ But even though statements can be classified by their general method of verification, each specific statement has its own unique verification. And each individual must determine what he would accept as verification. The model requires that the analyst make this determination before proceeding to see if the evidence provided supports the claim or at least makes explicit the basis on which the claim is made. Data is also gathered on whether the program obviates the need to examine evidence, and whether there is some effort made to prod the student to evaluate the quality of the evidence and its interpretation.

¹"Evidence" throughout, refers to observations of states of affairs, i.e. to observations of phenomena of nature.

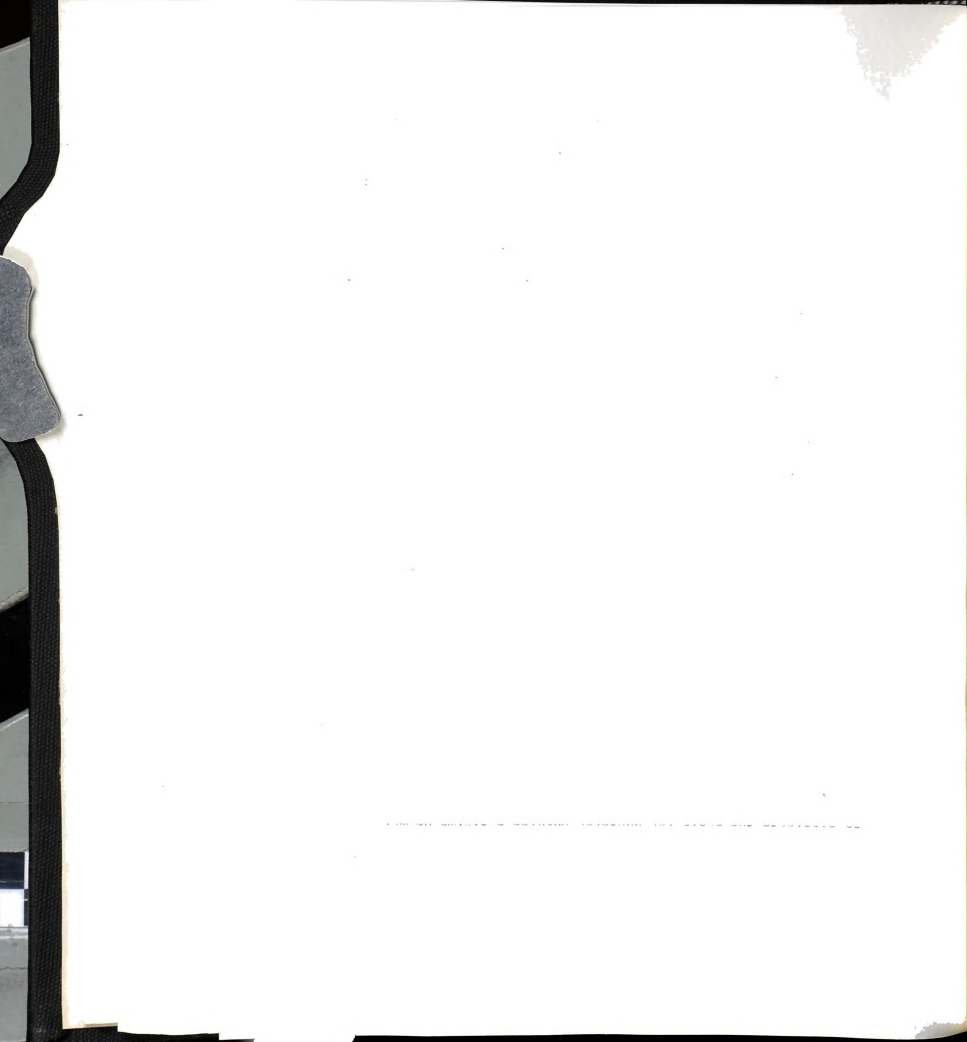
These data, gathered in well defined categories on each claim provide a very solid basis for making judgments about the epistemological quality of programs.

The model, derived from recognized philosophical principles and empirically developed procedures of application proved effective in this study, facilitating a detailed examination of two very diverse elementary science programs and leading to the identification of specific differences in their epistemological quality. The model does not make this kind of analysis easy-it makes it possible. The process is time consuming and requires both language and subject matter competence, and commitment to the view of the nature of scientific knowledge developed in Chapter II. Given these, the major problem in procedure is that of classifying sentences from the sample according to their function. Since the meaning of a sentence depends on what function the author intends for it to serve, the author has an obligation to help the reader in this respect. The degree to which he fails to do this may become the determining factor in rejecting a program as epistemologically unsound: if the analyst can not understand what the author is intending to communicate, it is hard to imagine that the children would fare better. And the basic issue identified at the outset is very much in focus at this point: the goal of scientific literacy demands that we proceed on the assumption that children do seek meaning and have the capacity of independent reason, i.e., given access to pertinent evidence and its interpretations, at levels of sophistication appropriate to the child's level of mental maturation, they can



evaluate these interpretations on the basis of the evidence with a view to accepting or rejecting them. This was never more clearly demonstrated than in this incident in the author's experience: a third grade boy brought into my office at International School, Bangkok, a small dark colored snake in a box. I began my usual routine on the danger of capturing snakes. "It's not poisonous," he said. I insisted that even experts can be fooled and that this snake could be dangerous. "This snake is not poisonous," he reaffirmed. In some exasperation I demanded to know how he knew it was not poisonous: "It bit me three days ago," he replied calmly. The probability of truth was strongly on his side of the argument. This model is designed to help analysts distinguish between programs that encourage children to depend on evidence from those that do not: that, whatever else they do, do not appeal directly to the child's ability to reason from evidence.

If evaluation of curriculum is to be closely tied to the stated goals for science education as affirmed in the Position Statement, and if those goals as argued in Chapter II are epistemological, then we have no choice but to evaluate curriculum on the basis of its epistemological quality, and to measure the effectiveness of science education in terms of increasing student epistemological sophistication. And it follows that teacher training should prepare the teacher to elucidate the basis for whatever knowledge claims he may be trying to teach, with evidence and argument that he fully understands. If measuring progress in this direction seems difficult, it is partly because we have not been obliged to do this before and we are



again reminded that "Where evaluation of valid clearly stated objectives turns out to be difficult, this should be interpreted as a weakness in our techniques of evaluation, not necessarily as a weakness in the objectives."¹ The model, it is hoped, will become one useful instrument in a massive assault on the problem of evaluating our current educational practice against the stated goals for science education.

Improvements and Recommendations for Further Research

To date the model has been applied and found useful only by the author. How successfully it can be communicated and made useful to others remains to be seen, and its further development at this point needs the input of other interested persons. One of the first tasks will be to assess the precision of the categories in the sentence sorting scheme, i.e., it must be determined how much agreement we can expect among analysts in the way they identify the functions of sentences. This could be investigated by randomizing the sequence of the categories and having a group that understands the model sort the sentences in a given sample. If agreement is low in some categories, they may need to be redefined.

A second area that needs investigation is sampling technique and sample size. When it has been determined by research what constitutes a representative sample, it may be that the amount of work for meaningful analysis is greatly reduced. Arbitrarily

¹NSTA Position Statement.



large samples were used in developing the model and generalizations beyond the samples themselves were made only in terms of agreement discovered between findings in the sample and statements made by the authors in the introductory material.

If substantial agreement among analysts using the model can be obtained as to what statements should be evidence supported, the model will have served its purpose: if then, responsible analysts begin to share their views as to what would constitute adequate evidence, and if this could begin to happen at the national level, the shift toward epistemology would become real and those preparing curricular materials would have the input they need to improve their offerings. And as analysts draw up lists of techniques thought to obviate the observation of natural phenomena or stimulate individual evaluation of evidence, the effect of these variables can be assessed in experimental studies.

