

An analytical scheme is developed in this study from selected theoretical perspectives on the nature of science and the concept of teaching. Interpretations of science by Carnap, Popper, and Kuhn are described and compared in terms of Körner's concept of a "categorical framework." The divergent views of Carnap, Popper, and Kuhn on different aspects of science are used to develop five dimensions of the analytical scheme. Then selected philosophical analyses of the concept of teaching are described and interpreted, yielding six more dimensions.

An initial assessment of its applicability is made by using the analytical scheme to examine arguments in eight passages selected from a sample of textbooks which discuss methods of teaching science. To permit analysis of the structure as well as the content of arguments, Toulmin's concept of an "argument-pattern" is used in conjunction with dimensions of the scheme. The analysis of arguments is presented in detail, to demonstrate the use of the scheme. On five criteria of applicability, the analytical scheme is judged to be a usable one. On the basis of the results of the initial assessment, one modification is made to express more clearly the difference between two of the scheme's dimensions.

The study is intentionally limited to the provision made for the development of views of science and teaching, and thus it does not consider the actual influence of science teacher education programs on teachers' views or teaching behaviors. The assessment of the analytical scheme is an initial one, limited to one element of science teacher education programs--the content of textbooks concerned with why and how science should be taught.

As developed, the analytical scheme may be used by science teacher educators in the design and evaluation of various aspects of their programs; several possible applications are noted. The theoretical perspectives developed in the study provide a sound conceptual basis for research concerned with views of science and teaching actually held by teachers, views implied by teachers' teaching behaviors, and processes by which views or teaching behaviors actually do change.

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## CHAPTER I

### ESTABLISHING THE PURPOSE OF THE STUDY

#### Introduction

How does one assess the provision science teacher education makes for teachers to develop their views of science and teaching? In this study the investigator develops an analytical scheme for judging the potential influence of claims about why and how science should be taught. To evaluate the applicability of the analytical scheme, the investigator uses it to examine excerpts from textbooks on the teaching of science.

Little is known about the potential or actual influence on teachers, of claims presented about the teaching of science. Yet a science teacher's views of science and teaching have significant consequences for the teacher and for his pupils. While this study does not examine the actual influence of claims presented to teachers, development of an analytical scheme makes it possible to assess systematically the provision made for teachers to develop their views of science and teaching.

The analytical scheme is developed from selected theoretical perspectives on the nature of science and the concept of teaching. The scheme permits one to scrutinize arguments which express, explicitly or implicitly, views of science and teaching. Textbook claims about methods of teaching science are taken as examples of the claims which may be presented in a science teacher education program.

This opening chapter of the study begins with discussion of an argument about how science should be taught, to illustrate that the argument has potential for influencing a teacher's ways of thinking. The illustration establishes a context for discussion of the significance of a teacher's views of science and teaching. Instances of potentially relevant research are reviewed to establish that there is a genuine need

for the study. Then an overview of subsequent chapters is presented and limitations of the study are discussed.

### The Research Problem

This study addresses the problem of assessing the provision a science teacher education program makes for teachers to develop their views of the nature of science and the concept of teaching. Science teacher education programs make claims about why and how science should be taught, including claims about what science teaching can be expected to achieve, how science should be represented to children, and how one should behave as a teacher. There is a potential for interaction between claims presented in science teacher education and the existing categories of thought of the individuals to whom the claims are presented. Detailed and systematic procedures for analyzing this potential conceptual interaction have not been available to those who plan, conduct, and evaluate science teacher education programs.

### An illustration of an argument's potential for influence

The following passage from a textbook on methods of teaching science at the secondary level illustrates that claims about why and how science should be taught are implicit, if not explicit, expressions of ways to think about science and about teaching, with clear potential for interaction with the views of science and teaching held by those who read them.

The scientific method of reasoning as a procedure in teaching has much to commend it. Although it demands adequate time for satisfactory development, the resulting learnings are sound. Pupils know the exact meaning of the general statement, they know its applications, and they know its limitations.

Although the scientific method of reasoning is little more than applied common sense, it is not something that can be taught by a lecture or a single illustration at the beginning of the year. The scientific method demands extensive practice in a wide variety of situations. It need not be formalized by listing it in sequential steps; indeed such formalization may interfere with the thinking of pupils. Pupils are generally intelligent enough to work out

satisfactory procedures for each particular situation without reference to a formal list.<sup>1</sup>

Some of the more obvious implications can be identified without undertaking systematic analysis of the passage. In the first paragraph, the authors speak of a teaching procedure. The content suggests that a method of reasoning may (and should) be regarded as a teaching procedure, and it implies that teaching procedures should be assessed in terms of time required and results achieved. The content implies that the relationship between teaching and learning is straightforward, and it suggests the kinds of results science instruction should strive to achieve.

The second paragraph begins with a comment on the status of "the scientific method;" the existence of the method continues to be taken for granted. Then the method is spoken of as an instructional outcome, and comments are made about teaching procedures intended to enable pupils to achieve the outcome. The shift from teaching procedure to instructional outcome passes without comment or explanation.

Clearly, this passage does contain messages about how to think about science and how to think about teaching. It is also apparent that the explicit content of the passage neither signals the presence nor supports the analysis of those messages. While one cannot be concerned at all times with messages of this type, the concern here is that readers may never be aware of, or attend to, these messages which may influence how they think about science and about teaching. As with values in general, views of science and views of teaching can be adopted or influenced without awareness, without examination of alternatives, and without the analysis and application which fosters personal confidence in and responsibility for the views one holds.

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<sup>1</sup>W. A. Thurber and A. T. Collette, Teaching Science in Today's Secondary Schools (3rd ed.; Boston: Allyn and Bacon, 1968), p. 59. The passage is part of Selection G in Chapter V.

The significance of views of science and views of teaching

Views of science and views of teaching have significant implications for a teacher's pupils and for the teacher himself. Views of science influence a teacher's selection and interpretation of both science content and teaching strategies, with direct consequences for the outcomes his pupils may achieve as a result of his teaching. Views of teaching also influence the design and interpretation of teaching strategies. Finally, views of science and teaching influence the teacher's ability to reflect upon and modify his teaching behavior.

The textbook passage cited and discussed above serves as a convenient illustration, if one compares the authors' implied views of science and teaching to their recommendations for what and how to teach. To say that the scientific method is "little more than common sense" is to suggest that there is a difference, but only a small one, between scientific inquiry and everyday problem-solving. The scientific method appears to have the status and significance of an item of information. When teaching strategies are suggested, the major consideration is the need for considerable and diverse practice. The familiar idea of the scientific method as a sequence of steps is rejected not from an analysis of scientific inquiry but on the grounds that pupils can reason without, and may be hampered by, such a sequence. The authors begin with a limited view of the scientific method; their suggested outcomes and teaching strategies are correspondingly limited.

Perhaps the simplest view of science is one which regards its statements as descriptions. Instructional outcomes based on this view might well be limited to mastery of the statements themselves, and teaching strategies might well be selected solely for their contribution to enabling pupils to recognize and recall statements of science. A more developed view of science might recognize the explanatory function of science, see science as an intellectual process of inquiry, and recognize that the history of science records an interaction between theory development and the events a theory explains. As one's view of science develops, there is a corresponding development of the instructional outcomes one may attempt to make provision for pupils to realize.

More fully developed views of science extend the apparent content of science and the range of outcomes associated with understanding science. New elements in a teacher's view of science may also add to the criteria he uses in the design of teaching strategies.

A similar case can be made for the significance of a teacher's ways of thinking about the activity of teaching. Perhaps the simplest view is one in which attempts are made to enable pupils to recall information already known by the teacher. The strategies a teacher recognizes and the criteria he uses to select them are extended by a more developed view of the teacher-pupil relationship, just as they are extended by a more developed view of the subject being taught.

The significance of views of science and views of teaching extends further than the outcomes pupils may realize from instruction in science. There is also good reason to expect these views to influence a teacher's ability to interpret the effects of his teaching--what he observes, how he interprets his observations of pupils, and how he assesses his own role in classroom events. Matters such as these influence a teacher's personal satisfaction with his work and his responses to opportunities for professional development.

Analyses of attempts to change the school curriculum illustrate the importance being given to teachers' views of what and how they teach. Sarason is one observer of schools who has explicitly called attention to the fact that an apparent curriculum change often has failed to alter many of the basic regularities of teacher-pupil interaction. He points out that it is relatively easy to change the books used in a classroom, but that the purpose of such a change is rarely stated clearly and what begins as the means to a goal tends to become the actual goal. From his perspective it has often been the case that "the more things change the more they remain the same."<sup>1</sup>

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<sup>1</sup>Seymour B. Sarason, The Culture of the School and the Problem of Change (Boston: Allyn and Bacon, Inc., 1971), p. 48.

McKinney and Westbury report a case study of curriculum change<sup>1</sup> in which events conform to the pattern suggested by Sarason. Their detailed analysis of changes in the science program in the Gary, Indiana public schools, from 1956 to 1970, culminates in an explanation for the return in 1969 to "more conventional" textbooks. They conclude that ". . . , in the absence of the necessary skills that made their use of the national programs [PSSC, BSCS, etc.] easy, Gary's teachers ultimately rejected the new national curricula in favor of more traditional approaches that were more compatible with their existing skills and competences."<sup>2</sup>

To argue for the importance of developing views of science and views of teaching is not to argue that all science teachers should view science and teaching in one "most developed" way. The discussions of science and teaching, in Chapters III and IV, recognize and respect the diversity among well-developed views of science and teaching. The point is, rather, than it is neither inevitable nor desirable that teachers be unaware of the existence and potential influence of ways of thinking about science and teaching. Nor is it desirable that science teachers lack opportunities to develop their views in relation to their professional responsibilities.

Available knowledge about views of science and views of teaching

Little systematic information is available concerning the views teachers hold of science and teaching or the ways such views can or do develop. Four studies are reported here to give some indication of how views of science and views of teaching have been examined. These reports extend the preceding discussion and provide additional opportunities to indicate the contribution of the present study.

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<sup>1</sup>W. Lynn McKinney and Ian Westbury, "Stability and Change: The Public Schools of Gary, Indiana, 1940-70," in William A. Reid and Decker F. Walker, Case Studies in Curriculum Change: Great Britain and the United States (London: Routledge & Kegan Paul, 1975), pp. i-53.

<sup>2</sup>Ibid., p. 31.

### Views of science

Herron's examination of issues related to the objective of having pupils understand the nature of "scientific enquiry" includes an investigation of teachers' views of enquiry.<sup>1</sup> Herron presents a framework for analyzing accounts of enquiry, demonstrates the use of the framework, and makes an analysis of science curriculum materials intended to develop an understanding of enquiry. He also presents an analysis of interviews of fifty science teachers. In the interviews, he explored the teachers' views of enquiry and their perceptions of the views of enquiry expressed in the teaching materials they used. In the analysis, Herron classifies responses on a scale ranging from exclusive concern with content to an understanding of enquiry significantly beyond that in their teaching materials. The average response was significantly below the understanding of enquiry expressed in the materials, and Herron raises serious doubts about the effectiveness of inservice training institutes in preparing science teachers to foster pupils' understanding of enquiry. The present study speaks to the assessment of science teacher education programs in terms of provision made for such preparation of teachers.

A study by Kimball illustrates the direct examination of views of science.<sup>2</sup> To compare the views held by scientists and science teachers, Kimball constructed a "Nature of Science Scale" using an eight-statement model of science based primarily on writings of Conant and Bronowski. Within the group of university graduates to whom the scale was administered, some had majored in science and had become either scientists or science teachers, while others had majored in philosophy. The philosophy majors showed significantly higher agreement with the model than did the science majors, particularly with respect to methods

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<sup>1</sup>Marshall D. Herron, "The Nature of Scientific Enquiry," School Review, LXXIX (February, 1971), 171-212.

<sup>2</sup>Merritt E. Kimball, "Understanding the Nature of Science: A Comparison of Scientists and Science Teachers," Journal of Research in Science Teaching, V (1967-68), 110-120.

of science. Kimball found no significant differences between scientists and science teachers.

These findings are consistent with the position that views of science are not adequately developed when they are treated as incidental outcomes of instruction in science. Kimball's recommendation that science majors take a philosophy of science course is indicative of the difficulties involved in moving from research to new practices, for it seems to assume that one such course might "correct" some of the apparently erroneous views held by science majors. It is not apparent that there is one best way to understand science, or that views of the nature of science are easily modified. The present study contributes to the resources available for studying how teachers develop and hold views of the nature of science.

#### Views of teaching

In a report of an informal study, Doran suggests that science teacher candidates tend to rely on a view of teaching as the transmission of information.<sup>1</sup> In his role as an educator of science teachers, Doran has noticed that mechanical analogies often appear in preservice science teachers' accounts of their early attempts to teach. Doran names and describes five "models"--hammer, assembly-line, sponge, photographic-developing, and agricultural--commonly implied by the teachers' talk. The use of such models suggests that the language of talk about teaching and learning is neither precise nor well-suited to its professional purposes. Doran hopes that his report of the models will stimulate teachers to reconsider their views of the nature and purpose of their interaction with pupils. The present study goes a great deal further, to the question of how one may assess the provision science teacher education makes for development of views of teaching.

Analysis of teachers' views of a particular type of teaching formed one component of a research project recently completed in England.

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<sup>1</sup>Rodney L. Doran, "Hammer or Sponge?" The Science Teacher, XLI (February, 1974), 34-35.

The Ford Teaching Project<sup>1</sup> at the University of East Anglia brought together a group of teachers interested in "Inquiry/Discovery" teaching. In discussions of what they meant by this type of teaching, the teachers used a variety of other terms in conjunction with the two themes of not telling pupils what they were to learn, and "enabling independent reasoning." Teachers were interviewed individually and groups of teachers met to discuss the various terms which appeared to be associated with inquiry/discovery. Analysis of transcripts yielded five bipolar dimensions which appeared reducible to three: (1) formal-informal, (2) structured-unstructured, and (3) guided-open ended. An analytical scheme with three dimensions--termed "situation," "aims," and "methods"--was constructed and used to examine teachers' teaching practices and attempts to foster independent reasoning.<sup>2</sup>

The Ford Teaching Project represents a significant effort to study teachers' views of teaching. As the project attempted to support teachers' efforts to change their teaching behavior, it also obtained information about the influence of views of teaching on teaching behavior. The present study's focus on the provision made for development of views represents an unexplored direction for considering the development and use of views of subject matter and teaching.

#### The Need for the Present Study

This study is not the first to recognize or to address the significance of views of science and views of teaching. However, it does represent a new approach, based on new perspectives on teacher education and science education research, as explained in Chapter II. Here it is appropriate to confirm that schemes suitable for assessing the interaction

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<sup>1</sup>This two-year project (1973-1975) was directed by John Elliott and funded by the Ford Foundation. For an account of the origins and design of the project, see John Elliott and Clem Adelman, "Reflecting Where the Action is: The Design of the Ford Teaching Project," Education for Teaching (Autumn, 1973), 8-20.

<sup>2</sup>John Elliott and Clem Adelman, The Language and Logic of Informal Teaching (Norwich, England: Centre for Applied Research in Education, University of East Anglia, 1975), pp. 1-9. Twenty other titles have been published in a series of booklets in which the activities and results of the project are described and interpreted.

between claims about, and views of, science and teaching have not been developed by previous investigators. For this purpose, three studies are examined. Two involve analysis of the nature of science; the third analyzes research and argument relevant to the concept of teaching.

#### Analysis of the nature of science

Robinson's study, The Nature of Science and Science Teaching,<sup>1</sup> is one of the most significant attempts to bring considerations from philosophy of science to bear on issues and problems of science education. Robinson examines six views of the nature of science--views expressed by Margenau, Frank, Bridgman, Woodger, Beckner, and Gerard--and ultimately synthesizes a list of "understandings" appropriate to individuals who are "developing scientific literacy." Robinson seeks to provide a more comprehensive analysis of scientific knowledge which can guide the revision of science curricula.

There are several major themes in Robinson's work. He is concerned with "the structure and organization of scientific thought,"<sup>2</sup> in the belief that these should be reflected in the teaching of science. He sees the possibility of developing a new view of the teaching of science. He seems to imply that in science teacher education programs, science teachers should come to understand the structure of scientific knowledge, in order to make similar provision for their students.<sup>3</sup> One of his major conclusions is that through the structure of science, methods of scientific inquiry are united with the knowledge they produce. In the following paragraphs, Robinson summarizes his conclusions in a manner which can be related to the problem being addressed in the present study.

An understanding of science is considered to be an essential outcome of general education in contemporary society. Achieving this educational goal requires comprehension of a useful structure of scientific knowledge. Such a structure may be clarified by

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<sup>1</sup>James T. Robinson, The Nature of Science and Science Teaching, (Belmont, California: Wadsworth Publishing Company, Inc., 1968).

<sup>2</sup>Ibid., pp. 138-140.

<sup>3</sup>Ibid., pp. 11-12.

making explicit the understandings that characterize scientifically literate individuals.

An artificial dichotomy of products and processes of science reflects the spectator-spectacle doctrine of classical physics but is incompatible with twentieth century science. A shift in perspective, especially a shift in the philosophical perspective with which a teacher interprets natural phenomena to students, requires significant shifts in the patterns of science education.<sup>1</sup>

Robinson's study provides a previously unavailable analysis of the nature of science. The value of the study is enhanced further by the derivation of an extensive list of "understandings" to be achieved for scientific literacy. However, there are several respects in which the study, and others like it, fails to solve the problem upon which the present study is focused. Robinson's study does not address the question of how a teacher or teacher candidate develops views of the nature of science--how present views are held and how they may come to be modified. It is assumed that the analysis of science presented is adequate and appropriate for all, and that all individuals will be able to modify their views of science accordingly. Also, the study is set in a context of the universality of the objective of scientific literacy. These are not faults of Robinson's study, but these considerations do indicate that Robinson's analysis of science does not speak directly to the concerns of the present study.

Bridgham has developed and contrasted three conceptions of the nature of science and used them effectively to account for the existing diversity of claims about why science should be taught to children.<sup>2</sup> His labels for the three conceptions of science are "rational empiricism," "systematic empiricism," and "paradigmatic research." Each is regarded as a subclass of the preceding conception, and Bridgham argues that "paradigmatic research" is the most defensible interpretation of science. For this conclusion, he draws upon analyses of science by Kuhn, Toulmin, and Schwab.<sup>3</sup> With Bridgham's scheme, various claims about outcomes of

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<sup>1</sup> Ibid., p. 112.

<sup>2</sup> Robert G. Bridgham, "Conceptions of Science and Learning Science," School Review, LXXVIII (November, 1969), 25-40.