The major recommendation for further research as indicated in Chapter IV is the extension of the model to provide more complete analysis of analytic statements. It has been stressed throughout the study that words have meaning only when they serve, by mutual agreement, as labels for experiences we have shared. It seems obvious then that program methods of developing meanings for words should come under careful scrutiny in the analysis of epistemological quality at all levels, but especially in early elementary grades. Some variables that might reflect differences in

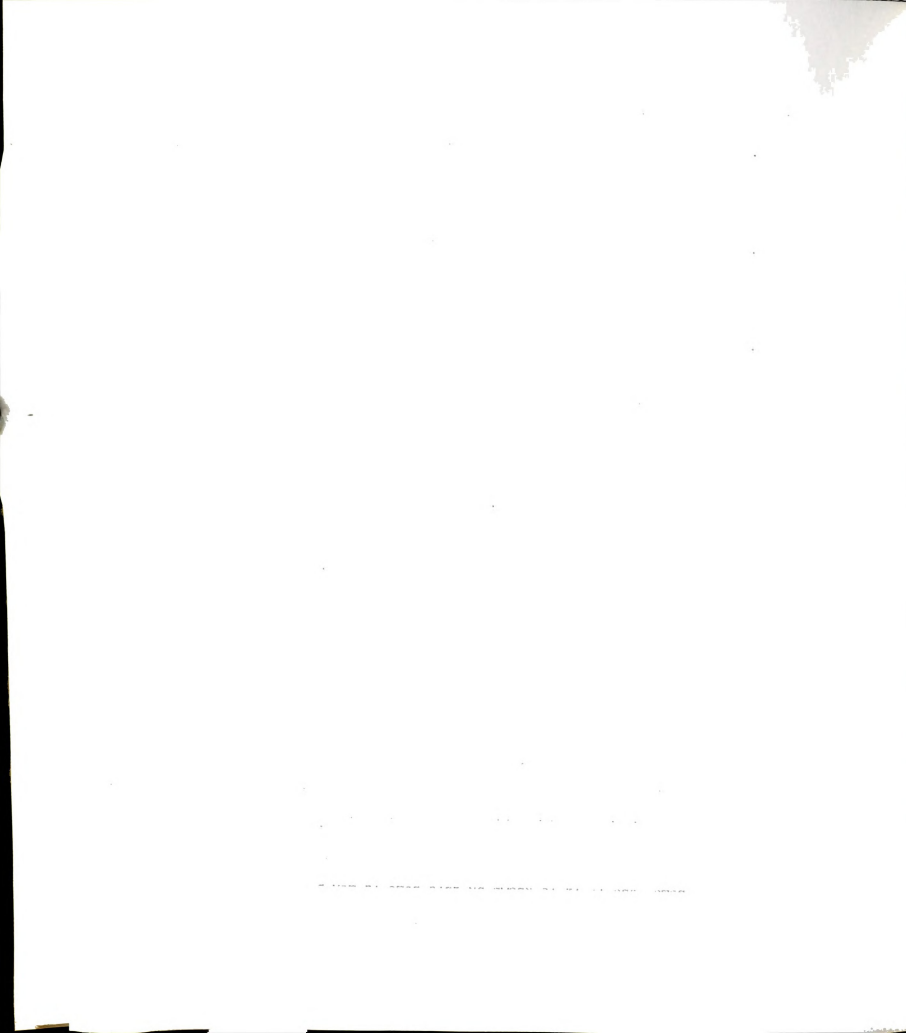
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epistemological quality are the following:

1. Experiences: Does the program provide each child with first hand experiences of natural phenomena (and not just words)?
2. Sequence: Is the lesson introduced with a word, for which meaning is then developed or is the lesson introduced with experiences for which words are later introduced as labels?
3. Information about words: How much is given?

Some techniques observed in this study for providing additional information about words are the following:

- (a) tandem wording - a word is followed immediately by a synonym and the student may infer that these words are used interchangeably.
- (b) repetition in context - a word is introduced in bold type and used repeatedly in a typical context. The student is to infer something about the way the word is to be used from its association in this context.
- (c) verbal illustration - a single example or illustration of the word meaning is provided.
- (d) denotation - a list of examples of things named by the word is provided.
- (e) designation - the properties of all objects that may properly be named by this word are identified. If an object has these properties it is to be known by this name, and if it is known by this name it may be supposed to have these properties.



Pictures and etymological notes may also provide information about words, but no two of the techniques described do precisely the same job. Knowing the denotation of a word, i.e., a list of examples, helps one to use the word appropriately within the limits of the list, but knowing the designation of a word enables a person to create or extend the list on his own. These are epistemologically significant differences.

From an epistemological perspective, it is reasonable that analytic statements dominate early elementary education, that synthetic statements begin to appear somewhat later and that theoretic statements not be introduced until much later. At whatever level students can experience and understand their evidential basis and the reasoning involved in its interpretation, they too must be examined. In terms of the ideas developed in Chapter II, analysis of theoretic statements might involve raising the following kinds of questions: Are the relevant laws identified? Are the assumptions identified? Is the logic complete? Is it sound? Does the theory simplify anything? Is its comprehensiveness demonstrated? Is the tentative quality clearly presented? This is an exciting area but its development should probably be delayed until the research in the other two areas is well established. Following the epistemological order of development of knowledge in the learning situation is an educational expression of the notion that ontogeny recapitulates phylogeny: the learning of each child follows the same sequence as the acquisition of knowledge by our species.

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If this model is further developed to the point that research into the epistemological quality of elementary science programs can be replicated, and if the results of this research are adequately publicized we might reasonably expect the following:

1. an increase in research of this kind.
2. some reaction among text book writers and publishers, resulting ultimately in much improved curricular materials.
3. a redistribution of science subject matter in the K-12 curriculum on the basis of students' ability to experience evidence and understand its relation to interpretations that may be made of it.
4. changes in teacher training programs to include instruction in the epistemological principles relevant to the knowledge claims they teach.
5. a favorable change in the attitude of elementary teachers toward the teaching of science as they come to understand the basis on which it is claimed.
6. new kinds of tests that measure growth in epistemological sophistication in children.
7. new kinds of tests to discriminate among adults, those for whom meaning resides ultimately in words, from those for whom meaning resides ultimately in experiences.
8. simplified procedures for assessing epistemological quality in programs.

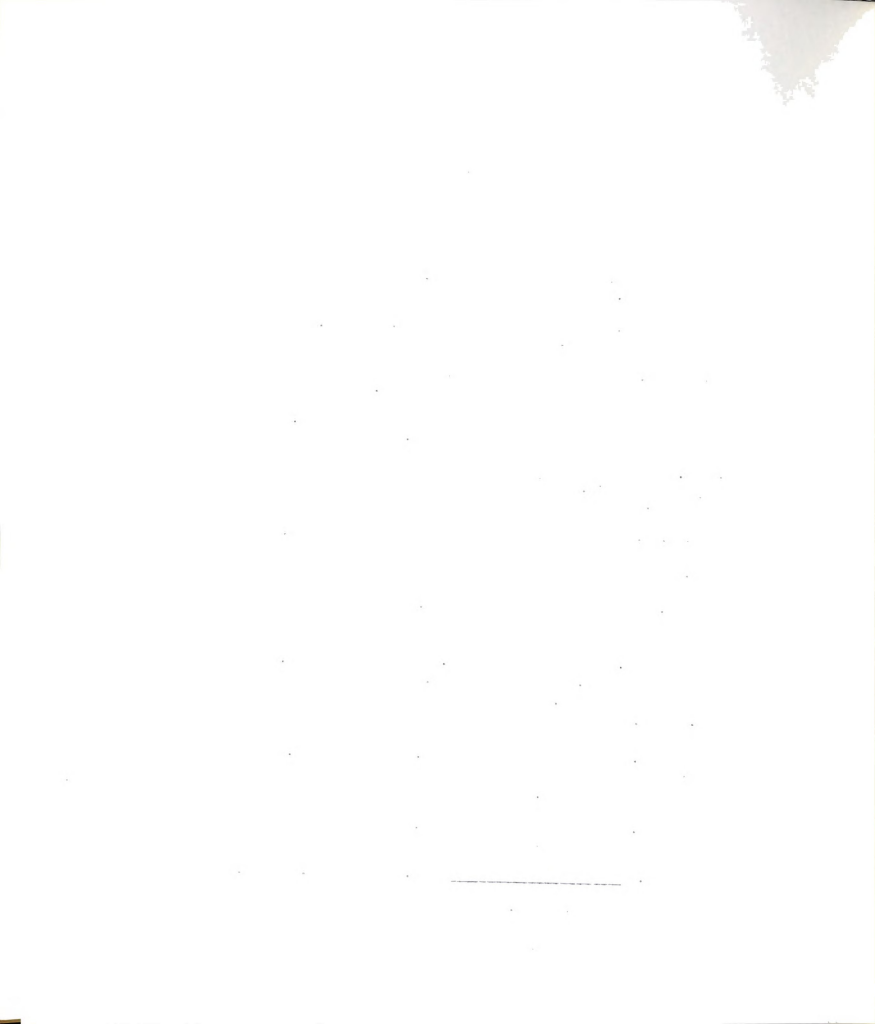
And it is hoped that the combined effect of all of these factors may be a rising level of scientific literacy in the population at large.

It remains to be seen who will take the NSTA Position Statement seriously enough to move strongly and deliberately into the field of program evaluation and development to insure that science programs adopted hold the best possible potential for helping students and teachers to a better understanding of the way scientific knowledge comes into being. Knowing how we know is a fundamental element in achieving scientific literacy.

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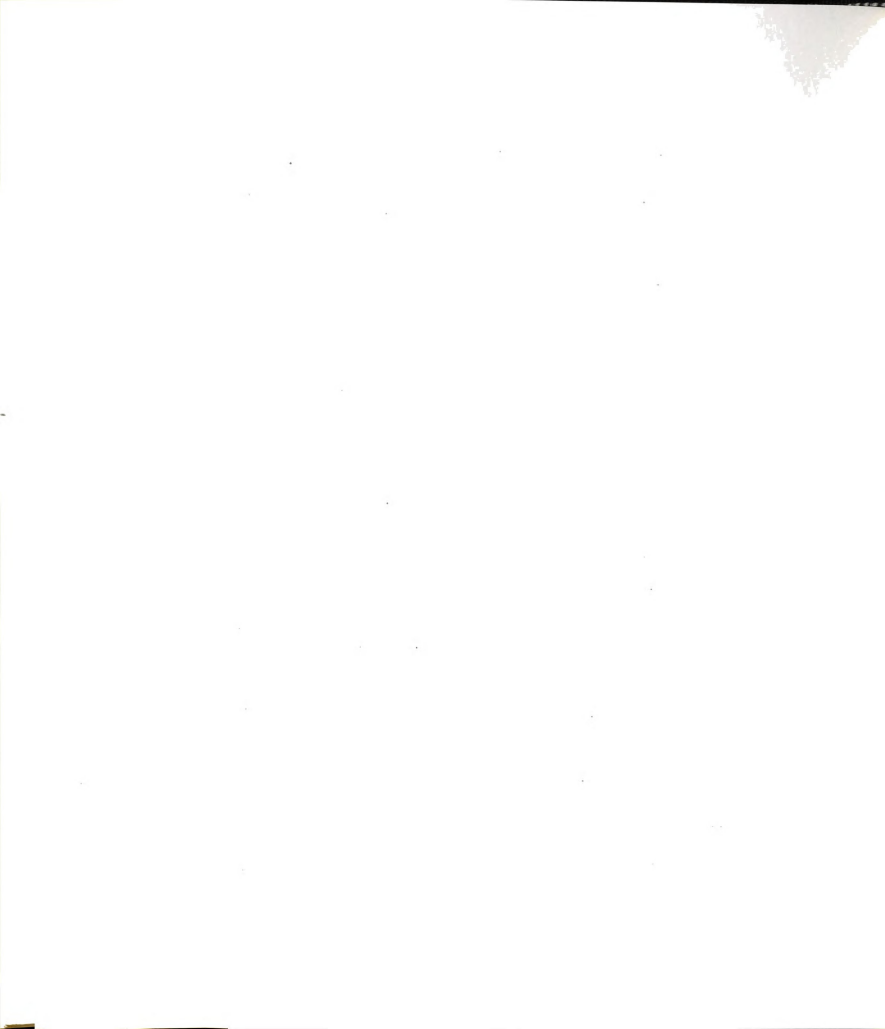


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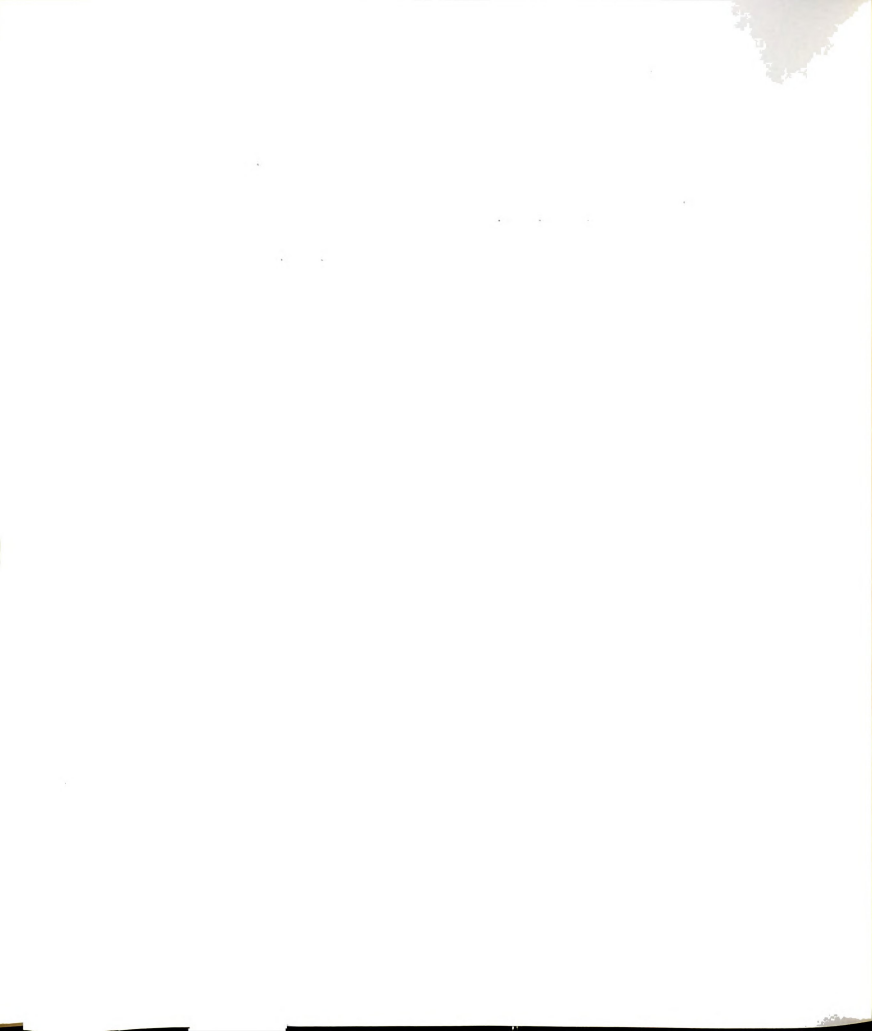


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APPENDICES

APPENDIX 1

PROPERTIES OF ANALYTIC STATEMENTS

Identification of a statement as analytic is difficult at times. One or more of these properties indicates a strong probability that the statement is analytic. Some are reworded several times.

1. What is said of the subject is part or all of the definition of the subject.

2. The subject and predicate are joined by "is" or "are", and cannot be stated with intransitive verbs.

3. The statement remains true if the verb is replaced by "means".

4. Negation of the predicate results in a logical contradiction.

5. The statement is not informative to anyone who knows the meaning of all its words.

6. The predicate asserts of the subject only what has already been asserted in calling it by name.

7. Truth of the statement lies in the fact that the predicate conveys all or part of the same information conveyed by the name of the subject.