<sup>3</sup> Ibid., pp. 26-34.

science teaching can be separated into three groups. Bridgham is then able to conclude that when science is interpreted as paradigmatic research, it is defensible to claim that the teaching of science can enable pupils to understand natural phenomena as science does and to understand contemporary scientific research.<sup>1</sup>

Bridgham's conceptions of science are useful for understanding the several ways in which science is popularly interpreted in western culture. While these conceptions can be related to claims about why science should be taught to children, they have not been prepared in a manner which can facilitate the analysis of individuals' development of conceptions of science. Nor is Bridgham's treatment adequate for the analysis of conceptual interaction between individuals' conceptions of science and claims about why science should be taught, a major concern of the present study. Bridgham concludes that the conception of science as "paradigmatic research" is more defensible than the others, but he has not considered alternative conceptions of science, such as those developed by other philosophers of science. In brief, with appropriate developments his scheme could be useful if it were agreed that all science teachers should adopt the Kuhn-Toulmin-Schwab conception of science. This agreement has not been achieved.

There is one study which has drawn upon philosophy of science in a manner which is more closely related to the problem at hand. Munby has derived from philosophical considerations an analytical scheme capable of detecting the provision made by science teaching for pupils to understand different views of the nature of science and how scientific knowledge claims are established.<sup>2</sup> Of interest in the present study is the contribution of science teacher education to a science teacher's understanding of the nature and significance of such consequences for pupils. Robinson and Bridgham demonstrate concern for these and related

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<sup>1</sup> Ibid., p. 37.

<sup>2</sup> A. Hugh Munby, "The Provision Made for Selected Intellectual Consequences by Science Teaching: Derivation and Application of an Analytical Scheme" (unpublished Ph.D. dissertation, University of Toronto, 1973).

consequences of science education, but their studies do not take that concern to the classroom, as Munby's does, or to science teacher education, as the present study does. Several other studies which have related philosophical analysis to aspects of science instruction are described in Chapter II. The investigator is not aware of any studies which have extended philosophical analysis of the nature of science and teaching to aspects of instruction in science teacher education programs.

#### Analysis of the concept of teaching

A paper by Nuthall and Snook, titled "Contemporary Models of Teaching,"<sup>1</sup> provides a reference point with respect to perspectives available for the analysis of claims about teaching. The paper has as its purpose the identification of ". . . those conceptual structures which have functioned as models in recent research and debate on teaching methods."<sup>2</sup> As such, the paper reflects a recent survey of a large body of literature relevant to the analysis of teaching.

Nuthall and Snook identify three models--behavior-control, discovery-learning, and rational--as dominant in contemporary research and argument about teaching. They conclude that the three models serve to define how teaching should be viewed, for research purposes and for planning activities of classroom teaching. They also conclude that research conducted according to one model remains dependent upon that model, so it is not possible to develop a "unified body of knowledge" about teaching.<sup>3</sup>

Understandably, Nuthall and Snook are more concerned with the role of a model in guiding research than in guiding teaching, but they do admit the latter possibility. Their conclusions suggest that the three models are mutually exclusive, in which case the models themselves are not likely to represent perspectives for interpreting the development of

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<sup>1</sup>Graham Nuthall and Ivan Snook, "Contemporary Models of Teaching," in Robert M. W. Travers (ed.), Second Handbook of Research on Teaching (Chicago: Rand McNally and Company, 1973), pp. 47-76.

<sup>2</sup>Ibid., p. 49.

<sup>3</sup>Ibid., pp. 70-71.

thought about teaching. It is possible, however, that the models are contrasted according to criteria which could serve as suitable perspectives. In fact, this does not appear to be the case. Each of the three models is discussed in terms of the description of teaching and learning it offers, associated research, and criticism to which it is subjected. The behavior-control model is depicted as an application of perspectives of behavioral psychology, and the discovery-learning model is described as an application of perspectives of cognitive psychology. The rational model is seen in terms of the application of analytic philosophy to issues related to teaching, with a rejection of behavioral-science assumptions.<sup>1</sup>

The analysis of models of teaching which Nuthall and Snook provide is dominated by debates between two schools of psychology and the contrast between behavioral science and philosophical analysis. The models they report are classification devices which lack general applicability to teaching, and the analysis of the models is not made in terms of criteria relevant to the development of thought about teaching. Their paper gives no indication that schemes have been constructed which are suitable for the research problem of the present study.

#### An Overview of the Study

The main body of the study begins in Chapter II with discussion of research and analysis which are indicative of the context of the study and the premises underlying the manner in which the problem is being addressed. It is the purpose of Chapter II to make explicit the perspectives which permit recognition of the research problem and design of the research procedure which is followed in the remainder of the study.

Chapters III and IV present the theoretical development of the analytical scheme. In Chapter III, three systematic interpretations of

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<sup>1</sup>Ibid., pp. 54-70. It does not appear necessary to reject assumptions of behavioral science when conducting a study from philosophical perspectives. The construction of perspectives on teaching, in Chapter IV of the study, permits an alternative interpretation of contemporary debates about teaching.

the nature of science are examined in detail. Stephan Körner's concept of a "categorical framework" is used as the basis for comparing interpretations of science developed by Rudolf Carnap, Karl Popper, and Thomas Kuhn. The first portion of the analytical scheme consists of five dimensions on which the interpretations of the nature of science may be compared.

In Chapter IV, five studies seeking analytic clarification of different aspects of the concept of teaching are first described and then interpreted in a manner which yields six dimensions suitable for comparison of alternative perspectives on the concept of teaching. These dimensions form the second portion of the analytical scheme. The three perspectives are not associated with particular individuals, as in the analysis of the nature of science. Rather, the five studies are interpreted as expressions of a "composite" perspective which seeks to unite and go beyond two opposing positions which give undue emphasis to particular aspects of teaching and learning.

While the major purpose of the study is the development of the analytical scheme for assessing the potential interaction between ways of thinking about science teaching and claims made in a science teacher education program, that development does not complete the study. In Chapter V, an initial assessment is made of the applicability of the analytical scheme. The assessment, which focuses on a selected aspect of science teacher education programs (textbook content), demonstrates how the analytical scheme may be applied to claims and supporting arguments, as it also demonstrates that the scheme is a usable one. Modifications of the analytical scheme are made in accordance with the results of the initial application of the scheme to textbooks which discuss methods of teaching science.

In Chapter VI, the study is brought to its conclusion with a summary and discussion of the applicability of the analytical scheme. A number of avenues for further research are noted.

### Limitations of the Study

Limitations of the study are of two general types: those associated with the theoretical development of the analytical scheme, and those associated with the assessment of the applicability of the scheme.

### Limitations of the theoretical development

The theoretical development of the analytical scheme has two parts, with different limitations. The most obvious limitation of the scheme's dimensions pertaining to the nature of science is the reference to only three systematic interpretations of science. The selection of the interpretations by Carnap, Popper, and Kuhn is justified in Chapter III. Here it is appropriate to note that there are many options available to the researcher who wishes to use the literature of philosophy of science to shed new light on questions of science education. To this investigator, it seems more valuable to make a reasoned selection and proceed accordingly than to search for or attempt to construct one "best" way to relate philosophy of science to science education. This study is limited by the theoretical boundaries of the selected approach to philosophy of science. The approach used in the study is only one of many possible approaches, each of which has the potential of yielding different results. There appears to be value in developing the application to science education of a number of different perspectives from philosophy of science.

The scheme's dimensions pertaining to the concept of teaching are limited by the selection of papers to be analyzed, and by the interpretation placed upon the arguments presented in the papers. Justification is given in Chapter IV for the choices of papers which subject the concept of teaching to philosophical analysis.

Philosophical analysis of educational concepts is one important root of the research design being followed in the study. Limitations associated with the design may be identified in the discussion of research styles in Chapter II. It is simultaneously a strength and a limitation that the analytical scheme is intended for examination of the

provision made for the development of views of science and teaching. "Provision made" is quite different from "effects achieved," but it makes the analysis of teaching more fruitful. When one is clear about what provision for learning has been made, the identification of actual learning outcomes is a more manageable task.

Limitations of the assessment  
of applicability

The most important limitation of the assessment of the analytical scheme's applicability is the fact that it does not include examination of science teachers' actual views of science and teaching, or of the development of those views. This study is limited to an assessment of the provision made for the development of views of science and teaching. The decision to assess the scheme's applicability with reference to the provision made by textbooks which discuss methods of teaching science is justified in Chapter V. The empirical component of the study is thus limited to revealing the potential influence of the textbook component of science teacher education programs on science teachers' views of science and teaching. The primary purpose of the empirical component is the assessment of applicability.

Every effort is made, in Chapter V, to open the assessment of applicability to the eyes of the critical reader. Claims about the scheme's applicability are not extended beyond the evidence available in that chapter. It is not apparent that a significantly improved initial assessment would be achieved by training independent assessors in the use of the scheme, to obtain additional opinions. The assessment is an initial one, intended to demonstrate that the scheme is a usable one and to indicate some of the ways in which it can be used.

## CHAPTER II

### BACKGROUND AND CONTEXT OF THE STUDY

#### Introduction

It is the purpose of this chapter to develop the background of thought and research upon which the present study is based. The two major topics are patterns of teacher education and styles of science education research.

A brief account of rationales and programs for science instruction and teacher education precedes the detailed examination of a new perspective on teacher education, identified in several different studies. This perspective accents the significance of a teacher's understanding of the nature of science and the concept of teaching.

The discussion of styles of research begins with a review of four styles commonly used in science education, with examples drawn from research on science teacher education. The present format of deriving an analytical scheme from theoretical perspectives is examined in some detail and illustrated by examples of the application of that style of research to questions of science education practice.

In this manner, the necessary elaboration is made of two points of view which are regarded as fundamental themes of the study. The perspectives on teacher education and science education research complement each other and highlight the significance of the subject and the method of the study.

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A Review of Rationales and Practices of  
Science Teaching and Teacher Education

The education of science teachers has not been significantly different from the education of teachers in general, but rationales for science instruction have had characteristics distinctively different from rationales for instruction in other areas of the school curriculum. Accordingly, it seems appropriate to review briefly the historical development of rationales for science instruction, as a preface to the discussion of teacher education in general.

Science teaching

Two references are particularly useful for obtaining an overview of developments in science education in this century. Hurd's Biological Education in American Secondary Schools, 1890-1960<sup>1</sup> provides in a single volume a comprehensive review of major American efforts to clarify and redirect goals and methods of science instruction, with special reference to the teaching of biology. Wall's annotated bibliography of forty-two science education documents spanning the years 1893 to 1972<sup>2</sup> identifies sources of first-hand information about changes in the direction of science education. From these references, a brief and selective summary is drawn, to indicate the kinds of changes which have occurred in rationales for teaching science.

Hurd attempts to characterize the major themes of science education in each decade from 1890 to 1960. The result is a picture of the various ways in which science has been molded to yield potential contributions to the changing ideals and problems of developing demo-

<sup>1</sup>Paul DeHart Hurd, Biological Education in American Secondary Schools, 1890-1960, Biological Sciences Curriculum Study Bulletin No. 1 (Washington, D.C.: American Institute of Biological Sciences, 1961).

<sup>2</sup>Charles A. Wall, "An Annotated Bibliography of Historical Documents in Science Education," Science Education, LVII (1973), 297-317.

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cratic societies. An emphasis on preparing secondary students for university entrance requirements gave way to concern for the practical applications of science to students' lives, as school enrollment expanded after 1900. The "scientific method" was stressed in the 1920's, while the 1930's saw renewed concern with meeting students' needs. The contribution of science to general education and students' understanding of the nature of science were themes which preceded the concern of science educators, late in the 1950's, to prepare the personnel needed by an increasingly technological society.<sup>1</sup>

Two broad impressions emerge from an examination of Hurd's study, one related to rationales and another to methods of science teaching. When one examines the rationales for science instruction in previous periods, it becomes apparent that today's rationales are not so clearly new and better as one might think. The form and context of rationales may be different, but themes recur. For example, the potential value of focusing upon inquiry and the conceptual schemes of science was recognized by groups examining the science component of the school curriculum in the period between the two world wars. The second broad impression conveyed by Hurd's study is that those who have deliberated rationales for teaching science have consistently complained about the survival on a large scale of teaching which emphasizes the simple storage and recall of information by pupils. The recognition that the goals of "packaged" science curriculum materials are subverted quickly and easily by inappropriate teaching styles<sup>2</sup> is but the latest variation on a theme which pervades the history of science teaching in this century.

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<sup>1</sup>Hurd, Biological Education in American Secondary Schools, pp. 19-164.

<sup>2</sup>This type of unintentional subversion of goals of the "new" science curricula of the 1960's was predicted by some. See Maurice Belanger, "The Study of Teaching and the New Science Curricula," The Science Teacher, XXXL (November, 1964), 31-35.

The documents selected by Wall for his bibliography<sup>1</sup> refer to both science instruction and science teacher education. One-half of the documents are dated 1960 or later, and the bibliography is thus a convenient source of information about developments subsequent to Hurd's study. Growing interest in the structure of scientific knowledge and the nature of scientific inquiry was reflected in the widely distributed statements by the National Science Teachers Association on conceptual schemes and processes of science.<sup>2</sup>

Wall cites four yearbooks of the National Society for the Study of Education. These provide detailed statements on various aspects of science instruction and teacher education. Published in the years 1904, 1932, 1947, and 1960, they are separated by intervals long enough to permit recognition of significant changes in rationales and programs.

#### Teacher education

It is valuable to examine the development of teacher education with a view to identifying implicit assumptions about the preparation an individual requires for the role of science teacher. Preservice programs provide one indication of such assumptions; patterns of inservice supervision provide another.

#### Preservice education

A variety of patterns for teacher education developed early in this century to meet the needs of a rapid expansion of the school population at both elementary and secondary levels. In the earliest stages of public education, both Canada and the United States were influenced by British and European patterns. Johnson records that in Canada, elementary school teachers were trained either by apprenticeship or, later and more commonly, by one or two year's attendance at a normal school. Secondary or grammar school teachers were regarded as qualified to teach

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<sup>1</sup>Wall, "An Annotated Bibliography."

<sup>2</sup>Ibid., p. 309.

if they had received a bachelor's degree at a university.<sup>1</sup> These two modes of preparation, originally alternative and later combined, reflect in simplest terms two themes which continue to pervade teacher education programs: subject-matter expertise and training in techniques of instruction. Teacher education began in normal schools, outside the system of universities. In the United States, normal schools developed into degree-granting teachers' colleges and state colleges and universities, as levels of education increased generally, as greater importance was attached to "academic respectability," and as universities instituted their own programs for teacher education.<sup>2</sup> The normal-school tradition continued for a much longer time in Canada.<sup>3</sup>

#### Inservice supervision

As public education has expanded and developed, there has been a sequence of patterns for the relationship between teachers and the individuals responsible for what happened in schools. The supervision teachers experience may be regarded as a special aspect of teacher education. Patterns of supervision express assumptions about the roles teachers are expected to perform. American education in the first half of the twentieth century has been seen as dominated by two major concepts, "scientific supervision" and "supervision as democratic human relations."<sup>4</sup> Lucio and McNeil interpret these concepts as two successive reactions against the "imposition of curriculum and method by personal authority of administrative officers."<sup>5</sup>

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<sup>1</sup>F. Henry Johnson, A Brief History of Canadian Education (Toronto: McGraw-Hill Company of Canada Limited, 1968).

<sup>2</sup>Seymour B. Sarason, Kenneth S. Davidson, and Burton Blatt, The Preparation of Teachers (New York: John Wiley and Sons, Inc., 1962), pp. 19-23.

<sup>3</sup>Johnson, A Brief History of Canadian Education, Chapter 15.

<sup>4</sup>William H. Lucio and John D. McNeil, Supervision: A Synthesis of Thought and Action (New York: McGraw-Hill Book Company, Inc., 1962).

<sup>5</sup>Ibid., p. 10.

Scientific supervision reflected the rise of the concept of "scientific management" and the hope that research and measurement would establish laws of educational practice suited to the growing educational population. Teacher and supervisor were seen as having separate but complementary roles. The supervisor would acquire expertise in knowing what procedures best suited the desired pupil development, and the teacher would acquire expertise in applying the procedures to achieve that development. As Lucio and McNeil point out, there is a significant similarity in recent efforts to determine instructional sequences which enable pupils to develop with minimal teacher influence.<sup>1</sup>

Democratic supervision came to the fore in the period from 1930 to 1950. During a period of concern for "the ideals of a democratic order," guidance replaced the concept of inspection, in the United States. Stress was placed on the maximum personal development of the individual teacher, and "supervision became associated with precepts respecting human personality and encouraging wide participation in the formulation of policy."<sup>2</sup> Lucio and McNeil advance the plausible suggestion that these alternative interpretations of supervision involve different interpretations of the nature of knowledge and of the most desirable kind of society.<sup>3</sup>

These discussions of teacher education indicate that assumptions are made about how teachers should be prepared for their roles and about how they should behave in them. These assumptions have shown change over time. Preparation has reflected assumptions that teachers require further study of subject matter, study of topics unique to the profession of teaching, and opportunities to practice professional skills. Supervision has assumed that teachers should be told how to teach or that they should be helped to develop their talents. These assumptions establish a context for the discussion of a new perspective on teacher education.

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<sup>1</sup>Ibid., pp. 8-10

<sup>2</sup>Ibid., p. 11.

<sup>3</sup>Ibid., p. 12.

### Science teacher education

Science teacher education has used the question "What are the needs of science teachers preparing to teach in the schools?" to guide its planning, and there have been several interpretations of the question. By 1930, the turn-of-the-century emphasis on knowledge of subject matter had given way to the view that preparation for science teaching required a combination of liberal and professional education. For Powers<sup>1</sup>, a liberal education implied both breadth and depth in the study of science, to attain "respectable scholarship." Training in professional methods completed the requirements for preparation to assume teaching responsibilities.

The discussion of science teacher education in the 1947 N.S.S.E. Yearbook on science education maintained the concern for scholarship in science but emphasized the use of science in understanding social issues.<sup>2</sup> Interestingly, special attention was called to the problems of relating psychological theory about human growth and learning processes to practical settings and of providing practice in the application of theory.<sup>3</sup> In 1960, the professional component of science teacher education was organized into the following topics.<sup>4</sup>

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<sup>1</sup>S. Ralph Powers, "Programs for the Education of Science Teachers in State Teachers Colleges," A Program for Teaching Science, The Thirty-First Yearbook of the National Society for the Study of Education, Part I (Bloomington, Illinois: Public School Publishing Company, 1932), pp. 325-344.

<sup>2</sup>"The Education of Science Teachers for Secondary Schools," Science Education in American Schools, The Forth-Sixth Yearbook of the National Society for the Study of Education, Part I (Chicago: The University of Chicago Press, 1947), pp. 273-288.

<sup>3</sup>Ibid., p. 285.

<sup>4</sup>John S. Richardson, et al., "The Education of the Science Teacher," Rethinking Science Education, The Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: The University of Chicago Press, 1960), pp. 263-266.