8. The truth of the statement can be demonstrated by equivalent word substitutions for subject or predicate or both.

9. When all words are clearly understood, the truth of the statement is self-evident.

10. The truth of the statement can be established without examining the phenomena of nature.

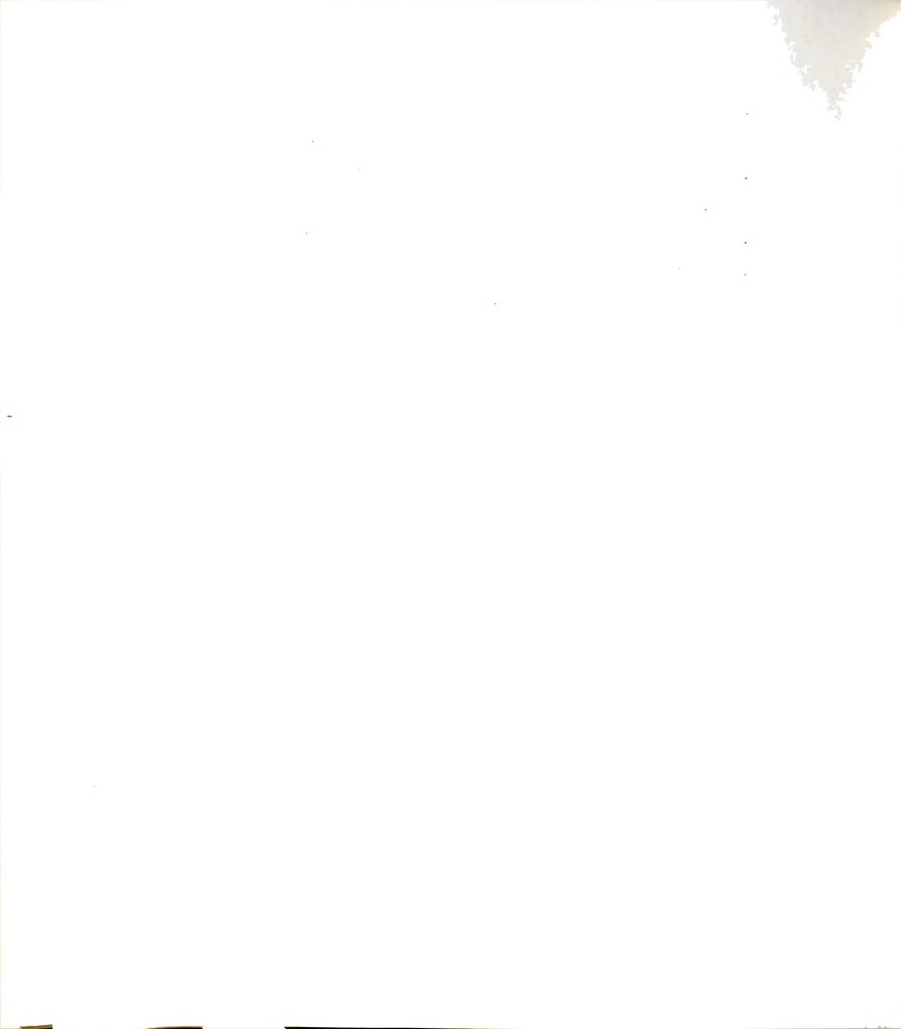


11. When all words are understood it is obvious that there is no way of introducing "evidence" for the truth of the statement.

12. The statement can not "unfold the nature" of the thing referred to.

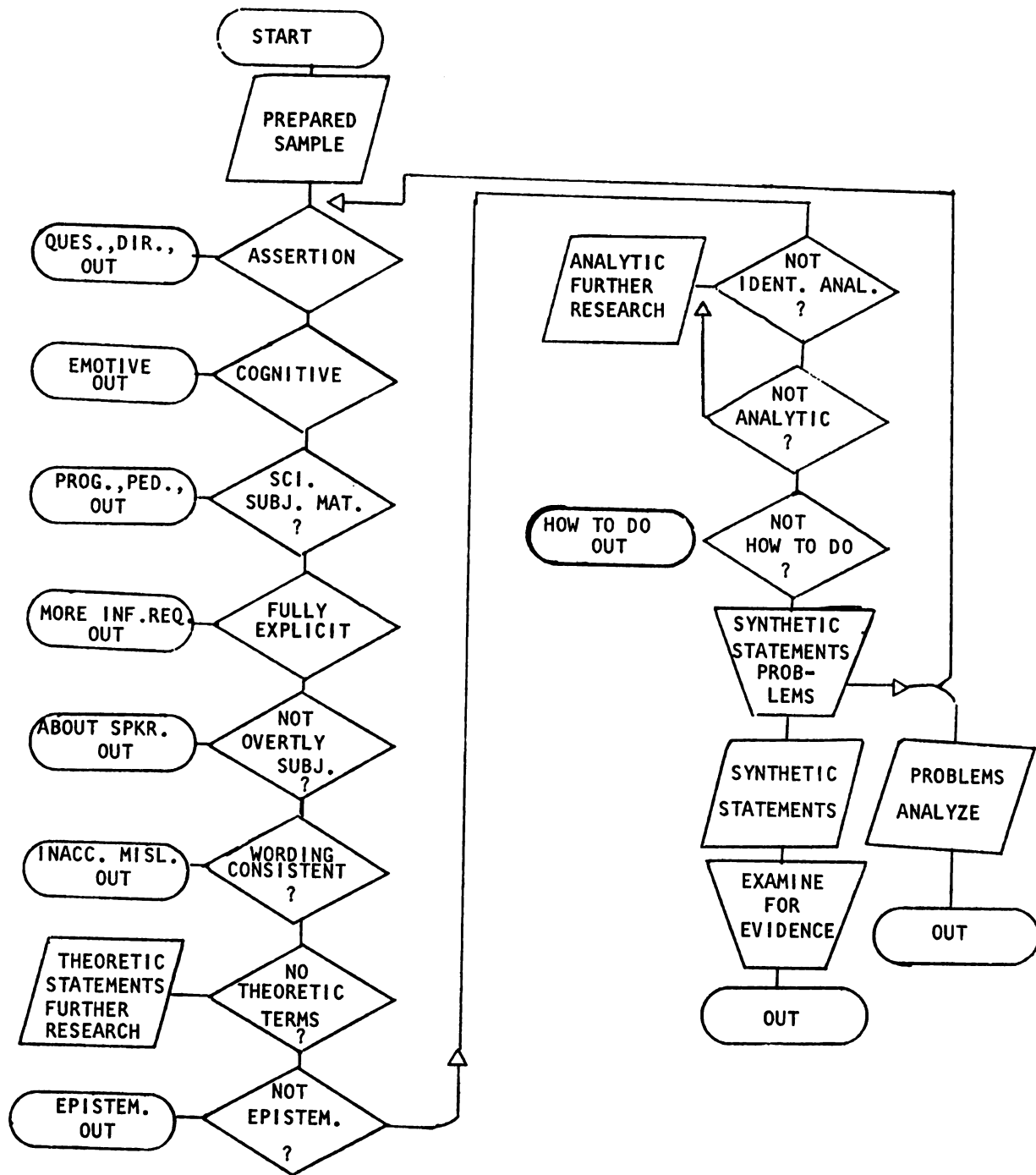
13. The statement does not imply real existence of the subject.

14. The statement can not be taken as a premise from which to reason out new truths about the world.



APPENDIX 2

SENTENCE SORT SCHEME



APPENDIX 3A
SAMPLE DATA SHEET
USED TO COLLECT DATA ON
CONCEPTS IN SCIENCE

UNIT III PLANET EARTH: CHANGING FORM				PROGRAM: CONCEPTS IN SCIENCE														
PAGE 113				SENTENCE SORT SCHEME													SHEET NO. 15	
Sentence #	1	2	3	4 _a	4 _b	5	6	7	8	9	10	11	12	13	14	15	16	
Assertion	-	+	+	+	+	+	+	+	+	+	-	+	+	+	+	-	-	
Not an Epist. State.	+	+	+	?	+	+	+	+	+	+	+	+	+	+	+	+	+	
Sci. Subj. Matter	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Fully Explicit	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Non-Trivial	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Not Ident. Analytic	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	
Literal Use of Lang.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Not Subjective	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Wording Consistent	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	
No Theoretic Terms	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Approp. to dem. Ev.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	
Not Verif. by Dict.	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Tentatively Analytic, T Theoretic Term, MB Make-Believe Teacher Note n Rn Repeat, rewording of																		

0 Tentatively Analytic, T Theoretic Term, MB Make-Believe ⊗ Teacher Note n Rn Repeat, rewording of

SENTENCE SORT SCHEMESHEET NO. 11

Separating Subsynt.

Eqpt. Note p. 53

Sentence #	1	2	3 _a	3 _b	c	d	4	5	6	7 _a	7 _b	8	1	2	3	4	5	6	7	8	9	10	11	12	13 _a	13 _b
Assertion?	+	+	+	+	+	+	+	+	+	+	+	+	D	+	+	+	D	D	D	D	D	D	D	D	D	+
Cognitive?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Sci. Subj. Matter?	+	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	-	+	+	+	+	+	+
Fully Explicit?	-	+	+	+	+	+	+	-	+	+	+	-	+	-	-	+	+	+	+	+	+	+	+	+	+	+
Not Subjective?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Wording Consistent?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
No Theoretic Terms?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Not Epistemol?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Not Ident. Verbal?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Not Verif. by Dict.?	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Not Knowledge How?	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

APPENDIX 3B
SAMPLE DATA SHEET
TO COLLECT DATA ON SCIS

Sep. S. 5 & 6: If the paper has small openings, large particles can not pass through.
If the pores are very fine you can remove all or almost all undissolved...
NFE How fine?

Clarity is presented as a condition for having a solution.

5 and 6 should be NFE:7_b there are neither separate particles...(?) What are separate particles?Eqpt. Note 2: Divergence (possibility) statement but introductory.

6-9: How to check evaporation rate and humidity.

+ Yes, - No, ↓ pass



APPENDIX 3C
 REVISED DATA SHEET
 RECOMMENDED FOR FUTURE USE

SENTENCE SORT SCHEME		PROGRAM	SHEET NO. _____
PAGE _____			
Sentence #			
Assertion?			
Cognitive?			
Sci. Subj. Matter?			
Fully Explicit?			
Not Subjective?			
Wording Consistent?			
No Theoretic Terms?			
Not Epistemol?			
Not Ident. Analytic?			
Not Analytic?			
Not How To Do?			