1. Role of the school in society
2. Human growth and development
3. Nature of the learning process, from learner and teacher viewpoints
4. Methods of teaching science
5. Student teaching
6. Guidance and counseling

#### Summary

This review of patterns and practices of teacher education, in general and with specific reference to science, is a survey, not an exhaustive analysis. It does lend credibility to the impression that there have been variations but not significant changes in the conceptualization of science teacher education in terms of subject-matter expertise and professional teaching skills. There have been significant changes as well as recurrent themes in rationales for the teaching of science. It is not clear that programs of science teacher education correspond adequately to the instructional outcomes desired for science students. To this investigator, it seems to be assumed that teachers can come to understand the nature of science adequately by taking more science courses, and that teachers can acquire necessary skills of instruction by studying various professional topics and engaging in periods of teaching practice.

#### New Perspectives on Teacher Education

In the literature of teacher education, four arguments have been identified which call for changes in assumptions about the nature of teacher education. Three of the arguments are compatible, developing in complementary ways assumptions appropriate to training teachers not to transmit information but to enable others to develop independence of judgment. Discussion of these new perspectives on teacher education is followed by analysis of a fourth argument, in which the call for a different shift in assumptions is rejected. In the light of the assumptions which are accepted, development of theoretical perspectives on science and teaching in a manner relevant to the conduct of science teacher education can be seen as an urgent and worthwhile task.

The teacher's role as observer-  
diagnostician-tactician

In a study based on psychological considerations,<sup>1</sup> Sarason, Davidson, and Blatt have argued that teachers should be trained for a role as "observer-diagnostician-tactician," while present teacher education practice seem better suited to training for the role of technician. They begin their study by asking whether programs of teacher education prepare teachers for the task of bringing about "productive learning" and communicating to pupils the "spirits and traditions" of the arts and sciences. This task is regarded generally as more appropriate than simply communicating information, and accordingly one may ask a very basic question.

What is the relevance of the contents and procedures of teacher training for the functions which a teacher performs by virtue of being a content provider for, stimulant to, and supporter and overseer of the intellectual development of children?<sup>2</sup>

To these investigators, the passivity of having teacher candidates listen and read, and then do teaching practice which focuses on the technical aspects of teaching, is ill-suited to the role teachers may be expected to assume.

To simultaneously account for the nature of present practices and illustrate the potential significance of the role for which teachers in their view, must be prepared, the investigators present three types of analysis: (1) a history of teacher education, including the continuing debate between "scholars" and "educationists," (2) an account of a classroom day, emphasizing the demands attendant upon concern for individual pupil differences, and (3) a report of an "observational seminar" conducted for teachers-in-training (in the third year of a four-year concurrent program) in each of three successive academic years.

The historical account of the development of teacher education in the United States establishes the context of the problem. The roots

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<sup>1</sup>Sarason, Davidson, and Blatt, The Preparation of Teachers.

<sup>2</sup>Ibid., p. 15.

of the concern that teachers possess a liberal education are identified. While not suggesting that one can teach a subject one does not know well, the investigators maintain that knowledge itself is no guarantee of effective communication to others. They suggest that teacher training has ignored this point, as it has ignored the in-the-classroom significance of individual differences among pupils. The account of one day in an elementary-school classroom speaks to this latter neglect, by giving practical import to the investigators' claims that teachers do observe selectively, make inferences from overt behavior to covert attitudes, and make decisions about appropriate action.

Two of the three investigators designed and conducted an observational seminar, to explore their "conceptual hunches" about the selectivity of the untrained observer and about the radical nature of the change from passive learning to active learning in which one assumes personal responsibility for what one learns. They concluded that teachers are not prepared for the role of psychological observer and tactician.

Unfortunately, many teachers do not possess sophistication in observation, they tend to be uncritical of the processes by which they go from observation to action, and they are unaware of the discrepancy between theory and practice.<sup>1</sup>

This study seems particularly valuable because it provides empirical illustration, of several types, of consequences associated with the role of a teacher as observer-diagnostician-tactician, derived from psychological considerations of differences between "productive learning" and learning of information. The analysis of a classroom day illustrates how the new role can be applied to the interpretation of a teacher's behavior. The report of the observational seminar shows how one might go about preparing teachers differently, in the light of the new role.

By an analytic route, the investigators arrive at the conclusion that teacher training relevant to the goal of "productive learning"

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<sup>1</sup>Ibid., p. 73.

demands specific attention to processes by which one recognizes instances to which theory applies and by which one uses theory to guide the practice of teaching. The implications are substantial for how theory is presented and for how teaching practice is conducted in programs of teacher education. Sarason, Davidson, and Blatt are careful to point out that they have achieved theoretical confirmation of their premises about an unstudied educational problem, but they have not thereby demonstrated that the changes they recommend would in fact ensure the achievement of productive learning. For that purpose, other types of research would be required.

Conceptualizing the teacher's role as observer-diagnostician-tactician appears to be a new and substantially different perspective on teacher education. The role is regarded as one which can be informed by theoretical perspectives on science and teaching, as developed and applied in this study. How one observes, analyzes, and selects further courses of action is very much a function of how one thinks about science teaching.

The construct of a teacher's "model of teaching" has been employed by Belanger in an analysis of preservice teacher education and by Cogan in the development of a new format for inservice teacher supervision. Scheffler has argued that teacher education has restricted itself by failing to encourage teacher candidates to develop philosophical perspectives on the subjects they teach. Their arguments are now examined, to demonstrate how they support and extend the perspective developed by Sarason, Davidson, and Blatt.

#### The construct of a "model of teaching"

From their professional experiences in teacher education, Belanger and Cogan have formulated rationales for regarding a teacher as having a conceptual framework for selecting and interpreting classroom events. They refer to such a conceptual framework as a "model of teaching." Their arguments are presented separately and then related to the position presented by Sarason and his colleagues.

Belanger's account

Belanger uses "model of teaching" as a construct which serves to explain the "initial teaching performances" of teacher candidates and to suggest a new way of thinking about the nature of teacher education. At the Harvard-Newton Summer School, liberal-arts graduates<sup>1</sup> were engaged in an intensive program of supervised teaching practice during the summer, in preparation for a semester-long teaching internship in a secondary school. In an analysis of his work with participants in the program, Belanger introduces the idea of a "model of teaching," in a discussion which stresses that the transition from student to teacher is a very difficult one. His premises are significantly different from earlier assumptions about teacher education, to the effect that teachers only need to know their subject(s) well and study additional topics unique to the profession.

One fact that teacher trainers too often fail to take into consideration is that a beginning education student already knows a great deal about teaching and learning before taking any formal course work in these areas. The student has, after all, been observing teachers for a long time, sixteen years in the case of our interns. He knows what school is like for that's where he has spent most of his life. In no other professional area does a student enter with a greater number of preconceived ideas about the nature of the work of the professional. He has been a learner in school and will now leave the student chair and cross over to the other side of the desk. This transition is by no means an easy one as can be attested by the initial teaching performances of interns. Early lessons range all the way from rigid script-like lessons to loose contentless "happenings." Regardless of the particular style of teaching carried out, the student teacher is nevertheless operating on the basis of a conception or model of teaching.<sup>2</sup>

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<sup>1</sup>The participants were candidates for the degree of Master of Arts in Teaching at Harvard University; the program was conducted in schools in Newton, Massachusetts. Belanger refers to the participants as "interns."

<sup>2</sup>Maurice Belanger, "A Psychology Course Planned for the 1968 Harvard-Newton Summer School," in Psychology in Teacher Preparation, ed. by John Herbert and David P. Ausubel, Monograph Series No. 5 (Toronto: The Ontario Institute for Studies in Education, 1969), pp. 99-100.

In the next paragraph of his analysis, Belanger outlines the view of the nature of teacher education which follows from the interpretation that candidates already have models of teaching, which must be developed to suit the requirements of a career as a teacher.

The purpose of the Harvard-Newton Summer School, as we are beginning to reconceive it, is to provide a clinical setting where the intern can make more explicit his model of teaching, examine it, have it challenged, modify and remodify it on the basis of knowledge and experience. In past years rather than starting with the intern's conception of teaching, we at Harvard-Newton have probably been too enamored with our own conceptions, our own knowledge, and even our own wisdom. The teacher trainer, of whatever variety, has built up his own complex model of teaching and learning over a period of many years. It is not surprising, therefore, that attempts to communicate directly items that are selected from this rich collection often fail to be assimilated into the intern's own model and are rejected as trivial and useless. What we know can be of service to the intern if we focus not on the attempt to use this knowledge to shape the intern's model to be congruent with our own, but rather on what the intern now knows and believes about teaching and learning, and use our knowledge to help him evolve more complex, rational, and effective models. Although a teacher-training institution can provide contexts where the initial process of personal reformulation can be accelerated, yet the process continues during an individual's total career. Teaching is a personal invention, and part of "being a professional" means constant reinvention.<sup>1</sup>

#### Cogan's account

Cogan, who was also associated with teacher education programs at Harvard University, has used the same construct of a model of teaching in developing a rationale for "clinical" supervision of inservice teachers. He emphasizes the importance of first identifying one's unconscious model of teaching in order to be able to replace elements with more appropriate ones as they become available and are recognized as such. Cogan sees clinical supervision as a procedure which could make it possible for teachers to engage in such development throughout their careers. Note that Cogan makes specific reference to the existence of a "popular assumption" that teacher education is a "short and simple" process.

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<sup>1</sup>Ibid., p. 100.

The profound underestimation of the difficulties teachers face in learning how to teach and in improving their teaching on the job is at the root of some of the major problems in the preservice and inservice education of teachers. The popular assumption is that learning to teach is easy and that the preparation for teaching should therefore be short and simple. The trouble with this assumption is that in a very genuine sense future teachers arrive in college with full-fledged models of teaching already well established in their minds. Their twelve years as students in elementary and secondary schools has provided them with certain models of what teachers are and what they do in class. They have unconsciously learned styles of teaching while being taught, just as they have learned to be parents, . . . , or law-abiding citizens or criminals while living in a culture in which such models exist.

One consequence of learning about teaching in this most pervasive and persuasive way is that the models learned are learned too well. They are difficult to uproot, to displace, to modify. As a result, future teachers face several difficult tasks. They must first unlearn the deeply etched patterns of teaching they arrive with, then select for their own use appropriate elements of the culturally "given" styles of teaching emerging today. This double task makes the preparation of competent teachers a long, demanding, and expensive operation. The rationale of clinical supervision demands, therefore, that the inputs it contributes to the education of teachers should be equal to the double task the teachers face. . . .<sup>1</sup>

Belanger and Cogan base their challenges to popular assumptions about teacher education on their supervisory work with both novice and experienced teachers. Their point is that development of a model of teaching begins when one first goes to school, not when one is completing a liberal education and begins specific preparation for teaching. They regard the development of a model of teaching as an inevitable consequence of school learning experiences in which frequent observation of the behavior of teachers is both natural and inevitable.

Belanger and Cogan see teacher education not as a process of adding information but as the much more complex process of changing one's patterns of thought and action--one's model of teaching. Their premises are compatible with those underlying the arguments presented by

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<sup>1</sup>Morris L. Cogan, Clinical Supervision (Boston: Houghton Mifflin Company, 1973), p. 15.

Sarason, Davidson, and Blatt; and it seems reasonable to combine the two perspectives. Observation and interpretation of classroom events and selection of subsequent teaching acts can be viewed as occurring on the basis of one's model of teaching, reflecting elements of its composition. Sarason and his colleagues can be read as identifying particularly significant inadequacies of models of teaching, the development of which must be addressed directly by teacher education programs.

The discussion turns now to another challenge to assumptions of teacher education. Scheffler argues that subject-matter competence has been interpreted in a limited sense. He may be read as identifying another important element of a model of teaching.

The importance of exploring  
philosophical perspectives

Scheffler challenges assumptions about teacher education by arguing that prevalent conceptions of subject-matter competence neglect the potential contribution of a philosophical perspective on the subject one teaches. In his paper, "Philosophy and the Curriculum,"<sup>1</sup> Scheffler describes four ways in which the philosophy of a particular subject could contribute to the teaching of the subject. For present purposes, the details of his suggestions are less relevant than his comments about teacher education. Scheffler takes the subject of science as his example, and thus his remarks have double relevance to the present study.

To develop for his readers the potential contribution of philosophy of science to science teaching, Scheffler explains that philosophy of science relates in quite different ways to the work of the practicing scientist, the philosopher of science, and the science teacher. Competence in scientific inquiry, required of the scientist, can be quite independent of knowledge of philosophy of science. The philosopher of science engages in reflection on the practice of scientific inquiry, an

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<sup>1</sup>Israel Scheffler, "Philosophy and the Curriculum," in Israel Scheffler, Reason and Teaching (Indianapolis: The Bobbs-Merrill Company, Inc., 1973), pp. 31-41.

activity which may but need not necessarily influence that practice. The science teacher engages in the very different enterprise of handing on the forms of scientific thought.

He needs to have a conception of the field of science as a whole, of its aims, methods, and standards; he needs to have principles for selecting materials and experiences suitable for inducting novices into the field, and he needs to be able to communicate both with novices and scientific sophisticates. . . . ; his professional purpose, that is to say, can be articulated only in terms of some inclusive conception of scientific activity which it is his object to foster.<sup>1</sup>

Scheffler sees the science teacher's activities as ones which require a perspective as broad as that of the philosopher of science.<sup>2</sup>

It is Scheffler's conclusion that reflections on science, available in philosophy of science, have considerable potential to influence science teaching practices. In the following excerpts, he stresses the point that a teacher who has not been introduced to philosophical perspectives on his subject adopts and reflects "incoherent" philosophical stances, without being aware of doing so. These remarks about teacher education extend an earlier discussion of his students' responses to an assignment requiring them to examine the philosophies of their teaching subjects.

Their reaction, if indeed it can be generalized, suggests that prevalent conceptions of teacher training are curiously restricted. For these conceptions typically emphasize three features: subject-matter competence, practice teaching, and the psychology and methodology of teaching. Since subject-matter competence is, moreover, interpreted as relating exclusively to the first-order proficiency of the practitioner, no attention is given to the need for a second-order, or philosophical, perspective on the subject matter in question. And since, as I have argued, such a perspective is demanded by the teaching role in any event, the result is that it is gained haphazardly and inefficiently by each teacher, without guidance and without awareness of alternatives. Lacking a systematic and critical introduction of philosophical considerations, dogmatic and incoherent philosophical attitudes are enabled to grow and to proliferate.<sup>3</sup>

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<sup>1</sup>Ibid., pp. 35-36.

<sup>2</sup>Ibid.

<sup>3</sup>Ibid., pp. 36-37.

Later in his argument, Scheffler touches on the kind of contribution the philosophy of a subject can make to an educator.

It goes without saying that philosophies-of do not provide the educator with firmly established views of justification; on the contrary, they present him with an array of controversial positions. But this array, although it does not fix his direction, liberates him from the dogmatism of ignorance, gives him a realistic apprehension of alternatives, and outlines relevant considerations . . . .<sup>1</sup>

Scheffler's position, based on philosophical considerations, directly complements the argument by Sarason, Davidson, and Blatt, based on psychological considerations. In both arguments, preparing teachers to bring about productive learning is shown to require activities quite different from more courses in one's subject(s) and passive study of topics unique to the teaching profession.

An alternative view of a teacher's use of theory and intellect

Three complementary arguments with implications for assumptions about the nature of teacher education have been described as a significant new perspective. Sarason and his colleagues, Belanger and Cogan, and Scheffler have argued that teacher education could be expected to attend to the development of a teacher's model of teaching, in an active manner which makes explicit the influence of that model on the conceptualization and the pursuit of outcomes for learners.

This perspective appears to be challenged by Jackson's study, Life in Classrooms,<sup>2</sup> which develops a potentially useful perspective on institutional characteristics of the school. At the close of the study, prescriptions for teacher behavior and teacher education are made which conflict with the assumptions already discussed. The anti-intellectual

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<sup>1</sup>Ibid., pp. 38-39. The manner in which philosophical perspectives on science are examined in Chapter III is consistent with the position expressed here by Scheffler.

<sup>2</sup>Philip W. Jackson, Life in Classrooms (New York: Holt, Rinehart and Winston, Inc., 1968).

Later in his argument, Scheffler touches on the kind of contribution the philosophy of a subject can make to an educator.

It goes without saying that philosophies-of do not provide the educator with firmly established views of justification; on the contrary, they present him with an array of controversial positions. But this array, although it does not fix his direction, liberates him from the dogmatism of ignorance, gives him a realistic apprehension of alternatives, and outlines relevant considerations . . . .<sup>1</sup>

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stance which is adopted is common enough to merit detailed scrutiny. Relevant aspects of Jackson's study are now reported and analyzed to demonstrate the basis on which Jackson's position is rejected.

#### A description of Jackson's study

In Life in Classrooms Jackson explores the possibility that the institutional constraints of school experience may rank with lesson content and psychological characteristics of pupils as highly significant factors influencing the educational experience. First a host of institutional characteristics which may impinge upon teachers and pupils in their classrooms are elaborated. Then pupils' attitudes toward school and the issues of pupil attention and involvement are considered, in an impressive combination of sensitive personal insights and relevant research. Finally, consideration is given to responses of fifty "good teachers" in elementary schools to four questions intended to elicit their views of classroom life.

Jackson reports four themes in his analysis of the teachers' responses. "Immediacy" refers to teachers' tendencies to judge their own teaching on the basis of immediate pupil responses, rather than on the basis of test results. The theme of "informality" expresses teachers' views that they are more casual and less formal than teachers of earlier times, although they recognize that they remain in authority. "Autonomy" expresses teachers' demand for freedom from a totally prescribed curriculum and from excessive evaluation by outsiders. The theme of "individuality" summarizes the teachers' indications that pupils' moments of individual insight and unexpected achievement provide their greatest satisfactions with their work as teachers.<sup>1</sup>

Having summarized the teachers' responses, Jackson moves on to consider the relevance of the responses to his theme of the institutional demands made by the school on those in attendance. Jackson notes "an absence of a technical vocabulary" in teachers' conversations. He also identifies a "conceptual simplicity" which seems to have four

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<sup>1</sup>Ibid., pp. 119-143.

major features: (1) Teachers seem to accept simple explanations of complex events, and to talk in terms of a "one cause-one effect" view of causality. (2) Teachers talk about their teaching activities in intuitive rather than rational terms, defending actions as "felt" rather than "known" to be right. (3) Teachers strongly defend particular teaching practices, relying upon personal experience for support. (4) Teachers use global terms in narrowly defined ways.<sup>1</sup> Finally, Jackson speaks of the teacher's world as having "sharp existential boundaries," limited to concrete experiences with particular students.<sup>2</sup> Jackson sums up these points metaphorically by suggesting that a "general myopia" characterizes "the classroom teacher's intellectual vision."<sup>3</sup>

All of these points are insightful, potentially valuable, and worthy of serious consideration, particularly in an analysis of teacher education. Careful justification is established by numerous references to the recorded responses of the teachers to Jackson's questions, which were based upon his perspective that the institutional aspects of the school may have substantial impact upon teaching and learning in classrooms. What is unusual in this study is Jackson's apparent leap to the conclusion that these characteristics of teachers' conversations may reflect the teachers' efforts to ameliorate the institutional harshness of the school. Jackson could be right, but the question is an empirical one, not a logical one. Jackson provides no evidence of what happens in the classrooms of teachers who are, for example, "more rational." He does not demonstrate that being more rational increases institutional harshness or that greater "myopia" produces amelioration of harshness. His suggestion is a sharp departure from the analytic style of the rest of his study, and it seems to involve the confusion of several important distinctions.