+ Yes, - No,  pass



APPENDIX 4

Sentences from Concepts in Science

As classified by the Sentence Sort Scheme

(with comments)

Filtered out at decision 1 - "Is this sentence in the form of an assertion?"

Questions, directives, exclamations, wishes, etc., are readily identified so have not been reproduced here.

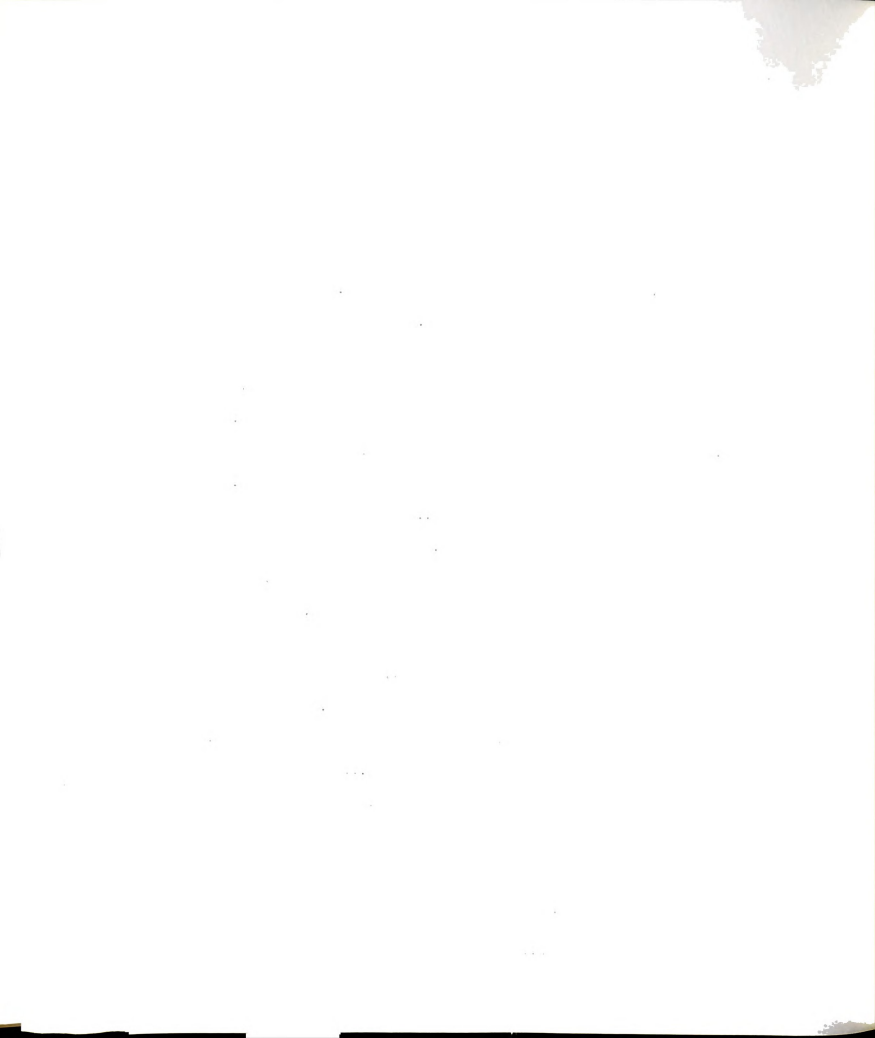
Filtered out at decision 2 - "Is this sentence in the cognitive domain?"

The following were classified as not in the cognitive domain. They are grouped under two sub-headings as discussed in Chapter IV.

a. Statements that do not make logical sense.

- | | | |
|-----|-----------|---|
| 94 | (23)* | "You've known that all along, of course." |
| | (24) | "You have seen..." |
| | (25) | "You've seen..." |
| 102 | (7,8,9) | "You would use your nose, of course. You'd smell the air over each bottle. You'd soon tell the vinegar from the perfume?" |
| 104 | (2a) | "You observed that..." |
| 105 | (9,10,11) | "You saw the drop of perfume. You saw it vanish. But you did not see any molecules." |
| 113 | (4a) | "But you know its there..." |
| 118 | (2) | "You know what happens." |
| 124 | (10) | "You know what is happening here." |

*page 94, sentence 23.



- 125 (4) "You can see the light and feel the heat."
 (12) "You dissolved sugar in water."
 (18) "Then you heated some sugar."
 129 (6) "Smoke is going into the air, as you see."

It does not make logical sense to inform some one of what he knows, or tell him that he is experiencing sense perceptions. Therefore these sentences are classified as non-cognitive. Many of these involve picture referents and their forceful wording tend to strengthen the illusion of actually having seen.

- b. Statements that do not contribute logically to what is being said.

- 106 (3) "Substance is a word that scientists use."
 106 (6b) "Every substance is made up of molecules scientists believe."
 (7a, 7b) "They believe that molecules are the smallest bits of substance."
 110 (12) "Scientists say that sugar dissolves in water." ("dissolves" in bold face)

Scientists do not use the words, "substance" and "dissolves" in any peculiar way. The sentences have an emotive appeal.

Filtered out at decision 3 - "Is the content of the statement science subject matter?"

Two sub-headings are needed here.

a. Statements from other disciplines e.g., history, geography.

132 (5, 6) "There was a time when it didn't seem to matter. The earth's air and water seemed endless."

b. Statements about the program.

93 (17) "You can begin to find out on the next page."

107 (5) "You will learn about these parts soon."

Filtered out at decision 4 - "Is the statement fully explicit?"

Statements that are not fully explicit are generalities that fall into three categories.

a. Statements that perform an introductory/conjunctive function.

100 (18b, 19) "A scientist's record of observation does not have to be in words or numbers always. There are other ways."

107 (1) "A molecule is small indeed."

113 (14) "Separating substances isn't always easy though."

115 (1) "Here is another way to separate a mixture of substances."

126 (17) "Different as they are air and water are alike in two ways."

(19) "Second, we are having trouble with Earth's stores of both air and water."

- 129 (1) "There are places on Earth where the air
is clear and pure."
(16) "Earth's store of water is in danger too."
131 (5) "All waste materials do not pollute water."

b. Generalities: (statements that are not followed up.)

- 100 (20) "Sometimes a picture is best of all."
117 (2) "There are many ways of separating mixtures."
131 (6-11) "Some wastes are used as food...Some wastes
settle to the bottom...Many wastes stay
in the water...Some rivers were once clear
and clean. Now oil and garbage...flow in
them. Now some rivers are ugly and even
dangerous."
132 (1-3) "Lakes that were for swimming are now
fenced off. Their waters are too polluted
to be safe. Even the wide oceans are
getting polluted."

As given, these statements either call for more information before they can be verified or for the interpretation that "some" means "at least one", in which case these very general statements become highly specific, hardly suggesting the idea of a world wide pollution problem.

c. Statements from which the reader is obviously expected to draw an inference.

- 93 (9) "The photograph shows one trial."
100 (21) "A boy in Texas drew small pictures of
his own in the record he kept."

- 103 (11, 12) "Here is what one class observed in
about an hour. And an hour later."
- 111 (12) "Here is what a class in Ohio saw on the
third day."

Filtered out at decision 5 - "Is the statement overtly subjective?"

Only two statements in the sample informed directly about the
author:

- 105 (12) "This is not surprising."
- (15) "We have made drawn models of molecules
much larger than molecules are, in the
pictures above, just to show how they
get around."

Filtered out at decision 6 - "Is the wording consistent with scientific
thought?"

Three sub-classes are helpful in dealing with this group:

a. Statements that are anthropomorphic.

- 94 (22) "Water can change its form."
- 96 (7) "Water can change from solid to liquid
and back again."
- 100 (12b) "Water can change from one form to
another."
- (13a) "When water changes its form..."

b. Statements that are inaccurate or misleading.

- 98 (8) "The water in the pan weighed less after
boiling."

- 98 (12) "Water vapor that cools and turns back into water."
- 110 (1-3) Molecules make sugar disappear in water.
(The actual sequence: "What makes sugar disappear in water? Magic? No, Molecules.")
- 112 (8-10) Molecules can make a solid substance disappear and appear again before your eyes. (The actual sequence: "Thus a solid substance can disappear and appear again before your eyes. Magic? No, Molecules.")
- 113 (9) "In a mixture, substances do not change."
(complex changes occur in solutions.)
- 122 (12, 13) "Carbon is made of only carbon atoms. A substance like carbon is called an element."
(Like carbon in what way?)
- 128 (16) "Water is mainly a liquid."
- 128 (18) "So do all animals. So do all plants."
(depend on air).*
- 129 (10) "When gasoline burns in automobile engines, smoke and gases are given off."
- c. Statements that include forced or strained word usage.
- 105 (8) "Your nose is a molecule detector."
- 112 (7) "The sugar molecules were left behind in the pan."