An analysis of Jackson's claim

Jackson offers several points in his attempt to link the conceptual simplicity or intellectual myopia of teachers' conversations to a

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<sup>1</sup>Ibid., pp. 143-147.

<sup>2</sup>Ibid., pp. 147-148.

<sup>3</sup>Ibid., p. 148.

coping strategy for lessening the institution's harshness, for both pupils and teachers. Jackson expresses doubt that teachers would do better in the classroom if they were more rational and open-minded.<sup>1</sup> He also sets the rational as an alternative to the intuitive, and then suggests that the distinction is comparable to that between "an army of human engineers" and "our present cadre of elementary school teachers, with all of their intellectual fuzziness and sticky sentimentality."<sup>2</sup> Jackson appropriately recognizes the "engineering" perspective implicit in the behavioral objectives movement, which may indeed reflect a return to the "scientific movement" which progressivism sought to supersede. Undeniably, the complexity and immediacy of classroom teaching make the simplifications required for science-like study virtually unattainable without loss of relevance. Yet neither of these observations can support Jackson's implicit conclusion that the process of acting on intuition cannot or should not be developed rationally to the fullest extent possible for any teacher. Such a conclusion commits the double error of equating "scientific" with "rational" and "intuitive" with "irrational."

This is the error which enables Jackson to adopt a position about teacher education so unlike and at odds with the positions expressed by Sarason and his colleagues, Belanger and Cogan, and Scheffler. Jackson seems to say that teacher education must avoid any activity which might modify a teacher's conceptual simplicity. Apparently, a teacher's model of teaching should not be developed for fear of destroying adaptations which lessen institutional harshness. So cast, the dilemma is seductive, for few could deny that institutional harshness should be minimized. Yet it seems somewhat akin to burying one's head in the sand to suggest that minimizing institutional harshness requires the perpetuation of conceptual simplicity and intellectual myopia.

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<sup>1</sup> Jackson has a personal right to such a doubt, but it is a personal expression, not an extension of, nor warranted by, his study.

<sup>2</sup> Ibid., p. 152.

Jackson does make valuable points during his discussion of his claim. He distinguishes between "preactive" and "interactive" aspects of teaching, appropriately noting that the outside-the-classroom phases of a teachers' work can be deliberative, analytic, and rational, while a teacher's interaction with pupils seems to proceed on an intuitive basis.<sup>1</sup> This point is extended into a distinction between a teacher's "primary" and "ultimate" concerns. To Jackson, not learning but the activity being conducted and sustained is the primary concern of the interactive teacher. Learning is the ultimate concern of a teacher, and it is considered when planning teaching activities, during preactive periods. As he develops these and other potentially valuable distinctions, Jackson consistently ignores and implicitly denies the possibility that a teacher may rationally develop the intuition upon which he relies during the interactive aspects of his work. This is the possibility which has been recognized in the arguments of Belanger, Cogan, and Scheffler, and explored in the observational seminar conducted by Sarason and Blatt.

Jackson realizes only too well that the professional education of teachers does not appear to have raised their intuitive ways of thinking above the common-sense level which develops during many years in the classroom role of learner. To suggest that a beginning teacher has a model of teaching is to recognize the role played by intuition. To suggest that it can be identified and developed for the demands of the role of teacher is to take the stance developed, from analyses of various experiences, in the arguments of Sarason, Davidson, and Blatt; Belanger and Cogan; and Scheffler. It is to suggest not that a teacher's interactive work can or should be made "scientific," but that the intuition he uses is based on prior experience and open to further development. The present study proceeds on this interpretation.

It has been important to note and examine Jackson's conclusion because his is an easy and sometimes popular position to adopt. In Chapter IV, the analysis of the concept of teaching includes reference

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<sup>1</sup>Ibid., pp. 151-152.

to a tendency to simplify complex issues by stressing one aspect which requires exclusion of an apparently polar opposite. It is such a tendency which Jackson seems to have followed, when it seemed to complement his main thesis so well. When this aspect of Jackson's study is so analyzed and removed, the remainder of the study can be interpreted as offering further empirical elaboration of many of the points made by Sarason and his colleagues.

#### Styles of Research in Science Education

The preceding discussion has centered on perspectives on teacher education. The second fundamental point of view indicative of the context of the study is concerned with styles of research in science education. As a prelude to describing the plan and rationale of the research procedure of the study, it is appropriate to review some of the major styles of research previously and currently used in the study of science education problems.

Understandably, research styles are to some extent functions of the problems which are identified and of the nature of the area of investigation. With educational research in general, science education research has shown an implicit faith in the research styles of science. Two general classes of research styles can be recognized: observation studies and achievement studies. In a manner not unlike that of natural history, many studies have been devoted to the systematic collection and classification of observations, opinions, and descriptive information. Seemingly in the hope that educational research might achieve some of the capacity science has developed for explanation, prediction, and control of phenomena, many studies have sought to establish cause-effect linkages to pupils' achievement of science education objectives.

Two styles of research are identifiable within each of the two classes. Within the observation class, there are studies recording instructional events and studies reporting program organizations and enrollments. Within the achievement class, some studies seek correlations between classroom characteristics or events and pupil achievement, while others compare pupil achievement obtained by alternative methods.

Each of the four styles has been applied to both science teaching and science teacher education. Most of the examples used here for illustration are studies related to science teacher education.<sup>1</sup>

### Observation studies

The two research styles within the class of observation studies represent different levels of asking the question, "What are the current practices (or attitudes)?" One style focuses on the recording of events in instructional settings; the other, sometimes referred to as the "status" study, focuses on how programs of instruction are organized.

The decade from 1960 to 1970 produced a large number of schemes for classroom observation, as part of a wave of interest in the recording of actual teaching and learning behaviors. Observation schemes provide sets of categories related to subject-matter content, instructional techniques, or both; events are recorded in terms of the categories in a scheme. Rosenshine and Furst report that more than four hundred schemes for observation have been developed.<sup>2</sup> Collections of

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<sup>1</sup>For a discussion of studies of science instruction using distinctions similar to those used here, one may consult A. Hugh Munby, "The Provision Made for Selected Intellectual Consequences by Science Teaching: Derivation and Application of an Analytical Scheme."

Two issues of the Review of Education Research (XXXIV [June, 1964] and XXXIX [October, 1969]) were devoted to science education. The classifications of research developed here can be applied to the many studies reported in those issues, which also illustrate other classifications, related more to nature of findings than style of research.

An extensive historical overview of science education research is available in the "Curtis Digests of Investigations in the Teaching of Science," by Francis D. Curtis, with sequels by Robert W. Boenig, J. Nathan Swift, and Elizabeth Phelan Lawlor. Teachers College Press published the sequels (1938 to 1957) in 1969 and 1970, and reprinted the original three digests by Curtis (research up to 1937) in 1971.

<sup>2</sup>Barak Rosenshine and Norma Furst, "Research on Teacher Performance Criteria," in B. O. Smith (ed.), Research on Teacher Education: A Symposium (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1971), p. 56.

observation instruments have been published under the title, Mirrors for Behavior.<sup>1</sup>

Any observation scheme is limited by the theoretical considerations from which its categories were developed, and a single scheme can consider only a small number of potential outcomes or types of behavior. Molchen<sup>2</sup> used Flanders' scheme of "Interaction Analysis"<sup>3</sup> to compare groups of science teacher candidates. Hough and Amidon<sup>4</sup> used the same scheme to permit teacher candidates to obtain feedback about their initial teaching behaviors. In these instances, observation schemes have been used to observe behaviors during teaching practice rather than to observe events in classes in which teacher candidates are enrolled.

The style of the status study has been applied to a wide range of questions about science education, from opinions about the significance of various objectives to descriptions of curriculum organization. Here it is relevant to note that one issue of the Journal of Research in Science Teaching<sup>5</sup> reported descriptions of a number of programs for education of secondary-school science teachers in the United States.

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<sup>1</sup>See Anita Simon and E. Gil Boyer (eds.), Mirrors for Behavior III (Wyncote, Pa.: Communication Materials Center, 1974).

<sup>2</sup>Kenneth J. Molchen, "A Study of Changes in Intentions, Perceptions and Classroom Verbal Behaviors of Science Interns and Apprentices" (unpublished Ed.D. dissertation, Harvard University, 1967).

<sup>3</sup>Flanders' instrument is one of the earliest and most widely known schemes for classroom observation. See Ned A. Flanders, Analyzing Teaching Behavior (Reading, Mass.: Addison-Wesley Publishing Company, Inc., 1970).

<sup>4</sup>John B. Hough and Edmund Amidon, "Behavioral Change in Student Teachers," in Edmund Amidon and John B. Hough (eds.), Interaction Analysis: Theory, Research, and Application (Reading, Mass.: Addison-Wesley Publishing Company, 1967), pp. 307-314.

<sup>5</sup>Journal of Research in Science Teaching, III 2 (1965).

More recently, the Association for the Education of Teachers in Science has collected similar information.<sup>1</sup>

The Research on Science Education Survey,<sup>2</sup> conducted in 1967 and 1968, is a comprehensive status study of characteristics of science teacher education in the United States. Two findings of this survey should be noted for their relevance to the present study. By means of an open-ended question, an effort was made to determine what attributes and qualities of a science teacher are regarded as essential, by those who teach science methods courses and by those who enroll in such courses. While there was considerable agreement between the two groups, there were some differences. The students gave less emphasis to "understanding the nature of science," "command of pedagogical techniques," and "related teaching skills," and more emphasis to "love for science and teaching" and "desirable personality qualities."<sup>3</sup> The teacher candidates appear to attach more significance to attitudes and attributes and less significance to skills and understandings.

Another relevant point concerns the "inquiry teaching style" often associated with the "new" science courses of the 1960's. Almost all methods course instructors expressed enthusiasm for this style, and their students appeared to have recognized the high value their instructors were attaching to inquiry teaching.<sup>4</sup> These results give some indication of how views of science and skills of teaching are regarded by science methods course instructors and science teacher candidates.

#### Achievement studies

Two styles of research belong to the class of achievement studies in the literature of science education. One seeks to establish

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<sup>1</sup>AETS Publications Committee, 1972-73, In Search of Promising Practices in Science Teacher Education (Columbus, Ohio: ERIC Information Analysis Center for Science, Mathematics, and Environmental Education, 1973).

<sup>2</sup>David E. Newton and Fletcher G. Watson, The Research on Science Education Survey (Cambridge, Mass.: Harvard University Graduate School of Education, 1968).

<sup>3</sup>Ibid., pp. v-vi.

<sup>4</sup>Ibid., p. viii.

correlations between classroom characteristics or events and pupil achievement, while the other seeks to determine which of two instructional methods produces more of a desired result.

Smith has edited papers from a symposium on Research in Teacher Education,<sup>1</sup> providing an up-to-date assessment of efforts to correlate teachers' behaviors with pupils' achievements, for the purpose of improving teacher education. The included paper by Rosenshine and Furst<sup>2</sup> gives particular attention to "process-product studies," which seek significant correlations between observed teacher behavior and measured pupil achievement. There is a long list of characteristics of teacher behavior which have resisted efforts to establish relationships with pupil achievement. Rosenshine and Furst report on eleven categories of studies which suggest that variation may produce differences in achievement. The five variables strongly supported by the studies reviewed are "clarity," "variability," "enthusiasm," "task-oriented and/or businesslike behaviors," and "student opportunity to learn criterion material."<sup>3</sup> Rosenshine and Furst make suggestions for improving this type of research, to achieve more definitive results.

Characteristics of the personalities and academic backgrounds of teachers have been studied in similar fashion, again without clear results. A study by Perkes illustrates application of this research style to science teachers.<sup>4</sup> Science teacher behaviors regarded as teacher-oriented correlated positively with factual recall by pupils,

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<sup>1</sup>B. O. Smith (ed.), Research on Teacher Education: A Symposium.

<sup>2</sup>Barak Rosenshine and Norma Furst, "Research on Teacher Performance Criteria," in B. O. Smith (ed.), Research on Teacher Education: A Symposium, pp. 37-72.

<sup>3</sup>Ibid., pp. 42-55.

<sup>4</sup>Victor A. Perkes, "Junior High School Science Teacher Preparation, Teaching Behavior and Student Achievement," Journal of Research in Science Teaching, V (1967-1968), 121-126.

while behaviors regarded as pupil-oriented correlated positively with application and interpretation by pupils. Three characteristics of backgrounds of science teachers showed positive correlation with application and interpretation. Two characteristics correlated positively with pupil-oriented teacher behaviors and one characteristic correlated positively with teacher-oriented behavior.

Like many studies conducted in this style, Perkes' study raises more questions that it answers. A host of potentially relevant variables are measured, and every significant correlation raises the question of how the linkage can be explained so that a general rule can be developed and tested. Until that further stage is reached, the results of such studies are very difficult to apply to the education, hiring, and supervision of science teachers.

A second style in the achievement class attempts to show that one method of instruction, to science students or to science teachers, produces a desired result more quickly or effectively than another method. Studies by George<sup>1</sup> and Menzel<sup>2</sup> are illustrative. In this style, significant differences tend to be elusive. A more substantial problem is ensuring that methods are carried out as planned. If one has that confidence and obtains significant differences between methods, one must address the questions of whether teachers can and will change their teaching behaviors accordingly.

#### An alternative research style

Each of the four styles, whether of the observation or the achievement variety, has significant strengths and limitations, some of

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<sup>1</sup>Kenneth D. George, "The Effect of BSCS and Conventional Biology on Critical Thinking," Journal of Research in Science Teaching, III (1965), 293-299.

<sup>2</sup>Ervin W. Menzel, "A Study of Preservice Elementary Teacher Education in Two Processes of Science" (unpublished Ed.D. dissertation, Temple University, 1968).

which are apparent in the preceding discussion. None of these styles is well suited to the problem being addressed in this study. Here a fifth style of science education research is used, one which has been used in a small number of studies described later in this chapter.

Why is an alternative research style necessary? A research style determines the kinds of results one obtains. Observation studies can be viewed as simply providing data. Achievement studies can be viewed as providing data from which science education theories could be developed, but this ultimate goal has eluded researchers. The present style seeks an intermediate goal of "theoretical perspectives" which can be used to analyze science education phenomena in systematic fashion. The process begins with the identification of important issues related to science education. By philosophical analysis, systematic theoretical perspectives are developed for understanding those issues. Then an analytical scheme is developed, to translate the perspectives into the context of practice. Finally, the analytical scheme is applied to achieve the desired analysis of phenomena.

This style of research recognizes the important role which conceptualization plays in observation, interpretation, and decision-making related to phenomena of education. Where formal disciplines have developed theories, the practical discipline of education has not. Theoretical perspectives on practical issues have some of the advantages of theory, yet they can be made relevant to practice. Research of this type provides results which are not limited to the problem for which they were developed. The results represent a conceptual basis for empirical research and a new point of view of potential value in the conduct of education.

The study by Sarason, Davidson, and Blatt<sup>1</sup> may be interpreted as an example of research in this style, although it is outside the field of science education. Sarason and his colleagues were concerned with teachers as practitioners of educational psychology. The theoretical

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<sup>1</sup>Sarason, Davidson, and Blatt, The Preparation of Teachers. See pages 26-28 of this study.

perspective which they develop uses psychological rather than philosophical analysis. They identify three roles which, on psychological grounds, teachers may be expected to perform in bringing about productive learning; the distinguishing features of these roles may be regarded as their analytical scheme. In the account of a classroom day, they demonstrate that their scheme can be applied to teachers' classroom behaviors. In the report of the observational seminar, they show the power of the scheme to suggest alternative teacher education practices. The investigators note that they have provided a basis for empirical research related to the actual achievement of productive learning by pupils.

It should be understood that this style of research is not an entirely new one, but that it represents an alternative to familiar styles of research in science education. The description of familiar styles helps to explain why an alternative format has been chosen, to begin an inquiry into the question of how science teacher education influences views of science and teaching. To simply observe science teacher education, or to study changes in views of science and teaching, would leave one uncertain about how one's program achieved whatever influence it had. Theoretical perspectives can make a link between program and change, at the level of provision made for influence. The derived analytical scheme can guide program planning and observation. A basis is established for subsequent empirical research on actual changes.

#### Recent Research Developing Theoretical Perspectives on Science Education Phenomena

Consideration has been given to rationales and programs of science instruction and teacher education and to styles of research into issues and problems associated with those programs. The present study has been identified as one which develops theoretical perspectives on the nature of science and the concept of teaching, and constructs a scheme for analyzing the content and structure of arguments made in science teacher education programs. The research problem and format

are consistent with a perspective on teacher education which recognizes the existence and significance of a teacher's "model of teaching," of which views of science and teaching are basic elements.

It is the purpose of this final section of the chapter to complete the analysis of the study's background and context by reviewing recent research in the style of developing theoretical perspectives relevant to practices of science education. Seven studies have been selected for examination; five yield analytical schemes applicable to science instruction, while the remaining two yield schemes applicable to science textbooks.

#### Studies related to science instruction

Two of the studies which focus on science instruction were conducted by Munby. In the first,<sup>1</sup> he develops and applies an analytical scheme based on Scheffler's analysis of three "philosophical models of teaching."<sup>2</sup> The study serves to make Scheffler's analysis specifically relevant to the teaching of science and to indicate how one may move from the theoretical level of Scheffler's models to the practical level of particular teaching acts. In his second study,<sup>3</sup> Munby develops and applies an analytical scheme based on theoretical perspectives on the nature of science and the establishment of scientific knowledge claims. He shows that it is possible to detect whether science instruction makes provision for pupils to develop a "realist" or an "instrumentalist" view

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<sup>1</sup>A. Hugh Munby, "The Use of Three Philosophical Models of Teaching to Analyze Selected Science Lessons" (unpublished M.A. thesis, University of Toronto, 1969).

<sup>2</sup>Israel Scheffler, "Philosophical Models of Teaching," Harvard Educational Review, XXXV (Spring, 1965), 131-143. This paper is discussed in Chapter IV, in the development of theoretical perspectives on the concept of teaching.

<sup>3</sup>A. Hugh Munby, "The Provision Made for Selected Intellectual Consequences by Science Teaching: Derivation and Application of an Analytical Scheme."

of the nature of science and whether that instruction makes provision for pupils' "intellectual independence" or "intellectual dependence" with respect to knowledge claims. The study makes it possible to analyze science instruction for these two important potential consequences for pupils studying science. Munby's analytical scheme has been formulated as a scheme of observation, and is included in Mirrors for Behavior III.<sup>1</sup>

The remaining three studies developing analytical schemes relevant to science instruction were conducted by Prusso, Finegold, and the present investigator. In a study of epistemological features of science teaching,<sup>2</sup> Prusso derives an analytical scheme with three epistemological dimensions and five categories of scientific statements. He then demonstrates that the scheme can be used to assess the discussion of knowledge claims by teacher and pupils in science lessons. The result is that the theoretical perspectives used to construct the analytical scheme may be brought to bear on the teaching of science.

Finegold has conducted an elaborate investigation of a specific kind of science instruction,<sup>3</sup> referred to as "enquiry into enquiry" because its goal is the recovery of meaning from original reports of scientific research. The main result of Finegold's study is an analytical scheme which can be used to describe and evaluate the success of enquiry discussion. Among the theoretical perspectives used in the study is that of Schwab on the nature of scientific enquiry.<sup>4</sup> Finegold's

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<sup>1</sup>A. Hugh Munby, "Munby System," in Anita Simon and E. Gil Boyer (eds.), Mirrors for Behavior III, pp. 441-452.

<sup>2</sup>Kenneth W. Prusso, "The Development of a Scheme for Analyzing and Describing the Epistemological Criteria Adhered to in Secondary School Natural Science Classroom Communication" (unpublished Ed.D. dissertation, Temple University, 1972).

<sup>3</sup>Menahem Finegold, "The Character of Classroom Discussion of Original Research Reports as a Mode of Instruction in Physics" (unpublished Ph.D. dissertation, University of Toronto, 1974).

<sup>4</sup>J. J. Schwab, "What Do Scientists Do?" Behavioral Science, V (January, 1960), 1-27.

study demonstrates the application of the analytical scheme to transcriptions of the particular type of science instruction for which it is designed.

The present investigator has conducted a study of the attitude toward authority which may be suggested by a science teacher's conduct of an argument.<sup>1</sup> Theoretical perspectives of Peters (on authority in education)<sup>2</sup> and Toulmin (on the pattern of arguments)<sup>3</sup> are used to develop a scheme for analyzing arguments involving the acceptance or application of a scientific law. It is demonstrated that the scheme may be used to determine whether an argument could suggest to pupils a traditional or a rational attitude toward authority.

#### Studies related to science teaching materials

Two studies by Kilbourn have produced analytical schemes relevant to science teaching materials. In the first,<sup>4</sup> epistemological perspectives are used to formulate a scheme for studying the scientific knowledge claims presented to pupils in textbooks. Application of the scheme to part of one science textbook shows that the scheme is workable and sheds light on the difficulties students experience in reading textbooks.

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<sup>1</sup>Thomas L. Russell, "Toward Understanding the Use of Argument and Authority in Science Teaching," Background Paper No. 7 for the Explanatory Modes Project (Toronto: The Ontario Institute for Studies in Education, Department of Curriculum, 1973).

<sup>2</sup>R. S. Peters, Ethics and Education (London: George Allen & Unwin Ltd., 1966), pp. 237-265. This perspective is discussed in Chapter IV.

<sup>3</sup>Stephen Toulmin, The Uses of Argument (Cambridge: Cambridge University Press, 1958), pp. 94-145. This perspective is discussed in Chapter V.

<sup>4</sup>Brent Kilbourn, "Analyzing the Basis for Knowledge Claims in Science Textbooks: A Method and a Case Study," Background Paper No. 6 for the Explanatory Modes Project (Toronto: The Ontario Institute for Studies in Education, Department of Curriculum, 1971).

In his second study,<sup>1</sup> Kilbourn uses the idea of world view to address the science educator's understandable concerns with various "anti-science" movements. From Pepper's theoretical perspective based on the concept "world hypotheses,"<sup>2</sup> he derives an analytical scheme for recognizing messages about world views which teaching materials project to pupils. Kilbourn demonstrates the applicability of his scheme by analyzing a biology textbook.

### Summary

In each of the seven studies, questions of science education practice are addressed by borrowing and/or developing relevant theoretical perspectives for the purpose of creating and applying to practice an analytical scheme.<sup>3</sup> Epistemology and various aspects of the nature of science are the dominant concerns. Each analytical scheme makes it possible to analyze science instruction or science teaching materials in terms of significant learner outcomes. As many of the investigators have noted in their studies, the schemes also have significant implications for science teacher education. Each scheme provides a basis for the development of particular aspects of a science teacher's "model" of teaching.

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<sup>1</sup>Brent Kilbourn, "Identifying World Views Projected by Science Teaching Materials: A Case Study Using Pepper's World Hypotheses to Analyze a Biology Textbook" (unpublished Ph.D. dissertation, University of Toronto, 1974).

<sup>2</sup>Stephen C. Pepper, World Hypotheses: A Study in Evidence (Berkeley: University of California Press, 1942).

<sup>3</sup>The descriptions of the studies are intentionally brief. More complete descriptions of most of these studies are available in a recent paper which describes this research style within the context of debates about how science education research should be conducted. See Douglas A. Roberts and Thomas L. Russell, "An Alternative Approach to Science Education Research: Drawing from Philosophical Analysis to Examine Practice," Curriculum Theory Network, V, 2 (1975), 107-125.

The present study may be viewed as a direct extension of this type of science education research to specific aspects of science teacher education. The study assembles additional theoretical perspectives on the nature of science and the concept of teaching, in order to develop an analytical scheme directly applicable to science teacher education programs. Application of the scheme to excerpts from science methods textbooks demonstrates how the theoretical perspectives may be brought to bear on one aspect of science teacher education practice. Thus the study continues a productive line of research and extends its application within the domain of science education.

## CHAPTER III

### ANALYSIS OF THREE PERSPECTIVES

#### ON THE NATURE OF SCIENCE

##### Introduction

This chapter and the next present, in two stages, the development of an analytical scheme for arguments about how and why science should be taught to children. Dimensions relevant to the nature of science are developed in this chapter; those relevant to the concept of teaching are developed in Chapter IV. The present chapter describes and analyzes three interpretations of science developed by Rudolf Carnap, Karl Popper, and Thomas Kuhn. This introduction explains how the interpretations were selected and how they are to be analyzed.

##### Selection of interpretations of science

The nature of science can be explored in a number of ways, and several alternatives have been considered in planning the argument which follows. Although philosophy of science has a relatively short history as a distinct branch of philosophy, concepts and issues treated by philosophers of science have a long and detailed history extending back at least as far as the writings of Plato and Aristotle. For present purposes, it is not necessary to survey that entire history.

Some analyses of science examine a selection of current issues and positions in the course of arguing for the acceptance of one particular position as an adequate basis for understanding science.<sup>1</sup>

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<sup>1</sup>Two examples are Stephen Toulmin, The Philosophy of Science: An Introduction (New York: Harper & Row, 1960) and R. Harré, The Philosophies of Science: An Introductory Survey (London: Oxford University Press, 1972).

From personal experiences of examining the nature of science and from experiences of working with teachers who were studying the nature of science, the investigator has developed a preference for original interpretations of science. These provide first-hand evidence and, in the long run, they seem to produce less "philosophical confusion" among individuals who have not had extensive training in philosophy.

Significant developments in the early history of modern science are associated with the names of Copernicus, Galileo, and Newton. The work of Newton in particular came to dominate western thought to the extent that we now speak of the surviving influences of the "Newtonian worldview." E. A. Burt, who has traced in detail the development of the metaphysical assumptions of that worldview, gives the following assessment of its central issues.

We have observed that the heart of the new scientific metaphysics is to be found in the ascription of ultimate reality and causal efficacy to the world of mathematics, which world is identified with the realm of material bodies moving in space and time. Expressed somewhat more fully, three essential points are to be distinguished in the transformation which issued in the victory of this metaphysical view; there is a change in the prevailing conception (1) of reality, (2) of causality, and (3) of the human mind.<sup>1</sup>

At the turn of the century several new developments, primarily associated with logic and with physics, generated effective challenges to the view of science derived from the then-unquestioned Newtonian perspective. One of the most famous and fundamental challenges was begun by Einstein in his 1905 paper which presented the special theory of relativity.<sup>2</sup> New accounts of the nature of science have been developed in the wake of those challenges. Among the most significant are the three accounts of science which have been selected for examination in

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<sup>1</sup>Edwin A. Burt, The Metaphysical Foundations of Modern Science (Garden City, N.Y.: Doubleday & Company, Inc., 1954), p. 303.

<sup>2</sup>Albert Einstein, "On the Electrodynamics of Moving Bodies," in H. A. Lorentz et al., The Principle of Relativity (New York: Dover Publications, Inc., 1923), pp. 37-71.

this study. These are Carnap's The Logical Structure of the World,<sup>1</sup> Popper's The Logic of Scientific Discovery,<sup>2</sup> and Kuhn's The Structure of Scientific Revolutions.<sup>3</sup> Consideration of three accounts provides some assurance of breadth while emphasizing that the interpretation of science is not limited either to perfecting one account or to determining which of two alternatives is correct.

The concept of a "categorical framework" as a basis for analysis

Stephan Körner's concept of a "categorical framework"<sup>4</sup> has been selected as a common basis for analysis of the three accounts of science. The need for such a perspective to facilitate systematic comparison of the accounts is illustrated by an issue from the analysis which follows. To the question of how science may be demarcated from non-science, Carnap replies that scientific statements are verifiable, while Popper argues that scientific statements are falsifiable. Kuhn's answer is that scientists engage in solving puzzles which are identified in terms of the disciplinary matrix shared by a community of scientists. Each of these assertions belongs to an internally consistent account of the nature of science, yet they are obviously different.

"Which of these replies is true?" is a fruitless, if not absurd, question. Yet the differences are clear, and they invite and demand further analysis. The investigator has considered constructing an original scheme for comparing the accounts, but has selected Körner's concept for its generality and its appropriateness to analysis of

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<sup>1</sup>Rudolf Carnap, The Logical Structure of the World & Pseudoproblems in Philosophy, trans. by Rolf A. George (Berkeley: University of California Press, 1969).

<sup>2</sup>Karl R. Popper, The Logic of Scientific Discovery (2nd Harper Torchbook edition; New York: Harper & Row, Publishers, 1968).

<sup>3</sup>Thomas S. Kuhn, The Structure of Scientific Revolutions (2nd ed., enlarged; Chicago: The University of Chicago Press, 1970).

<sup>4</sup>Stephan Körner, Categorical Frameworks (Oxford: Basil Blackwell, 1970).

philosophical and metaphysical arguments. In particular, analysis in terms of categorial frameworks can deal with the fact that statements which seem unquestionable in one context become vulnerable to many forms of criticism in other contexts. In his very systematic analysis, Körner uses the terms "in corrigible" and "corrigible" to refer to this difference. Part of Körner's rationale for developing the "categorial framework" concept is indicated in the following statement.

Because of a natural inclination to elevate the peculiarities of one's own thinking into universal characteristics of all rational thought, philosophers tend to regard categorial frameworks as only apparently different and as reducible to a common standard type. If we are to avoid the distortions resulting from this point of view we must try to understand the sense in which, and the extent to which, *the propositions and distinctions which are characteristic of a categorial framework are incorrigible if viewed from the inside and corrigible if viewed from the outside of it.*<sup>1</sup>

Körner's concept of a categorial framework serves to make explicit the existential and logical assumptions which an individual is likely to regard as unquestionable. It is used for that purpose in the following presentations of accounts of science developed by Carnap, Popper, and Kuhn. Accordingly, the first section of the chapter presents a summary of the argument in Körner's book, Categorial Frameworks.

#### Körner's Concept of a Categorial Framework

##### Overview of the argument

Körner's argument develops and demonstrates the thesis that an individual's categorization of experience has significant relationships to his metaphysical beliefs and his explanatory standards. The opening lines of the preface speak clearly to this point.

The manner in which a person classifies the objects of his experience into highest classes or categories, the standards of intelligibility which he applies, and the metaphysical beliefs which he holds are intimately related. To give an obvious example, the employment of the category of causally determined events, the demand that all or some explanations be causal, and the belief that nature is at least partly a deterministic system so involve each other that they are either all present in a person's thinking or else all absent

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<sup>1</sup>Ibid., p. 14. Italics added.

from it. Groups of persons, societies, and whole civilizations exhibit, in so far as they can be said to think, a similar correlation between their categories, standards of intelligibility and metaphysical beliefs.<sup>1</sup>

It is necessary to follow Körner's text closely because a number of specialized terms are introduced, based on considerations familiar to students of philosophy. In this overview of the argument, some of the terms are introduced and discussed very briefly. Further details are provided in the discussion of each step in the argument.

Körner begins by explaining the basic elements of a categorial framework:

1. "Highest categories" (or "maximal kinds") of objects of experience. Familiar examples from philosophy are "minds," "bodies," and "physical events."

2. "Constitutive" and "individuating" principles associated with the highest categories (maximal kinds). These principles serve to make a classification explicit by indicating critical attributes of particulars of a maximal kind. For example, Newton's principle of inertia expresses a "constitutive" attribute of particulars of the maximal kind, "material objects." "Being a material object logically implies being capable of moving . . . with uniform speed in a straight line."<sup>2</sup>

3. The underlying logic of an individual's thinking, according to which the logical validity of propositions is determined. "Classical" logic is the most familiar, but other logics are possible.

Körner's second step is consideration of differences between perspectives "internal" and "external" to a categorial framework. He argues that the "constitutive" and "individuating" principles of a framework are internally but not externally "incorrigible."

The final step in the argument establishes the "intimate relationship" mentioned in the opening sentence of the preface, quoted above. Körner argues that the "constitutive" and "individuating" principles of a categorial framework are *metaphysical* principles, which also

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<sup>1</sup>Körner, Categorial Frameworks, p. ix.

<sup>2</sup>Ibid., p. 67.

function as standards of intelligibility, or explanation, for the individual holding the framework. Then, reflecting back on his argument, Körner considers the important topic of categorial change, and discusses the influence of philosophical argument on such change.<sup>1</sup>

#### The concept of a categorial framework

Körner specifies precisely the elements included in a "categorial framework." Each of the three elements requires separate discussion.

To indicate a thinker's categorial framework is to make explicit (i) his categorization of objects, (ii) the constitutive and individuating principles associated with the maximal kinds of his categorization, (iii) the logic underlying his thinking.<sup>2</sup>

#### Categorization of objects

The term "categorization" is used in the special sense of the "higher levels of a total classification," set out in a series of partitions which acknowledge or reject two distinctions. The first is between particulars and attributes: particulars are "logically ultimate" objects which have, but are not themselves, characteristics. The second distinction is between independent and dependent particulars or attributes: independent objects are "ontologically fundamental," existing "apart from and independently of other objects."<sup>3</sup>

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<sup>1</sup>In working one's way into Körner's terminology and through his argument, it may be helpful to recall the context developed by the discussion of new perspectives on teacher education, in Chapter II. There are significant parallels between "model of teaching" and "categorial framework," although it is not possible to explore the parallels in this study. The broad intuitive notion of a "model of teaching," sketched by Belanger and Cogan, may correspond directly to Körner's carefully developed concept of a "categorial framework." Sarason and his colleagues focused on the selective nature of observation and interpretation, and this selectivity might be analyzed in terms of the statements an individual regards as "internally incorrigible." Also, Scheffler's conclusion about the value of philosophical perspectives on the subject one teaches seems to correspond to Körner's point that philosophical argument contributes to the clarification of categorial frameworks.

<sup>2</sup>Körner, Categorial Frameworks, p. 10.

<sup>3</sup>Ibid., pp. 2-6.

Körner mentions the example of a categorization of objects which takes "minds" and "bodies" as particulars. Both may be regarded as independent particulars, either may be regarded as independent and the other as dependent, or both may be taken to be dependent particulars (with some other particular[s] taken to be independent).<sup>1</sup>

Logically, these two distinctions can generate four classes, although "empty" classes are possible in a categorization of objects. Any of the classes may or may not be partitioned into two or more "maximal classes," or "maximal kinds."<sup>2</sup> Körner's primary interest is in the various possible maximal kinds of particulars; whether they are independent or dependent particulars is a secondary interest.<sup>3</sup>

#### Constitutive and individuating principles

In the following passage, Körner distinguishes between constitutive and individuating attributes of maximal kinds of particulars. He also indicates that they function to make explicit the principles by which a person makes categorizations.

Frequently, . . . , these instinctive classifications and identifications can be made more explicit, especially by indicating (a) attributes which characterize a particular as a member of a maximal kind and (b) attributes which characterize a particular which is a member of a maximal kind as a distinct, individual member of it. In accordance with traditional usage--or at least without grossly violating it--the former attributes will be called 'constitutive' and the latter 'individuating'.<sup>4</sup>

For example, the proposition that dogs have immortal souls<sup>5</sup> implies that having an immortal soul is a constitutive attribute of the maximal kind, "animals." For the maximal kind, "physical objects," location in space and time would be an individuating attribute. A constitutive or individuating principle is a proposition the assertion

<sup>1</sup>Ibid., p. 5.

<sup>2</sup>Ibid., p. 4.

<sup>3</sup>Ibid., pp. 5-6.

<sup>4</sup>Ibid., p. 7.

<sup>5</sup>The examples are Körner's.

of which asserts that a certain attribute is either constitutive or individuating for the particulars of a maximal kind.<sup>1</sup>

#### Underlying logic

Finally, the underlying logic of a categorial framework is that logic with respect to which the logical validity of propositions is determined, including the logical implications applied in a categorization of objects into maximal kinds. Just as there are many actual and possible categorizations and associated categorial principles, so there are many possible logics. Classical logic is the most familiar. "Constructive" logic admits propositions whose truth-value (true or false) is indefinite. Körner also discusses "extensions" of these logics to admit inexact as well as exact attributes.<sup>2</sup> Körner formally examines these logics in his appendix, "Some logical systems."<sup>3</sup>

Before examining arguments in which the "categorial framework" concept is put to use, it should be noted that Körner makes explicit an important point: "To employ a categorial framework" does not mean ". . . to be explicitly and continually aware of the distinctions and assumptions to which the term 'categorial framework' refers."<sup>4</sup> The distinctions may not be as definite as his definitions suggest, they may be changed, and it may even be possible to think without using a categorial framework.<sup>5</sup>

#### Categorial frameworks and incorrigibility

As mentioned earlier, "incorrigibility" is an important issue for Körner. Strictly speaking, a proposition is "incorrigible" with respect to a categorial framework *if rejection of the proposition constitutes abandonment of the framework*. "Internal" incorrigibility, or incorrigibility with respect to *one particular* categorial framework, may be

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<sup>1</sup>Körner, Categorial Frameworks, p. 7.

<sup>2</sup>Ibid., pp. 8-10.

<sup>3</sup>Ibid., pp. 75-81.