*This ignores existence of anaerobes or uses "depend" in two different ways.



118 (7) "You can taste them." (the sugar molecules.)

(10) "Sugar molecules can be changed though."

Filtered out at decision 7 - "Is the statement without theoretic terms?"

Statements that include theoretic terms can be conveniently grouped in four categories.

a. Epistemological statements.

105 (13) "The molecules are so very small that they cannot be seen."

(14) "No one has ever seen (molecules) not even with a powerful microscope."

(16) "We can't see molecules."

(17) "Yet there is plenty of evidence that molecules are there."

105 (18) "You have evidence of molecules from using your nose."

106 (1) "You have evidence of molecules from using your nose to smell things."

107 (2) "A molecule can't be seen."

110 (7) "The molecules of sugar are too small to be seen of course."

118 (6a) "Even though you can't see them...(the sugar molecules are there.)"

(7) "You can taste them."



b. Statements specifying word usage.

- 104 (10) "These tiny bits are called molecules."
- 106 (8) "For example, the smallest bit of sugar
is a sugar molecule."
- (10) "The smallest bit of water is a water
molecule."
- 107 (7) "The smallest bit of each substance is
a molecule."

c. Statements purporting to explain.

- 104 (11-15) "Molecules of perfume left the drop...
spread through the air...kept on
spreading...(You smelled the perfume)
when some of the perfume molecules
reached your nose!"
- 105 (7) "Whatever it is, you smell it when
molecules from it reach your nose."
- 110 (6) "The tiny lumps of sugar come apart into
molecules."
- (7, 8) "The molecules of sugar are too small
to be seen of course. So the sugar
disappears." "When sugar dissolves, it
comes apart into molecules. The mole-
cules of sugar scatter among the molecules
of water. When sugar dissolves in water
sugar molecules mix with water molecules.
But you can get the sugar molecules
together again."

- 118 (5) "It comes apart into its molecules."
- (8) "When sugar dissolves its molecules are not changed."
- (9) "When sugar is part of a mixture its molecules are not changed."
- 121 (11) "When sugar gets hot enough its molecules break up."
- (12) "The carbon atoms are left behind."
- 122 (4,5) "When sugar molecules break up the oxygen and hydrogen atoms join together. They form water."
- (9-12) (When sugar is heated) "It's molecules break up. The hydrogen and oxygen atoms form water. The carbon atoms are left behind. The carbon is made of only carbon atoms."
- (14-26) "An element is made of just one kind of atom. The oxygen in the air you breathe is an element. Oxygen is made up of oxygen atoms only. Sugar is not an element. Its molecules are made up of three different kinds of atoms. Sugar is a compound. A compound is made up of more than one kind of atom. Most of the materials you see and use are compounds. Your food, clothing, even your body is made up of



compounds. But you see and use elements too...Elements: iron, aluminum, silver, mercury. Compounds: vinegar, gasoline, baking soda."

- 124 (13) "It's molecules are still the same."
 (14) "Melting does not change the molecules."
 (16) "It's molecules have not changed."
 125 (11) "It's molecules have broken up."
 (13) "The sugar molecules mix with the molecules of water."
 (17) "The sugar molecules had not changed."
 (21) "The sugar molecules had changed."
 126 (10b) "...it's molecules do not change."
 (16) "It's molecules change."

d. Statements that simply postulate.

- 110 (9) "Yet the molecules are there."
 118 (6b) "...the sugar molecules are there."

Filtered out at decision 8 - "Is the statement non-epistemological?"

Some will have gone out at decision 7. Those remaining should pertain to non-theoretical knowledge. They may be grouped into three groups as follows:

a. Specific method of verification indicated.

- 93 (2a) "If you have ever jumped into water and hit hard, you know that..."
 94 (19b) "You can see." (picture referent)



- 98 (3a) "You could see bubbles of gas..."
- (7) "Of course" (you have evidence that water left the pan.)
- (9) One more bit of evidence. (visible steam cloud)
- 110 (4) (We know the molecules of sugar are there because) "the tast of sugar is still there!"
- 121 (2) "Tests show that this black stuff is not sugar."

b. The author's assurance that there is evidence.

- 96 (3) "Many experiments have shown the same thing."
- 99 (12) "Many investigations by many scientists have shown that..."

c. Ways we cannot know.

- 94 (20a) "You cannot see it but..." (picture referent)
- 96 (11) "But you can't see it." (water vapor)
- 102 (12) "You can't see anything coming from the bottles."
- 105 (6b) "Gases that you cannot see are given off too."

Filtered out at decision 9 - "Is the statement not identified analytic?"

Analytic statements may be identified by such expressions as "means" (for the verb) "is another way of saying", "is another word for", etc. No subcategories are needed:

- | | | |
|-----|--------|--|
| 94 | (6) | "It is in solid form we say." |
| 96 | (10) | "Water in gas form is called water vapor." |
| 104 | (5, 6) | "The perfume changed from liquid form to gas form. It <u>evaporated</u> ."
(Evaporated in bold type) |
| 106 | (4, 5) | "Substance is a word that scientists use. Perfumes, bananas,... and all the other things in the world are substances. A substance can be a solid, a liquid, or a gas." |
| 113 | (8) | "Sugar and water make a <u>mixture</u> ." (bold type) |
| 126 | (4) | ("The butter melts.) It changes but its still butter." |
| 126 | (17) | "This kind of change is a <u>chemical change</u> , scientists say." (bold type) |
| 129 | (14) | "(Smoke, etc.) make the air dirty or <u>polluted</u> ." (bold type) |



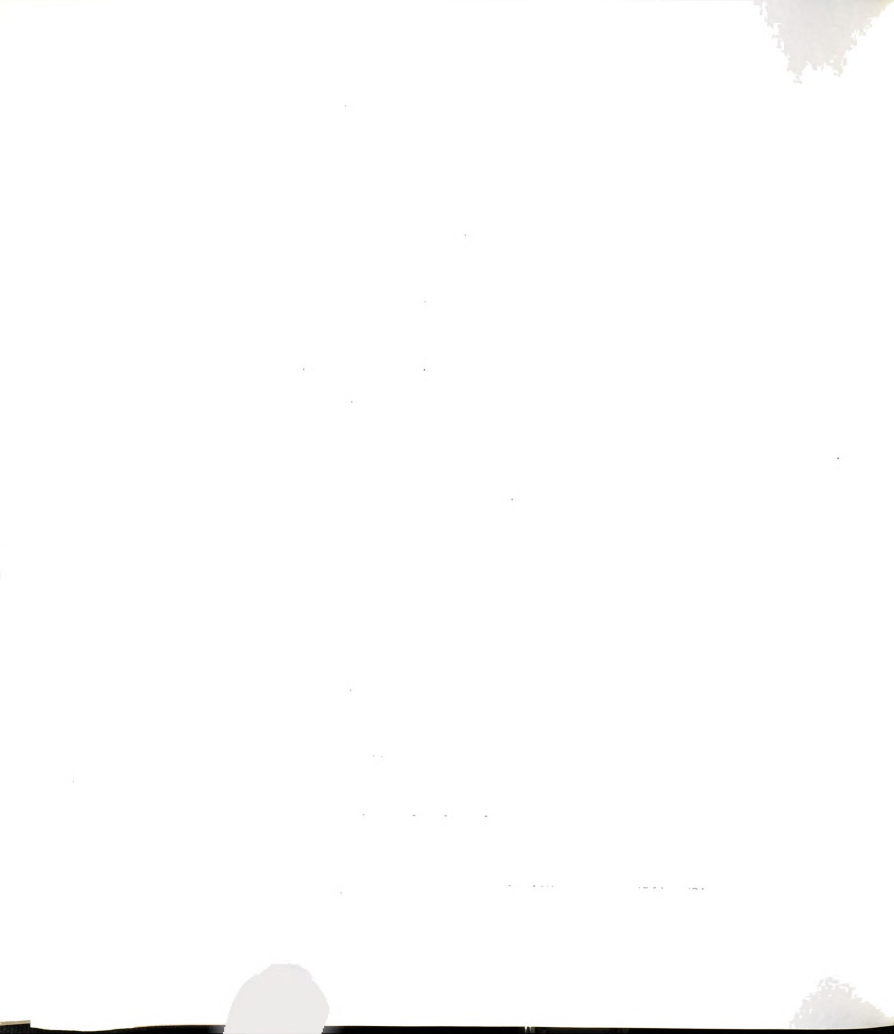
Filtered out at decision 10 - "Is the statement not verifiable by the dictionary?"