<sup>4</sup>Ibid., p. 12.

<sup>5</sup>Ibid., pp. 12-13.

distinguished from "external" incorrigibility, or incorrigibility with respect to *any actual or possible* framework. The distinction is of fundamental importance for Körner, who argues consistently that internal incorrigibility does not imply external incorrigibility.<sup>1</sup>

Körner uses the "dogs have immortal souls" example to illustrate the distinction. If the propositions characterizing a categorial framework ("incorrigibly existential" and "incorrigibly logical" propositions, as defined below) logically imply that dogs have immortal souls, then that framework includes a maximal kind "animals" with a constitutive attribute "having an immortal soul." The external *corrigibility* of the internally incorrigible proposition "Dogs have immortal souls" is demonstrated by presenting another categorial framework whose characterizing propositions do not imply that dogs have immortal souls. The divergence between the two frameworks may involve their categorization of objects (and associated constitutive and individuating principles), their underlying logics, or both.<sup>2</sup>

One important reason for demonstrating that internal incorrigibility does not imply external incorrigibility is that existential and logical assumptions are so often regarded as unquestionable. Körner applies the incorrigibility distinction to existential and logical propositions, to the classification of particulars as independent or dependent, and to the classification of logical systems as primary or secondary.

Körner gives complex definitions of incorrigibly existential and logical propositions. An existential proposition, implying the existence of one or more particulars, is *existential with respect to a categorial framework* (F) if it is ". . . consistent with the proposition that no maximal kind of F is empty and that every particular belongs to one of them."<sup>3</sup> That proposition expresses the "*basic existential thesis*" of the framework. An existential proposition is incorrigibly existential if it is logically implied by the basic existential thesis of the framework.<sup>4</sup>

<sup>1</sup>Ibid., pp. 14-16.

<sup>2</sup>Ibid.

<sup>3</sup>Ibid., pp. 12-13.

<sup>4</sup>Ibid., p. 17.

Of the logical propositions which are incorrigible with respect to a categorial framework (F), Körner gives the following account.

If S is the logic underlying F then the logical propositions which are incorrigible with respect to F are (i) the logical principles of S which characterize the logically valid propositions of S in terms of propositional forms and their substitution instances; and (ii) the logically valid propositions themselves.<sup>1</sup>

After demonstrating that internally incorrigible existential or logical propositions are not externally incorrigible, Körner acknowledges a debt to terminology developed by Kant.

The notions of internally incorrigible, internally incorrigible existential and internally incorrigible logical propositions are to some extent relativized versions of Kant's *a priori*, *a priori* synthetic, and *a priori* analytic propositions.<sup>2</sup>

Körner explains that every constitutive or individuating principle of a categorial framework is an internally incorrigible existential proposition, because every such principle is a conjunction of an internally incorrigible existential proposition and an internally incorrigible logical proposition.<sup>3</sup>

To complete his discussion, Körner cautions against confusing internal incorrigibility with truth. Incorrigibility is defined with respect to the conjunction of propositions which describe a framework, but ". . . the truth of at least some propositions depends on their relation to non-propositional entities."<sup>4</sup> An internally incorrigible proposition can be false, true, neither verifiable nor falsifiable, or even lacking in truth value if the primary logic is "constructive."<sup>5</sup> "Most, if not all, propositions which are regarded as 'metaphysical' are internally incorrigible, unverifiable and [un]falsifiable propositions."<sup>6</sup>

#### Four significant types of thinking

Körner continues his explication of the concept of a categorial framework by showing how different types of thinking influence the structure of categorial frameworks. Körner's main points are simply noted, for they do not bear directly on the present study.

<sup>1</sup>Ibid., p. 18.

<sup>2</sup>Ibid., p. 19.

<sup>3</sup>Ibid.

<sup>4</sup>Ibid., P. 24.

<sup>5</sup>Ibid.

<sup>6</sup>Ibid., p. 25.

Körner's first distinction is between "constructive" thinking, associated with an underlying intuitionist logic, and "factual" thinking, associated with an underlying classical logic. "Practical" thinking is examined as a particularly interesting type of constructive thinking.<sup>1</sup> Körner's second distinction is between "commonsense" and "scientific" thinking; the distinction is applicable to both factual and constructive thinking. Inexactness of attributes and indefiniteness of propositions are characteristics of commonsense thinking which are excluded from scientific thinking based on classical logic.<sup>2</sup> From Körner's perspective emphasizing external corrigibility, it is more worthwhile to understand the relationships between different types of logic than to try to decide which type is ontologically primary. As with decisions about the ontological primacy of different object types, ". . . , the proper logico-epistemological attitude is again one of tolerant impartiality."<sup>3</sup>

Metaphysical principles and explanatory standards

To begin to bring his argument to a close, Körner turns his attention from differences within frameworks to differences between frameworks. Körner first considers how divergent interpretations and divergent idealizations can generate differences between categorial frameworks, including frameworks arising from the same set of particulars and attributes. Divergent interpretations result from different ways of adding non-descriptive elements to a description, as in the interpretation that a sequence of situations is causal. Divergent idealizations result from different ways of modifying a description, as in moving from statements about a perceptual triangle to ones about a Euclidean triangle.<sup>4</sup>

The basic sources of divergence are the different ways of including non-perceptual content in interpretative and idealizing attributes. Three types of interpretative attributes seem to be particularly significant.

In a more detailed study of interpretative attributes the following three types would deserve special attention as characteristic of

<sup>1</sup>Ibid., pp. 26-38.    <sup>2</sup>Ibid., pp. 39-50.    <sup>3</sup>Ibid., p. 49.

<sup>4</sup>Ibid., p. 55. The examples are Körner's.

most--possibly all--categorial frameworks so far employed. These are attributes which, roughly speaking, serve the transformation of a plurality of particulars into a unified particular of a new kind; attributes which serve the transformation of private particulars into public particulars; and attributes which serve the transformation of transient into permanent particulars.<sup>1</sup>

It is Körner's view that divergent interpretations, divergent idealizations, and alternative categorizations are the most important factors in accounting for the variety of categorial frameworks, actual and possible.<sup>2</sup>

Körner links categorial frameworks with metaphysics by suggesting that principles of categorial frameworks are part of the class of metaphysical principles. He points out that most metaphysicians and epistemologists ". . . have been chiefly interested in constitutive and individuating attributes which are non-perceptual or contain non-perceptual ingredients and in the framework-principles corresponding to such attributes."<sup>3</sup>

Whatever else it may be, metaphysics aims at the exhibition of implicitly accepted categorial frameworks, at their critical examination and, sometimes, also at their modification.<sup>4</sup>

Körner reports that four common characteristics of metaphysical principles are those of being non-empirical, not logically true, comprehensive in applicability and ". . . 'prior to experience' in the sense of *somehow* determining the structure of experience, rather than being determined by it."<sup>5</sup>

Admitting the vagueness of these conditions, especially of the last, we must, I think, also admit that if they are satisfied at all, they are satisfied by framework-principles.<sup>6</sup>

To complete the development of his central thesis, Körner argues that there is a relationship between an individual's categorial framework (F) and his standards of explanation. A proposition is regarded as

<sup>1</sup>Ibid., pp. 53-54.

<sup>2</sup>Ibid., p. 58.

<sup>3</sup>Ibid.

<sup>4</sup>Ibid., p. 59.

<sup>5</sup>Ibid.

<sup>6</sup>Ibid.

explanatory of something for someone if failure to believe the proposition would render that something unintelligible for that person. A person's standards of explanation will include many criteria, and among them will be compatibility with the internally incorrigible principles of his categorial framework.<sup>1</sup>

In so far as the compatibility of any proposition *g* with the internally incorrigible principles of *F* is a necessary condition of the proposition's explaining anything, these principles represent for the person who employs *F* not only metaphysical beliefs, but also standards of intelligibility.<sup>2</sup>

Categorial change and the  
influence of philosophical argument

Körner concludes his discussion of categorial frameworks with an exploration of the topic of categorial change. He first distinguishes the informative from the explanatory function of a categorial framework, arguing that ". . . , explanation is framework-bound whereas information is not."<sup>3</sup> Ignoring this characteristic can lead to two different errors which may confuse the topic of categorial change. Inferring from the fact that explanation is framework-bound that information is also framework-bound ". . . tends to support an anthropologism which exaggerates cultural relativity to a point where any understanding of the users of one categorial framework by those of another is completely ruled out."<sup>4</sup> Inferring from the fact that information is not framework-bound that explanation is not framework-bound ". . . tends to support a scientism which equates increase of information with improvement of explanation . . . ." <sup>5</sup> On this view, quantity of information could [erroneously] be identified with quality of explanation.

To Körner, the experience of categorial change may be comparable to the perceptual change of a Gestalt switch or to the change of attitude from approval to disapproval, but a change of belief is also involved.

<sup>1</sup>Ibid., pp. 61-62.

<sup>2</sup>Ibid., p. 62.

<sup>3</sup>Ibid., p.64.

<sup>4</sup>Ibid., p. 65.

<sup>5</sup>Ibid.

Yet a categorial change is not, or not only, a change in perception or evaluative attitude. It results in modifying a prior categorization, its associated constitutive or individuating principles or its underlying logic, and is therefore also a change of belief--from belief in one set of propositions to belief in another.<sup>1</sup>

Three examples of changes in constitutive principles are illustrative of features of categorial change. Körner discusses the challenges posed to existing frameworks by the introduction of Darwin's concept of species, Newton's concept of inertia, and the quantum-mechanical concept of an event. Such challenges may be resolved by rejecting the new thesis, granting it the status of a heuristic principle, or accepting it, with corresponding consequences for the status of the original maximal kind.<sup>2</sup>

Philosophical arguments may be employed in attempts to preserve, change, or reject an accepted categorial framework. Regardless of the outcome of such arguments, they also serve ". . . to clarify the structure of the categorial frameworks whose choice, change, or preservation is at issue, or to present new thought-possibilities previously not available or not recognized."<sup>3</sup>

Körner characterizes several types of methods of philosophical argument and notes the usual effect of each on categorial frameworks. He declines the task of identifying all the varieties of philosophical argument and showing that each is incapable of establishing the truth of one categorial framework. Instead he notes that such arguments for uniqueness involve either the circularity of using a given framework to establish criteria for the uniqueness of that same framework, or the impossible task of examining ". . . a potentially infinite set of categorial frameworks, some of which are not even known."<sup>4</sup> Yet Körner has recognized that all types of philosophical argument may contribute to clarification, and to the creation and recognition of new possibilities. Accordingly, he closes his argument by extending his posture of

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<sup>1</sup> Ibid.

<sup>2</sup> Ibid., pp. 66-68.

<sup>3</sup> Ibid., p. 69.

<sup>4</sup> Ibid., pp. 70-73.

tolerance to ". . . metaphysical thought-experiments by metaphysicians . . ." <sup>1</sup> He hopes that these will be encouraged for their potential contribution to the continuing creation of new categorial frameworks.

### Summary

As developed by Körner, the concept of a categorial framework includes a categorization of objects of experience, associated constitutive and individuating principles, and an underlying logic. Körner argues that there are close and important relationships among an individual's categorial framework, his metaphysical beliefs, and his explanatory standards. Specifically, he argues that the principles (constitutive, individuating, and logical) of a categorial framework are metaphysical principles which also function as standards of intelligibility.

In the remainder of this chapter, three different interpretations of the nature of science are described. Carnap, Popper, and Kuhn have developed coherent, internally consistent positions which permit different solutions to various metaphysical problems. For each of the three accounts, the following general format is followed. First, the basic features of the position are described in detail sufficient to permit an outline of the implicit categorial framework. Then the solutions to metaphysical problems are outlined. This format permits each analysis to illustrate to some extent the relationships between the categorial framework and the associated metaphysical beliefs.

## Carnap's Analysis of Science

### Introduction

In The Logical Structure of the World, Carnap applies achievements in logic and mathematics to scientific analysis in a manner intended to eliminate metaphysical issues from the domain of science. Carnap argues that all the "objects" of science can be "constructed" from a small number

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<sup>1</sup>Ibid., p. 74.

of "basic objects." The latter are derived from "the individual stream of experience," which is taken as given and for which neither reality nor nonreality is claimed.<sup>1</sup>

Carnap is concerned with the justification of statements in science, not with their discovery or development. Accordingly, his argument bears primarily upon epistemological features of science. In the preface of his work, Carnap identifies some general features of his point of view. The method provided by developments in logic and mathematics is said to make it possible to develop ". . . a uniform reductional system of the concepts which occur in science,"<sup>2</sup> and thus to answer the question of how cognitions may be reduced to one another. Carnap declares that every thesis of science requires ". . . a purely empirical-rational justification."<sup>3</sup> He speaks of the goal he shared with others in the group now referred to as the Vienna Circle as a ". . . call for clarity, for a science that is free from metaphysics, . . ."<sup>4</sup> While emotion and intuition may be involved in handling problems and discovering solutions, the justification of statements must be purely intellectual.

The opening chapters describe the objective and the plan of the study. The opening paragraphs of the study are particularly indicative of Carnap's goal.

The present investigations aim to establish a "constructional system", that is, an epistemic-logical system of objects or concepts. The word "object" is here always used in its widest sense, namely, for anything about which a statement can be made. Thus, among objects we count not only things, but also properties and classes, relations in extension and intension, states and events, what is actual as well as what is not.

Unlike other conceptual systems, a constructional system undertakes more than the division of concepts into various kinds and the investigation of the differences and mutual relations between these kinds. In addition, it attempts a step-by-step derivation or "construction" of all concepts from certain fundamental concepts, so

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<sup>1</sup>Carnap, The Logical Structure of the World, pp. 101-107.

<sup>2</sup>Ibid., p. xvi.

<sup>3</sup>Ibid., p. xvii.

<sup>4</sup>Ibid.

that a genealogy of concepts results in which each one has its definite place. It is the main thesis of construction theory that all concepts can in this way be derived from a few fundamental concepts, and it is in this respect that it differs from most other ontologies.<sup>1</sup>

Carnap refers to his study as ". . . an attempt to apply the theory of relations to the task of analyzing reality."<sup>2</sup> Methodologically, he sees himself bringing together two rather independent branches of science--symbolic logic and the reduction of reality to the given--which are both required for further scientific progress.<sup>3</sup> With a view to eliminating metaphysical issues from science, Carnap points out that the language of construction theory is regarded as completely neutral. He sees no logical difference between "concept" and "object," only a psychological difference. His theory is to be neutral with respect to the controversy between idealism and realism, between objects created by thought and objects apprehended by thought.<sup>4</sup>

Carnap develops his argument with care, attempting to identify and explain each move required for progress toward his objective of a constructional system of concepts or objects. His argument is summarized here by examining in detail three topics which are dominant and fundamental: (1) the thesis that scientific statements are transformable to structure statements, by the method of purely structural definite descriptions, (2) the thesis that a new constructional level is reached by giving a "definition in use" to define the extension of a propositional function, and (3) the thesis that a constructional system requires only a small number of basic relations taken as undefined basic objects. Each of these topics is examined in turn.

#### The nature of scientific statements

Carnap's discussion of the nature of scientific statements indicates a fundamental aspect of his approach. The thesis which he maintains, and

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<sup>1</sup>Ibid., p. 5.

<sup>3</sup>Ibid.

<sup>2</sup>Ibid., p. 7.

<sup>4</sup>Ibid., p. 10.

is seeking to establish, is ". . . that *science deals only with the description of structural properties of objects.*"<sup>1</sup> The goal thus set for all scientific statements is to indicate formal (structural) properties only, to the exclusion of individual (material) properties. This requirement is made to insure the objectivity of science by removing the subjectivity of any reference to material. It is recognized that empirical science uses material entities initially, with an ultimate goal of purely structural definite descriptions.<sup>2</sup>

The concept of a structure begins with the distinction between a property description and a relation description. The former indicates properties of individual objects; the latter indicates relations between objects, making no assertion about the objects as individuals. A relation description which specifies neither properties nor relations but only the structure of the relation is called a structure description.

Thus, our thesis, namely that scientific statements relate only to structural properties, amounts to the assertion that scientific statements speak only of forms without stating what the elements and the relations of these forms are.<sup>3</sup>

Arguing that definite descriptions which are purely structural are possible, Carnap submits that scientific discrimination is limited to the possibility of definite description through pure structure statements.

It becomes clear from the preceding investigations about structural definite descriptions that each object name which appears in a scientific statement can in principle (if enough information is available) be replaced by a structural definite description of the object, together with an indication of the object domain to which the description refers. This holds, not only for the names of individual objects, but also for general names, that is, for names of concepts, classes, relations . . . . Thus each scientific statement can in principle be transformed into a statement which contains only structural properties and the indication of one or more object domains. Now, the fundamental thesis of construction theory . . . , which we will attempt to demonstrate in the following investigation, asserts that fundamentally there is only one object domain and that each scientific statement is about the objects in this domain. Thus, it becomes unnecessary to indicate for each statement the object domain, and the result is that *each scientific statement can in principle be so transformed that it is nothing but a structure statement.* But this

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<sup>1</sup>Ibid., p. 19.

<sup>2</sup>Ibid., pp. 19-23.

<sup>3</sup>Ibid., p. 23.

transformation is not only possible, it is imperative. For science wants to speak about what is objective, and whatever does not belong to the structure but to the material (i.e., anything that can be pointed out in a concrete ostensive definition) is, in the final analysis, subjective.<sup>1</sup>

In concluding his remarks on the possibility of purely structural definite descriptions, Carnap recognizes a distinction between a constructional form and a linguistic form of scientific statements.

*. . . , for science, it is possible and at the same time necessary to restrict itself to structure statements. This is what we asserted in our thesis. It is nevertheless evident from what has been said [earlier] that scientific statements may have the linguistic form of a material relation description or even the form of a property description.*<sup>2</sup>

#### Developing a constructional system

The two remaining topics selected for detailed examination cover what Carnap describes as the four main problems of construction theory. The problems of basis (choice of lowest level), object form (construction of objects of various types), and system form (overall form produced by stratified arrangement of object types) are interrelated and are said to involve "extralogical" considerations. First Carnap treats the fourth, "formal-logical" problem of ascension forms, which will be used repeatedly to "ascend" to higher levels in the system.<sup>3</sup>

#### Reaching new constructional levels

Carnap regards virtually all objects of science as "quasi objects" which are incomplete symbols used as though they designated objects as object names do. At issue here is the relationship between linguistic signs and the objects they designate. Following Frege, Russell used the term "incomplete symbol" for a symbol which has no meaning in isolation, but only in certain contexts in which its use is defined.<sup>4</sup> The incomplete

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<sup>1</sup>Ibid., pp. 28-29.      <sup>2</sup>Ibid., p. 30.      <sup>3</sup>Ibid., pp. 47-48.