Statements that are verifiable by the dictionary are also analytic and should be so identified. Two subcategories are needed.

a. word-word relationship:

- | | | |
|-----|---------|---|
| 94 | (8-10) | "Sometimes water can be poured. It takes the shape of its container. It is in liquid form. |
| | (11-13) | "Sometimes water has no shape. It spreads out and mixes with the air. It is in gas form." |
| | (14-15) | "Water has three forms. It can be solid, liquid or gas." |
| 97 | (12) | "The bubbles have gas in them." |
| 98 | (11) | "Steam is made of very tiny drops of water." |
| 107 | (6) | "The world is made up of many different substances." |
| 108 | (8-15) | ("When sugar is stirred into water, it is still there even though it disappears)."
(Rewording) |
| 113 | (2,3) | (When sugar is stirred into water) "It disappears. It dissolves." ("Sugar - any of a class of water soluble crystalline carbohydrates..." American Heritage Dictionary) |

- 116 (7) "Sand is a solid substance."
- (8) "Water is a liquid substance."
- 117 (19) "If you can separate the substances in a mixture you will find that they have not changed."
- 117 (21) "A filter can separate solid substances from liquid ones."
- 118 (1,3,4) "Stir a little sugar into water. The sugar disappears. It dissolves."
- 120 (10) "Sugar dissolves in water."
- 124 (5) (If you keep on tearing pieces of paper in half) "the pieces will get very, very small."
- 124 (12) "(Water) changes from one form to another but it is still water."
- (15) "Whether it is solid, liquid, or gas, water is still water."
- 126 (8-10) (By breaking and cutting) "You are changing sizes and shapes. You still have wood, candy, apple. The substance changes in some ways..."
- 126 (14,15) (When you burn a stick) "The wood changes and not just in size and shape. It changes to other substances."
- 128 (15) "Air is a mixture of gases."



b. word-thing relationship:

This is an important kind of analytic statement.

Verification is possible by the dictionary used in connection with the object.

115 (8) "You have a filter, ready to use."

Synthetic statements.

a. Statements that refer to a single event (i.e., are not generalized) 99 (9-13), 100 (1-11) A long anecdotal account is given, second hand. It is not reproduced here.

b. General statements - generalizations in the language of observation put forward as everywhere applicable and predictable under the conditions known to be relevant.

94 (4,5,6) "When water changes from solid to liquid form it does not change weight. The same is true when water changes from liquid to solid form. No water is lost or gained."

100 (13) "No water is lost or gained as a result of changing it from liquid to gas and back to liquid."

110 (4,5) "When sugar is put in water the sugar comes apart. The tiny lumps come apart into the smallest bits."

113 (7) (When water is evaporated from a sugar solution) "the sugar has not changed nor has the water."



- 113 (10,11,12,13) (When pennies and sugar are stirred in a pan, the pennies and the sugar are not changed by the stirring) "It's easy to separate the pennies and the sugar."
- 115 (9) "Scientists often use a filter."
- 120 (1) "Heat sugar and it becomes a black substance."
- 121 (2b) "...this black stuff is not sugar."
(13) "That black substance left when sugar is heated is carbon."
- 126 (3,4) (If you spread butter on hot toast)
"The butter melts."
- 128 (7,8) "We could not live without air for more than a few moments. We depend on air."
- 129 (2-5) "But around big cities the air is changing. Sometimes it stings people's eyes. Sometimes it is hard for people to breathe. Plants cannot grow well in it."
- 129 (12,13) "Smoke and invisible gases go into the air. They mix with the gases in the air."
(15) "Earth's air store is becoming more and more polluted."
- 131 (2) "Much the same thing (as illustrated) is happening to the Earth's clean water."
(3) "It is becoming more and more polluted."
(4) "For we are putting more and more waste materials into the Earth's water."



132 (8) "And we are making more and more waste."

c. Statements about how to do something.

99 (4,5,6,8) "You can easily change some water into water vapor. Boil the water, of course. But you would have to collect the water vapor...There is a way."

113 (4,5,6) (When sugar dissolves in water) "You can get it back. Just evaporate the water. That separates the sugar and the water."

114 (15) "The tissue paper makes it easy to remove filings from the magnet."

d. Pseudo-protocol:

Statements derived from previously made generalizations but worded as though they were first hand observations of specific classroom events.

93 (13b) "Somehow/water made its way unseen from the bottom glass to the top one."

(14b) "Water could be seen/again."

97 (6) "The first bubbles you see are air bubbles."

(7) "The water has air in it."

(8a) "When the water is heated, the air comes out in bubbles/like these."

(10,11) "Now watch for a different kind of bubble. It is larger and livlier than the air bubbles. More and more appear as the water comes to a boil."



- 98 (1) "On the bottom of the pan water turned from a liquid to a gas."
- (3b) "You could see/bubbles of gas being born."
- (4a,b.) "They rose/and let their water vapor escape into the air."
- (5a,b.) "Water left the pan/in the form of a colorless gas."
- 102 (13) "Something from each bottle reaches your nose."
- 104 (2b) "You observed that/it got smaller and smaller."
- (3) "And at last it vanished!"
- (5) "The perfume changed from liquid form to gas form."
- (8) "Very tiny bits of perfume left the drop."
- (9) "Very tiny bits leaped from the drop to the air around the drop."
- 112 (5,6) "The water changed from a liquid to a gas. The gas went into the air."
- 119 (5,6,7) "Observe the sugar as it is heated. The sugar melts. Then it boils. Bubbles form and pop."
- 122 (2) "Remember that something was given off from the bubbling sugar? It was water that was given off."



- 122 (3) "It was water that popped from the bubbles in the melting sugar."
- 125 (6a) "Gases/that you cannot see/are given off too."
- 129 (7) "Invisible gases are going into the air too."
- (8) "Some come pouring out of factory chimneys."
- (9) "Much of the invisible gases comes from automobiles."

e. Make-believe statements:

Statements that break down the distinction between the phenomena of nature and representations of them, i.e., words, pictures, models. All of these statements refer to pictures in the text.

- 94 (18,19) "Yes, the ice is melting. The solid water is changing to liquid form, you can see."
- 97 (8b) "When the water is heated the air comes out in bubbles/like these."
- 102 (1,2,3) "Here are two bottles. One bottle holds perfume. The other bottle holds vinegar."
(Note: teacher is to prepare two such bottles and, "Let children know you have prepared them like those in the picture."
The teaching focus is the picture)

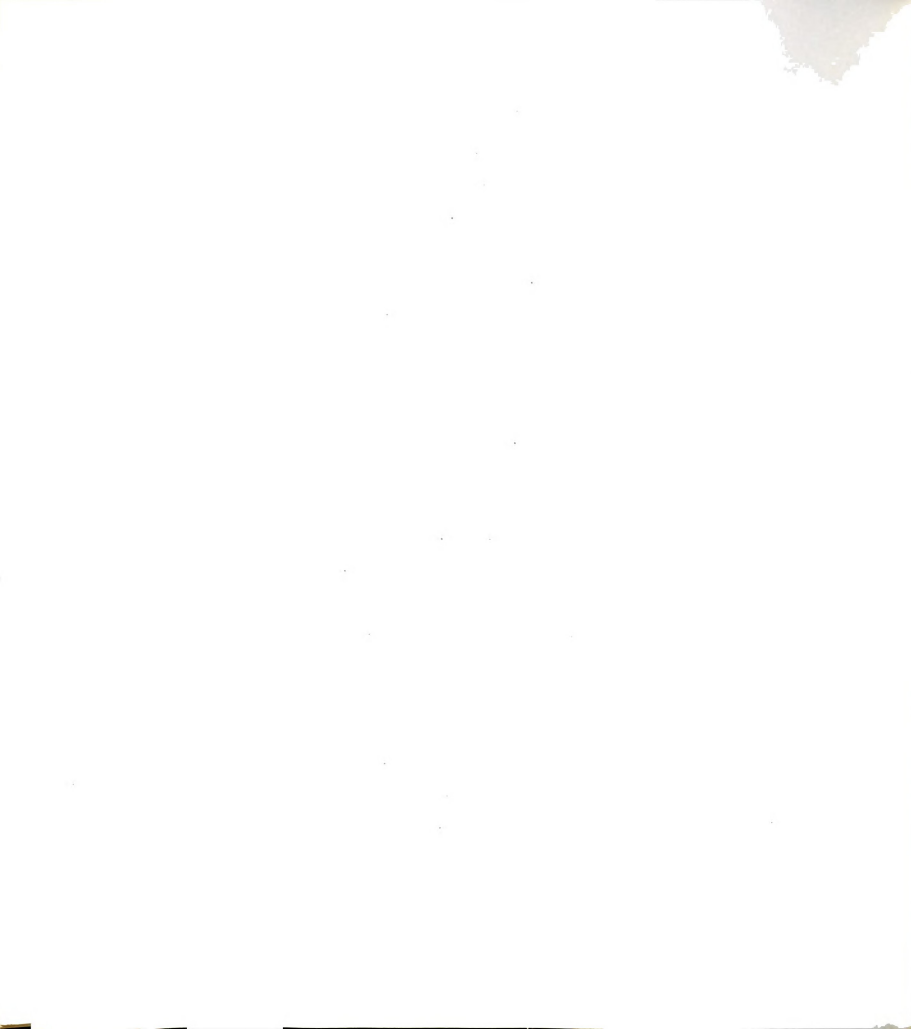
- 105 (15) "We have made drawn models of molecules..."
(Note: the drawn models they have "made" are just black dots.)
- 106 (9) "Here is a model of a sugar molecule."
(11) "Here is a model of a water molecule."
("Model" here refers to a picture of a ball and stick model.)
- 107 (1-4) "A molecule is small indeed. It can't be seen. Yet you can observe something interesting about the models. Those molecules of water and sugar are made of parts that are even smaller!"
- 121 (6,7,8) The sugar molecule is made up of atoms. In this model different kinds of atoms have different colors. How many kinds of atoms do you see? (Note: In these last two examples the author is talking about a picture, which he first refers to as a model, and then as the thing itself:
"How many kinds of atoms do you see?)
- 124 (6) "Look at one of the tiny scraps." (The referent is a picture. In this case the teacher is instructed to have the children tear paper into tiny scraps.)
(11) "Water is changing from solid to liquid."
(The reference is to a picture only.)