<sup>4</sup>A.N. Whitehead and B. Russell, Principia Mathematica (2nd ed.; London: Cambridge University Press, 1935), I, 66.

symbol which remains when names of objects and quasi objects (the arguments) are deleted from a sentence (that is, deleted from the argument positions) is said to designate a propositional function. Two types of propositional functions are distinguished. A property (or property concept) has one argument position; a relation (or relational concept) has two or more argument positions.<sup>1</sup>

The "extensional procedure" for producing the extension of a propositional function involves assigning the same symbol to propositional functions which are satisfied by exactly the same arguments and thus said to be coextensive. This condition is achieved when every object (or pair or triple of objects, etc.) which satisfies one of the propositional functions satisfies all the others (that is, results in a true sentence). The symbols assigned to coextensive propositional functions are called "extension symbols." Used as though there were objects (extensions) which they designate, extension symbols have no independent meaning and thus are termed incomplete symbols. When using the extension symbol produced in an extensional procedure, ". . . we obviously disregard all points of difference between coextensive propositional functions and express only those factors in which they agree."<sup>2</sup> Two types of extensions of propositional functions are distinguished. A class is an extension of a property; a relation extension is an extension of a relation.<sup>3</sup>

To construct a concept from others is to indicate its "constructional definition" using only those concepts to which the constructed concept is said to be reducible.<sup>4</sup> Two types of constructional definition are distinguished. An explicit definition gives to a new symbol the same meaning as a combination of known symbols. A definition in use introduces a symbol which lacks independent meaning by explaining how the symbol is used in complete sentences. A definition in use equates the expressions for two propositional functions, one containing the new (constructed) object name and the other containing only previously constructed names, both containing the same variables.<sup>5</sup>

<sup>1</sup>Ibid., pp. 50-51.

<sup>2</sup>Ibid., p. 56.

<sup>3</sup>Ibid., pp. 57-60.

<sup>4</sup>Ibid., pp. 60-61.

<sup>5</sup>Ibid., pp. 65-67.

The "ascension" to a new constructional level requires a definition in use. Hence this type of definition is of central importance for the task Carnap has set. A definition in use establishes that two propositional functions have the same meaning, that is, they are satisfied by the same objects. The propositional function which includes the new symbol will be associated with all propositional functions coextensive with the established propositional function used in the definition. A definition in use always defines either a class or a relation extension, depending on the number of argument positions.<sup>1</sup>

Selecting basic objects for  
a constructional system

The third topic of central importance in a description of Carnap's interpretation of science concerns the selection of "basic objects" from which all other objects are to be constructed. To explain his choice of "basic relations" for this purpose, Carnap first explains his use of an "epistemic" system form in which objects are constructed from others which are "epistemically primary." While either a physical or a psychological basis seems to be available, Carnap regards autopsychological objects (one's own psychological processes) as epistemically primary in relation to physical objects. He sees the following epistemic sequence of important object types: autopsychological, physical, heteropsychological (other person's psychological processes), and cultural objects.<sup>2</sup>

Carnap argues that objectivity in an intersubjective sense is possible with an autopsychological basis because, ". . . , even though the *material* of individual streams of experience is completely different, . . . , certain *structural properties* are analogous for all streams of experience."<sup>3</sup> The necessary objectivity is possible because structure is the essential concern of science.

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<sup>1</sup>Ibid., pp. 67-70.

<sup>2</sup>Ibid., pp. 88-94.

<sup>3</sup>Ibid., p. 107.

As "basic elements"--the members of the basic relations--of a constructional system, Carnap selects "elementary experiences," units of "experiences of the self."<sup>1</sup> These are "essentially unanalyzable units" which cannot be analyzed by construction with the available ascension forms. Carnap describes a synthetic procedure termed "quasi analysis" to ". . . overcome the difficulty which results from the fact that elementary experiences are unanalyzable."<sup>2</sup> As initial ordering concepts of his constructional system, Carnap selects basic relations rather than basic classes, since only the basic relations are of the form required to make assertions about the basic elements, the elementary experiences.<sup>3</sup>

The basic relations, not the basic elements, are the "undefined basic objects" or concepts from which all other objects of the system are constructed. Carnap argues that one basic relation called "recollection of similarity" appears to be sufficient as the basic relation of a constructional system with an autopsychological basis, but this claim is recognized as having the status of a conjecture.<sup>4</sup>

The outline of a  
constructional system

The interpretation of scientific statements as structure statements, the explanation of the definition in use as an ascension form, and the selection of basic relations among elementary experiences as the undefined basic objects of the constructional system are three fundamental aspects of Carnap's argument. In the concluding sections of The Logical Structure of the World, Carnap outlines a constructional system and then examines various philosophical problems in the light of the results of his study. A brief description of the outline of a constructional system precedes the statement of Carnap's categorial

<sup>1</sup>Ibid., pp. 107-109.

<sup>2</sup>Ibid., p. 110.

<sup>3</sup>Ibid., p. 122.

<sup>4</sup>Ibid., p. 134.

framework. Carnap's philosophical reflections are cited subsequently, to permit observation of the interaction between Carnap's categorization of objects of experience and his metaphysical beliefs and explanatory standards.

Carnap introduces the outline of a constructional system with a reminder of the purpose for which it is presented. His remarks reflect Russell's sharp distinction between analytic and empirical statements. The latter indicate ". . . the relations between constructed objects which can be ascertained only through experience."<sup>1</sup> Note in the following that Carnap's concern is not with the "complete material correctness" of empirical findings but with the problem of translating empirical findings into a constructional system.

As concerns the content of our constructional system, let us emphasize again that it is only a tentative example. The content depends upon the material findings of the empirical sciences; for the lower levels in particular upon the findings of the phenomenology of perception, and psychology. The results of these sciences are themselves subject to debate; since a constructional system is merely the translation of such findings, its complete material correctness cannot be guaranteed. *The actual purpose of our exposition of construction theory is to pose the problem of a constructional system, and to carry out a logical investigation of the method which will lead to such a system; the formulation of the system is not itself part of the actual purpose.* We have nevertheless formulated some levels of the system and have indicated further levels. We have done this mostly to illustrate the problem, rather than to attempt a beginning of its solution.

Carnap begins his outline with logical objects and the illustrative construction of an autopsychological object. Discussion of a possible procedure for constructing physical objects proceeds from space-time through the visual and other senses to the objects of physics and biology. Relations required to construct heteropsychological and cultural objects, and empirical problems associated with the relations, complete the outline.

In describing the construction of cultural objects, Carnap reiterates the absence of metaphysical implications and the exclusive

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<sup>1</sup>Ibid., p. 176.

<sup>2</sup>Ibid.

concern of scientific statements with "formal-logical" relations between object types.<sup>1</sup> Having outlined a constructional system in a preliminary fashion, Carnap assumes the possibility of achieving the system with a basis in elementary experiences, in order to consider the contributions of such an achievement to a variety of philosophical problems. His assessment of those contributions is examined after the following summary of the categorial framework indicated by his arguments.

#### Carnap's categorial framework

In Körner's analysis, indication of a categorial framework calls for the identification of a thinker's categorization of objects, the associated constitutive and individuating principles, and the underlying logic. Carnap's argument takes "objects of reference" and "elementary experiences" as maximal kinds of independent particulars in a categorization of objects of experience. Constitutive and individuating attributes associated with these maximal kinds are indicated by the following statements which are internally incorrigible in Carnap's argument.

1. Objects of reference have structural properties.
2. Scientific statements are empirical descriptions of structural properties of objects of reference.
3. Structural description proceeds according to Russellian logic, including the definition in use (property and relation extensions).
4. Elementary experiences are epistemically primary and essentially unanalyzable (immediately given, exhibiting no properties or constituents).
5. By a procedure of quasi analysis, derived from the Frege-Russell "principle of abstraction," structural properties may be assigned to elementary experiences.

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<sup>1</sup>Ibid., p. 233.

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<sup>1</sup>Ibid., p. 233.

6. There is an absolute contrast between 'structure' and 'content' (between formal and material properties.)

7. There is an absolute contrast between analytic statements and empirical statements.

8. In the final analysis, the truth of scientific statements is determined by correlating basic relations among elementary experiences, perhaps only of the form of recollections of similarity.

Classical logic is the primary logic underlying Carnap's categorial framework.

#### Carnap's metaphysical stance

Carnap considers a number of philosophical problems and in each case states the perspective afforded by the possibility of a constructional system. The following statement summarizes basic points in his argument while illustrating that philosophical problems are approached with a sharp distinction between science and metaphysics.

The constructional system shows that all objects can be constructed from "my elementary experiences" as basic elements. In other words (and this is what is meant by the expression "to construct"), all (scientific) statements can be transformed into statements about my experiences (more precisely, into statements about relations between my experiences) where the logical value is retained. Thus, each object which is not itself one of my experiences, is a quasi object; I use its name as a convenient abbreviation in order to speak about my experiences. In fact, within construction theory, and thus within rational science, its name is *nothing but* an abbreviation. Whether, in addition, it also designates something which "exists by itself" is a question of metaphysics which has no place in science. . . .<sup>1</sup>

The same approach to philosophical problems is found in the following passage in which Carnap distinguishes the "constructional essence" of an object from the "metaphysical essence" of an object. The first is concerned with the derivation of an object from the basic objects of the constructional system. Metaphysical essence is concerned with the "object-in-itself," and questions of this type are neither justified nor meaningful in science.

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<sup>1</sup>Ibid., p. 255.

Strictly speaking, the question [of the essence of an object] should not be phrased as "What is the nominatum of this object sign?", but "Which sentences in which this object sign can occur are true?" *We can make an unambiguous assessment only of the truth or falsity of a sentence, not of the nominatum of a sign, not even of an object sign.* Thus, the indication of the essence of an object or, what amounts to the same, the indication of the nominatum of the sign of an object, consists in an indication of the truth criteria for those sentences in which the sign of this object can occur. Such criteria can be formulated in various different ways; these various ways then indicate the respective character of the essence description in question. If the constructional essence of an object is to be indicated, the criterion consists in the constructional formula of the object, which is a transformation rule that allows us to translate step by step every sentence in which the sign of the object occurs into sentences about objects on a lower constructional level and, finally, into a sentence about the basic relation(s) alone.<sup>1</sup>

The problem of the parallelism between autopsychological and physiological events, termed the "psychophysical" problem, is considered in terms of a sharp distinction between determining the nature and extent of "parallel sequences" within a constructional system and subsequently explaining what is determined to be the case. Only the former activity is within science.<sup>2</sup>

In exploring the problem of reality, Carnap first specifies criteria for distinguishing between reality and non-reality within a constructional system. All real objects belong to comprehensive systems, are intersubjective in some sense, and have position in the temporal order.<sup>3</sup> From this distinction, Carnap proceeds to the metaphysical problem of reality, where the question is asked whether "reality" in some special sense (typically, "independence from the cognizing consciousness"<sup>4</sup>) must be ascribed to objects which are real in the constructional or empirical sense. Here a distinction is made between "empirical reality" and "metaphysical reality." Carnap argues that the three schools of realism, idealism, and phenomenalism diverge from

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<sup>1</sup>Ibid., pp. 256-257.

<sup>2</sup>Ibid., p. 270.

<sup>3</sup>Ibid., pp. 275-276.

<sup>4</sup>Ibid., p. 281.

each other only when they go beyond the boundaries of construction theory to take positions concerning metaphysical reality, positions among which no experience can decide. Construction theory is seen as expressing the common content of these divergent positions. Construction theory regards metaphysical reality as meaningless, and it achieves objectivity by stopping at the determination of "lawlike regularities."<sup>1</sup>

The sharp demarcation between empirical science and metaphysics continues into Carnap's summary of his account of science. "The aim of science consists in finding and ordering the true statements about the objects of cognition . . . ."<sup>2</sup> This involves first constructing objects and then establishing their empirical properties and relations. The indicated order is logical, not chronological. The process of establishing by convention the "constructional formula" of an object is the only way to give ". . . a verifiable meaning to such statements [about an object], for verification means testing on the basis of experiences."<sup>3</sup>

Following the position of Wittgenstein in the Tractatus Logico-Philosophicus,<sup>4</sup> Carnap describes science as having no limits. By this he means that ". . . there is no question whose answer is in principle unattainable by science."<sup>5</sup> This position is, most briefly, that if a question can be asked at all, it can in principle be answered. "In the strictly logical sense, to pose a question is to give a statement together with the task of deciding whether this statement or its negation is true."<sup>6</sup> All the questions which can be asked in the specified sense fall within the domain of unified science. This formulation of aims and limits of science indicates the basis of the term "logical empiricism" which is often applied to Carnap's position.

This brief review of implications of a constructional system for the resolution of certain philosophical problems completes the

<sup>1</sup>Ibid. . . . 281-287.

<sup>2</sup>Ibid., p. 288.

<sup>3</sup>Ibid., p. 289.

<sup>4</sup>L. Wittgenstein, Tractatus Logico-Philosophicus, trans. by D.F. Pears and B.F. McGuinness (London: Routledge & Kegan Paul Ltd., 1961).

<sup>5</sup>Carnap, op. cit., p. 290.

<sup>6</sup>Ibid.

present examination of The Logical Structure of the World. Carnap's problem-solutions illustrate the manner in which principles of a categorial framework function as metaphysical principles and explanatory standards, as argued by Körner. Carnap has modified and developed his position since writing his first major work. To examine criticisms of this work and the subsequent development of Carnap's work in philosophy of science would take the discussion well beyond the scope of the present study.<sup>1</sup> Carnap's study is here regarded as a clear and significant argument concerning the nature of scientific knowledge.

### Popper's Analysis of Science

#### Introduction

In The Logic of Scientific Discovery, Popper develops an account of science in which "falsifiability" is adopted as a criterion of demarcation for distinguishing empirical science from metaphysics. Popper thus recognizes the problem which Carnap attempted to solve by adopting verifiability as a criterion of meaningfulness, but he strongly and explicitly disagrees with the proposed solution. Popper rejects inductive logic in favor of the testing of consequences deductively derived from theories. Theories are regarded as universal statements which can be falsified by single contradictory instances, as in the familiar example in which accepting the report of one black swan dismisses the generalization that all swans are white.

An initial summary of major issues raised by Popper serves to identify some of the significant differences between the positions of Popper and Carnap and to provide a background for the subsequent detailed analysis of Popper's account of science. The initial issues

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<sup>1</sup>See Paul Arthur Schilpp (ed.), The Philosophy of Rudolf Carnap LaSalle, Illinois: The Open Court Publishing Co., 1963 for Carnap's "Intellectual Autobiography," discussions of his work by other philosophers, and Carnap's replies to those discussions.

are the testing of scientific statements, the demarcation of science from non-science, the objectivity of scientific statements, and the scope of a theory of scientific method.

The method of testing  
scientific statements

The Logic of Scientific Discovery is a systematic development of a position based on deductive testing of theories, and it demonstrates the solutions of epistemological problems which that position permits. With the phrase "logic of scientific discovery," Popper refers to logical analysis of the procedure by which a scientist constructs and tests hypotheses. Those who would characterize empirical science by its use of inductive methods would regard the logic of scientific discovery as the logic of those inductive methods by which the truth of universal statements is based on experience. Popper cites Hume's analysis of the principle of induction and explains his own view that inductive logic involves a number of difficulties which he regards as insurmountable.<sup>1</sup>

Popper describes his own theory as that of the "deductive method of testing" empirical hypotheses which are put forward for acceptance.<sup>2</sup> Although his view of the distinctive features of science is very different from Carnap's view, Popper shares with Carnap an interest in logical justification of statements. In different ways, both exclude attempts to analyze psychological facts associated with an individual's development of a new hypothesis.<sup>3</sup> Popper describes four ways in which conclusions deduced from a tentative hypothesis can be examined: (1) checking for internal consistency among conclusions, (2) determining that the hypothesis is empirical, (3) determining whether the hypothesis represents an advance over other theories, and (4) testing empirical applications of the hypothesis. Verification of singular conclusions establishes neither the truth nor the probability of a theory, in Popper's view, only temporary support which he refers to as "corroboration."<sup>4</sup>

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<sup>1</sup>Popper, The Logic of Scientific Discovery, pp. 27-29.

<sup>2</sup>Ibid., p. 30.

<sup>3</sup>Ibid., pp. 31-32.

<sup>4</sup>Ibid., pp. 32-34.

### The criterion of demarcation

When considering how his rejection of induction influences the view that the method of induction distinguishes empirical science from metaphysics, Popper submits that the problem of demarcation is more fundamental than the problem of induction. He criticizes positivists for their "naturalistic" interpretation that demarcation is a problem of natural science, to be solved by finding an existing difference between empirical science and metaphysics. Popper contends that Wittgenstein's criterion of meaningfulness, which coincides with induction as a criterion of demarcation, actually excludes natural laws (universal statements) from science. Popper describes his own goal not as the exclusion of metaphysics but as the characterization of the statements of empirical science. He sees himself proposing a convention which should be assessed on the basis of its logical consequences.<sup>1</sup>

In place of verifiability, Popper proposes that the falsifiability of a theoretical system be regarded as a criterion of demarcation. This view of an empirical or scientific system is a negative rather than a positive one, as Popper demands that the logical form of a scientific system must permit the refutation of the system by experience. Popper suggests that "experience" may be viewed as a method. This method rather than the inductive method is characteristic of the theoretical system of empirical science, which must be distinguishable as representing "our world of experience." For Popper this requires the application of the deductive method of testing which he analyzes in the main body of his argument. Falsification is compatible with Popper's deductive method because it is possible to argue deductively from the truth of a singular statement to the conclusion that a universal statement is false. Logical evasion of falsification, by ad hoc modification of a system, is to be explicitly excluded by characterizing the empirical

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<sup>1</sup>Ibid., pp. 34-39.

method as one which exposes a system to falsification "in every conceivable way."<sup>1</sup>

#### The objectivity of scientific statements.

Popper realizes that there are problems with the empirical nature of singular statements which he must answer in his analysis. His solution includes a distinction between "subjective" psychological feelings of conviction and "objective" logical relations. Popper agrees with Carnap that feelings of conviction cannot justify a statement, but Popper takes the view ". . . that the *objectivity* of scientific statements lies in the fact that they can be *inter-subjectively tested*."<sup>2</sup> Popper requires that "basic statements--those which can serve as premises in empirical falsifications--be intersubjectively testable like all other (objective) scientific statements. This leads Popper to the conclusion, markedly different from Carnap's, that science has no ultimate statements and that there is no logical way ". . . to reduce the truth of scientific statements to our experiences."<sup>3</sup> Rather, while all scientific statements must be testable, some can be accepted without actually having been tested.

#### The need for methodological rules

Popper sees the theory of scientific method--which he identifies with epistemology or the logic of scientific discovery--as a theory which treats not only the logical analysis of relations among statements but also the selection of methods for dealing with scientific statements. Methods, or rules, selected for his "empirical method" are to be ones which ensure the falsifiability of statements in science.<sup>4</sup> Where positivists see logical criteria (verifiability, meaningfulness) as characteristic of scientific statements, Popper regards "susceptibility to revision" as their distinctive characteristic. Given that scientific statements can be criticized and replaced by better ones, Popper's goal

<sup>1</sup> *Ibid.*, pp. 39-42.