- 125 (1-8) "What's happening to this paper? There is a flame. Light energy and heat are given off. You can see the light and feel the heat. Smoke drifts into the air. Gases that you cannot see are given off too. The flame dies out. Thin, thin ashes are left behind." (Note: Even though it is suggested that the teacher demonstrate this, the instruction is to be performed with reference to the pictures. "Call attention to the upper picture, and have children read the first two paragraphs and then examine the second picture.")
- 126 (12) "Here is a physical change." (Note: reference is to a picture of a piece of paper being torn in two.)
- 129 (6) "Smoke is going into the air as you see." (Note: reference is to a picture.)

Problem Sentences:

For one reason or another, these do not fit into any category in the scheme. The first group seems intended to stimulate thought, the second, recall, the third mental imagery. The last one illustrates one problem of a deductive approach: some very simple assertions



are non-verifiable.

- 117 (22,23) (If a substance is dissolved and filtered)
 "The molecules of the solid substance
 may pass through the filter."
- 112 (1-4) (These sentences recall an earlier
 exercise from the same chapter.)
- 125 (14,16,19,20) (These sentences recall an earlier
 exercise from the same chapter.)
- 126 (2,5,6,7) These sentences could probably be
 classified as affective. They create
 mental images because of their form.
 "You spread butter on hot toast:..."
 "You break a stick." "Break a candy bar
 in half. Cut up an apple" (All these
 are used in the sense of, "when you...")
- (15) (When a stick burns) "It changes to
 other substances." (But the concept of
 properties is not made explicit and there
 is no way to talk about chemical changes
 except from a theoretical approach, i.e.,
 in terms of molecular rearrangements, and
 the statement is non-verifiable.) It
 could have been included under "Not Fully
 Explicit" but the problem seems specially
 significant.



APPENDIX 5

STATEMENTS FROM SCIS THAT CAME THROUGH THE FILTER BECAUSE THEY WERE HARD TO CLASSIFY

A. Synthetic statements that are necessarily epistemological:

(These were examined for evidence but are listed here as examples of this type of statement.)

- p. 52 Schlieren (1) "One characteristic you see as liquid solutions form is a wavy pattern that distorts the background when you look through the liquid."
- p. 62 Adv. Prep (7) "The movement of the schlieren near the tea bags will be visible."
- p. 71 Freon (4) "Freon-11 looks very much like water and it may be mistaken for water when it is in a container that confines its odor."

B. Other epistemological statements:

- p. 59 Tchg. Sugg(7) "The vials and tumblers had been capped and not opened so that what is in them now is the very same system each person put in even though it looks different." (This tells how you can know that the system has not been changed.)
- p. 62 Adv. Prep (5a) "Since one's predictions are often only approximate..." (This cautions as to the uncertainty attached to predictions.)



- 72 Histograms (4) "In practice it is never possible to maintain or recreate all experimental conditions so that they are identical." (This cautions as to the uncertainty resulting from our inability to control all variables.)

C. Analytic statements:

- p. 70 Melt. temp. (1) "At ordinary atmospheric pressure, a pure substance such as distilled water, changes from solid to liquid (melts) or from liquid to solid (freezes) at one fixed temperature..."

Classification of this statement depends on how "pure" is defined, but it is not defined in the program. If we define a "pure substance" in terms of its observable properties (of which melting point is an important one, then it is analytic. That is, this property is part of what we mean by "pure substance." The following statements are also analytic:

- p. 70 Melt. temp. (2) "For the substance water, the melting temperature is 32°F..."

- (6) "At unusual pressures or when impure, however, a substance changes from solid to liquid and vice versa at a temperature different from its ordinary melting temperature."

- p. 71 Boiling temp.

- (1) "At ordinary atmospheric pressure a pure substance boils...at a certain fixed temperature..."



(2) "For pure water the boiling temperature is 212°F."

p. 71 Freon

(6) "Some characteristics of Freon-11 are:

1. It has a strong odor.
2. It does not form a solution with water but forms a layer underneath any water with which it is mixed."

(10) "Freon-12 boils at -22°F."

p. 88 Tchg.Sugg

(2) "The melting ice systems had nearly the same temperatures in many experiments."

This one was difficult. It is a statement about what we mean by "melting ice systems."



APPENDIX 6

SYNTHETIC STATEMENTS FROM SCIS PERFORMING AN AUXILIARY FUNCTION

p. 51 Prep. Sol. (5,6,7) "Salt and alcohol are soluble in water but salt is insoluble in alcohol. Sand and dry cleaning fluid are insoluble in water. Oxygen is slightly soluble in water."

This group of sentences accounts for six separate propositions all shown by the context to be providing examples of substances that are soluble, insoluble, or slightly soluble. They will not be examined for evidence. (The children do have extensive experiences with salt and sand in water in this connection.)

The following statements seem intended to provide illustrations for teacher use, reminding of past experience:

p. 52 Schlieren (4) "Warm and cold air mixing over a hot radiator or over a hot highway also give rise to Schlieren."

Another group of synthetic statements is offered in support of two rather startling denials of "common sense knowledge:"

That freezing need not be associated with coldness, and

That boiling need not be associated with heat.

These statements are offered in support:

p. 71 Mill temp. (8) "Paraffin and lead are two materials that melt and solidify (freeze) above room temperature, and many others do so as well." "Some liquid materials such as

liquid air and gasoline...boil at much lower temperatures than water does."

All of these statements are synthetic, and evidence could be readily produced for their verification. They are included here as examples of "auxiliary function" statements. (Twelve separate assertions are contained in them.)

Statements about phenomena and events that are part of this program and not generalized beyond.

- | | | |
|-----------------------|-----|--|
| p. 40 Powdered Mix... | (4) | "The color of the liquid will turn to blue." |
| p. 60 Sol. Syst. | (9) | "The liquid draining through the filter paper will be clear green." |
| p. 65 Adv. Prep. | (2) | "Depending on the amount of liquid that was used and the humidity in your classroom evaporation of the liquid will take place in one to three days." |
| p. 71 Freon | (6) | "It...dissolves the tumblers but not the plastic cups." |
| p. 74 Adv. Prep | (6) | "The plastic bags, cups, and pails are Freon resistant." |
| p. 78 Adv. Prep Note | (6) | "When Freon is poured into the bags some of the powder will mix with the Freon but it will not dissolve." |
| p. 79 Dis. & Inv. | (8) | "...the bags deflate slowly but...no liquid appears inside." |



Statements that look like Pseudo-protocol statements in isolation: the context shows them to be legitimate statements that are part of instruction to the teacher.

- p. 39 D & I (19) "The third material is sand."
- p. 59 Tchg Sugg. (4) "Originally two of these were clear and two were cloudy."
- p. 60 Sol. Subsys. (17) "For instance water is in the original tumbler, on the filter paper, and in the tumbler of clear liquid."
- p. 88 Tchg Sugg. (2) "The various water systems have widely differing temperatures."







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