<sup>2</sup> *Ibid.*, p. 44.

<sup>3</sup> *Ibid.*, pp. 46-47.

<sup>4</sup> *Ibid.*, p. 49.

is to analyze how choices are made between conflicting theories, choices which result in the progress of scientific knowledge.<sup>1</sup>

Popper's objections to a purely logical analysis of scientific statements stem from the inability of such analysis to exclude the possibility that an obsolete theory will be defended as true. He characterizes the positivistic view of methodology as naturalistic, involving empirical study of scientists' behaviors or scientific procedures. Popper regards this position as one which follows from the view that logical tautologies and empirical statements are the only two kinds of statements. Popper's view, in contrast, is that methodological rules are conventions, adopted when analysis of their consequences shows that they are helpful and cannot be omitted without loss. He intends to require that methodological rules be such that scientific statements are not protected from falsification but rather are exposed to it.<sup>2</sup>

Popper concludes his introductory remarks with the declaration that he is proposing falsifiability as a criterion of demarcation because of its value in clarifying problems of the theory of knowledge. Thus his goal is similar to Carnap's, yet his perspective is very different. The discussion turns now to the details of Popper's argument and the subsequent statement of the categorial framework indicated by his analysis of the form and the testing of scientific statements. His account is examined in terms of three topics which capture fundamental features of his position. The first topic is the logical form of theories and of the statements required for their deductive testing. It is followed by consideration of the empirical basis of science and the comparison of alternative scientific theories.

#### The logical form of universal and singular scientific statements

Popper characterizes scientific hypotheses as strictly universal statements, and "basic" statements required for their deductive testing

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<sup>1</sup>Ibid., pp. 49-50. This interest of Popper's is shared by Kuhn, whose alternative interpretation is examined later in this chapter.

<sup>2</sup>Ibid., pp. 50-54.

as singular existential statements. To explain these characterizations, Popper elaborates several related distinctions. Synthetic statements, which make assertions about reality, are either universal or singular. Prediction requires the conjunction of statements of both kinds: deduction of a singular statement (a specific prediction) from a universal statement (a natural law) requires a singular statement of the characteristics of a specific event (the initial conditions). Universality may be either strict or numerical. A strictly universal statement is a ". . . universal assertion about an unlimited number of individuals." It is asserted for all places and times. A numerically universal statement refers to ". . . a finite class of specific elements within a finite individual (or particular) spatio-temporal region." Popper regards a numerically universal statement as equivalent to a singular statement, for it is in principle possible to enumerate each individual in a finite class.<sup>1</sup>

Whether the universality of natural laws is strict or numerical is, for Popper, a question to be settled not by argument but by agreement or convention. His methodological decision is that it is

. . . both useful and fruitful to regard natural laws as synthetic and strictly universal statements ('all-statements'). This is to regard them as non-verifiable statements which can be put in the form: 'Of all points in space and time (or in all regions of space and time) it is true that . . .'. By contrast, statements which relate only to certain finite regions of space and time I call 'specific' or 'singular' statements.<sup>2</sup>

The distinction between universal and singular statements demands a distinction between universal and individual concepts or names. The latter distinction is excluded by Carnap,<sup>3</sup> and Popper explicitly declares his rejection of Carnap's position.<sup>4</sup> To Popper, it is impossible to

<sup>1</sup>Ibid., pp. 59-63.

<sup>2</sup>Ibid., p. 63.

<sup>3</sup>Carnap, The Logical Structure of the World, p. 10 and p. 247.

<sup>4</sup>Popper, The Logic of Scientific Discovery, p. 67.

determine ". . . whether there are any individual things corresponding to a description by means of universal names, and if so how many, . . ." <sup>1</sup> Similarly, Popper rejects the possibility of defining universal names with the help of individual ones, just as he earlier rejected the possibility of moving by induction from singular to universal statements. He specifically rejects the possibility of solving either the problem of induction or the problem of universals by applying techniques of symbolic logic. <sup>2</sup>

There are, Popper points out, two types of statements which lack individual names or concepts. In addition to the strictly universal statements already discussed, there are strictly existential statements. Each is equivalent to the negation of the other, and strictly universal statements may be said to have the logical form of "non-existence" statements. Popper illustrates with the example of the black raven. Negation of the strictly universal "All ravens are black" (which denies the existence of non-black ravens) yields "Not all ravens are black," which is equivalent to the strictly existential "There are non-black ravens." <sup>3</sup> Strictly existential statements cannot be falsified by any singular statements concerning an observed event. Hence they are regarded as metaphysical (non-empirical) by the criterion of demarcation. As Popper explains, recognition that strictly universal statements are non-existence statements permits the comparison of natural laws to prohibitions. Because it explicitly excludes certain possibilities, a strictly universal statement is falsifiable by the acceptance of a singular statement reporting the prohibited occurrence. <sup>4</sup>

Characterization of the "basic" statements to be used in deductive testing of universal statements requires a distinction between singular existential and singular non-existential statements, also equivalent to negations of each other. Singular existential statements make an assertion about a particular region of time and space, while

<sup>1</sup> Ibid., p. 66.

<sup>2</sup> Ibid., p. 63.

<sup>3</sup> Ibid., p. 68.

<sup>4</sup> Ibid., p. 69.

singular non-existential statements make a comparable denial. The formal requirements that a basic statement must be able to contradict a universal statement (for falsification) and that from a universal statement lacking initial conditions it must not be possible to deduce a basic statement demand that basic statements have the logical form of singular existential statements.<sup>1</sup>

#### The empirical basis of science

All singular statements meet the formal requirements of basic statements. Popper also specifies a material requirement to ensure that basic statements are ". . . testable, intersubjectively, by 'observation'."<sup>2</sup> Popper requires ". . . that every basic statement must either be itself a statement about relative positions of physical bodies, or that it must be equivalent to some basic statement of this 'mechanistic' or 'materialistic' kind."<sup>3</sup> More concisely, the . . . which a basic statement asserts is occurring in a specified region of space and time must be "observable."<sup>4</sup>

Basic statements play a role both in characterizing a theoretical system as falsifiable and in specifying the conditions required for falsification of a theoretical system. Popper examines and rejects several ways of characterizing a theory as "empirical" by its relation to singular statements. He then proposes the following criterion of falsifiability.

A theory is to be called 'empirical' or 'falsifiable' if it divides the class of all possible basic statements unambiguously into the following two non-empty subclasses. First, the class of all those basic statements with which it is inconsistent (or which it rules out, or prohibits): we call this the class of the *potential falsifiers* of the theory; and secondly, the class of those basic statements which it does not contradict (or which it "permits"). We can put this more briefly by saying: a theory is falsifiable if the class of its potential falsifiers is not empty.<sup>5</sup>

Falsification is quite different from falsifiability. It requires reference not to all logically possible basic statements but to basic

<sup>1</sup>Ibid., pp. 100-102.

<sup>2</sup>Ibid., p. 102.

<sup>3</sup>Ibid., p. 103.

<sup>4</sup>Ibid. Popper denies that he is using the term "observable event" in a psychologistic sense. He regards the term as one which is undefined and learned in use, by examples.

<sup>5</sup>Ibid., p. 86.

statements which have been accepted as "corroborating" a "falsifying hypothesis." Falsification demands the discovery of ". . . a *reproducible effect* which refutes the theory." In Popper's words, ". . . we only accept the falsification if a low-level empirical hypothesis which describes such an effect is proposed and corroborated."<sup>1</sup>

It is Popper's position that experiences can never justify basic statements but they can motivate decisions to accept basic statements. Any basic statement can always be the subject of further tests. To bring the procedure of deductive testing to a temporary conclusion requires that the testing stop at statements which are such that intersubjective agreement on acceptance or rejection is relatively easy to obtain. This view that basic statements are accepted by decision requires a methodological rule that basic statements only be accepted in the process of testing theories. Theories provide viewpoints and problems which establish contexts for the acceptance of basic statements.

Agreement upon the acceptance or rejection of basic statements is reached, as a rule, on the occasion of applying a theory; the agreement, in fact, is part of an application which puts the theory to the test. Coming to an agreement upon basic statements is, like other kinds of applications, to perform a purposeful action, guided by various theoretical considerations.<sup>2</sup>

#### Criteria for comparing scientific hypotheses

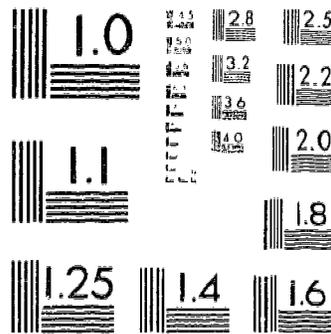
Popper extends his account of the deductive method of testing by identifying a number of criteria for the comparison of different theories. Of particular interest are comparisons of alternative theories which are competing for acceptance as the "better" theory. The two most important criteria for comparing theories are "empirical content" and "degree of corroboration."

Theories may be distinguished by the amount of empirical information they convey. Popper gives the following introduction of the phrases "empirical content" and "degree of falsifiability."

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<sup>1</sup>ibid.

<sup>2</sup>ibid.



MICROCOPY RESOLUTION TEST CHART  
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A theory is falsifiable, . . . , if the class of its potential falsifiers is not empty. . . . if the class of potential falsifiers of one theory is 'larger' than that of another, there will be more opportunities for the first theory to be refuted by experience; thus compared with the second theory, the first theory may be said to be 'falsifiable in a higher degree'. This also means that the first theory *says more* about the world of experience than the second theory, for it rules out a larger class of basic statements . . . . Thus it can be said that the amount of empirical information conveyed by a theory, or its empirical content, increases with its degree of falsifiability.<sup>1</sup>

In these terms Popper elaborates a methodological requirement that scientific theories have the greatest possible empirical content. Level of universality and degree of precision are two attributes of theories which are particularly relevant to that goal, for an increase in either increases a theory's falsifiability or testability.<sup>2</sup>

The empirical content of a theory is associated with its falsifiability and the class of all logically possible basic statements. In contrast, the "degree of corroboration" of a theory is associated with its testing and thus with the class of basic statements which are accepted in that process. As an alternative to discussions of the probability of an hypothesis, Popper suggests the assessment of how far a theory has been corroborated.<sup>3</sup>

The appraisal of the corroboration [of a theory]. . . can be derived if we are given the theory as well as the accepted basic statements. It asserts the fact that these basic statements do not contradict the theory, and it does this with due regard to the degree of testability of the theory, and to the severity of the tests to which the theory has been subjected, up to a stated period of time.<sup>4</sup>

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<sup>1</sup>Ibid., pp. 112-113.

<sup>2</sup>Ibid., pp. 121-123.

<sup>3</sup>The Logic of Scientific Discovery includes an extensive analysis of probability which is not examined here. At the time Popper was writing, difficulties associated with establishing complete verification had prompted analyses of the probability of hypotheses. The topic of probability is regarded as more specialized than the present study requires. Popper uses "corroboration" to avoid the context of proof and verification associated with the term "confirmation."

<sup>4</sup>Ibid., p. 266.

Saying that a theory has been corroborated indicates that the theory has stood up to its tests. However, the degree of corroboration of a theory reflects not the number of tests passed but the severity of the possible and actual tests. Severity thus depends upon testability, a reflection of the degree of falsifiability. The greater the empirical content of a theory, the greater the potential degree of corroboration. The actual corroboration of a theory is never attributed to the theory alone, as truth might be. Attributing some degree of corroboration to a theory requires reference to the basic statements which have been accepted up to a particular time in the course of devising and conducting deductive tests of the theory.<sup>1</sup>

#### Popper's categorial framework

Popper's argument takes "observable events" and "individuals" as maximal kinds of particulars in a categorization of objects. Constitutive and individuating attributes are included in the following list of propositions which appear to be internally incorrigible with respect to his analysis of science, as described above. The first statement indicates that the maximal kind "observable events" could be identified equivalently as "material objects." The former term is used more frequently by Popper.

1. Observable events involve ". . . position and movement of macroscopic physical bodies."<sup>2</sup>

2. There is an absolute contrast between individual concepts and universal concepts.

3. There is an absolute contrast between singular statements and strictly universal statements.

4. Basic statements describe the occurrence of observable events in individual regions of space and time. They have the logical form of singular existential statements.

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<sup>1</sup>Ibid., pp. 251-276.

<sup>2</sup>Ibid., p. 103.

5. Scientific hypotheses prohibit, for all regions of space and time, at least one event.<sup>1</sup> They have the logical form of strictly universal statements.

6. Individuals can agree to adopt methodological rules for dealing with scientific statements, including the rule that all other methodological rules must be designed so that no scientific statement is protected from falsification.

7. Basic statements are accepted or rejected by agreement among individuals concerning experiences which test deductive consequences of a scientific hypothesis.

8. Scientific hypotheses can be compared in terms of size of class of potential falsifiers. Those with the highest "degree of falsifiability" are preferred.

9. Scientific hypotheses can be compared in terms of the severity of possible and actual testing of their deductive consequences. Those with the highest "degree of corroboration" are preferred.

Classical logic is the primary logic underlying Popper's categorial framework. Deductive testing is based upon the *modus tollens* of classical logic: ". . . : 'If  $p$  is derivable from  $t$ , and if  $p$  is false, then  $t$  is also false.'"<sup>2</sup> In the terms used by Popper, the acceptance of a basic statement which negates a prediction deduced from a conjunction of an hypothesis and initial conditions negates that conjunction of hypothesis and initial conditions.

#### The resolution of metaphysical issues

Several aspects of Popper's metaphysical position were indicated in the introductory remarks, in notations that Popper would develop alternative answers to several questions which were also of concern to Carnap. Popper's argument extends the criterion that statements of empirical

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<sup>1</sup>An "event" denotes what is universal about an occurrence. *Ibid.*, pp. 88-89.

<sup>2</sup>*Ibid.*, p. 76.

science must be falsifiable by experience. Popper thus rejects the view that inductive verification distinguishes scientific from metaphysical statements. This concluding segment of the analysis of Popper's argument examines in somewhat greater detail his treatment of three issues already mentioned: the achievement of objectivity in science, the nature of the empirical basis of science, and the nature of scientific progress.

Popper achieves an objective, non-psychologistic perspective by requiring that all scientific statements be intersubjectively testable. When he considers the views of Carnap, Neurath, and Reinerger, he finds them lacking because they ask how experience can be defended against doubt, or justified. Carnap in particular is characterized by Popper as translating the psychologistic approach into the formal mode of speech by maintaining that sentences which describe "the contents of immediate experience" do not require confirmation. Popper's alternative proposal calls for a sharp distinction between objective science and our knowledge of facts by observation. For Popper, "our knowledge" does not establish the truth of any statement. Accordingly, the epistemological question is not "On what does our knowledge rest?" but rather "How do we test scientific statements by their deductive consequences?"<sup>1</sup> In a footnote to the English translation, Popper poses this question as "How can we best *criticize* our theories (our hypotheses, our guesses), rather than defend them against doubt?"<sup>2</sup>

Popper sees his account of the empirical basis of science as one which distinguishes him from both positivists and conventionalists. The testing of theories depends upon decisions to accept or reject basic statements, not upon the justification of basic statements by our immediate experiences as positivists maintain, and not upon decision to accept universal statements as conventionalists maintain.<sup>3</sup> Popper does not require "final certainty" of science. Instead, as already indicated, Popper wishes to account for our choices between competing theories and for the processes by which new theoretical systems supersede previously

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<sup>1</sup>Ibid., pp. 96-98.

<sup>2</sup>Ibid., p. 98.

<sup>3</sup>Ibid., p. 109.

accepted ones. The following metaphor conveys some sense of Popper's associated view of the empirical basis of science.

The empirical basis of objective science has thus nothing 'absolute' about it. Science does not rest upon solid bedrock. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or 'given' base; and if we stop driving the piles deeper, it is not because we have reached firm ground. We simply stop when we are satisfied that the piles are firm enough to carry the structure, at least for the time being.<sup>1</sup>

In the context of his discussion of empirical content, Popper provides an interesting analysis of the concept of "simplicity." He notes that philosophers of science have often attached considerable importance to simplicity without critically examining its use. Popper identifies three senses of simplicity--aesthetic, pragmatic, and epistemological--and rejects the first two as "extra-logical" uses of the concept. Epistemological simplicity raises questions which can be answered, from Popper's perspective, by equating this sense of simplicity with degree of falsifiability.<sup>2</sup> "Simple statements, if knowledge is our object, are to be prized more highly than less simple ones *because they tell us more; because their empirical content is greater; and because they are better testable.*"<sup>3</sup>

Popper concludes his analysis of science in The Logic of Scientific Discovery with a summary of his view of how science progresses. He regards the successive replacement of theories by better ones as advances not by induction but by achievement of greater degrees of falsifiability and corroboration. While the greatest possible universality is desired of theories, the need to test new theories demands that they also address the existing scientific "problem situation." Popper readily admits the potential contribution of metaphysics to the solving of problems, yet he consistently emphasizes the importance of testability for reaching empirical decisions between competing theories.<sup>4</sup>

<sup>1</sup>Ibid., p. 111.

<sup>3</sup>Ibid., p. 142.

<sup>2</sup>Ibid., pp. 136-145.

<sup>4</sup>Ibid., pp. 276-278.

Conjectures or hypotheses for solving problems must not be defended but rather criticized by attempts to demonstrate their refutation. As his closing remarks indicate, Popper has interpreted science in a way which emphasizes criticism and rejects the view of progress toward certainty.

The old scientific ideal of *epistēmē*--of absolutely certain, demonstrable knowledge--has proved to be an idol. The demand for scientific objectivity makes it inevitable that every scientific statement must remain *tentative for ever*. It may indeed be corroborated, but every corroboration is relative to other statements which, again, are tentative. Only in our subjective experiences of conviction, in our subjective faith, can we be 'absolutely certain' . . . . .  
 . . . Science never pursues the illusory aim of making its answers final, or even probable. Its advance is, rather, towards an infinite yet attainable aim: that of ever discovering new, deeper, and more general problems, and of subjecting our ever tentative answers to ever renewed and ever more rigorous tests.<sup>1</sup>

### Kuhn's Analysis of Science

#### Introduction

In The Structure of Scientific Revolutions, Kuhn presents an argument that science has developed by the occurrence of revolution-like changes in research perspectives shared by communities of scientists. His concern with epistemological issues in science is secondary to his stated aim to outline a conception of science drawn from ". . . the historical record of the research activity itself."<sup>2</sup> Kuhn regards his

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<sup>1</sup>Ibid., pp. 280-281.

<sup>2</sup>Kuhn, The Structure of Scientific Revolutions, p. 1. Kuhn's work was first published in 1962, a time of major curriculum development projects in the natural sciences. Its argument has received considerable attention in education as well as in history and in philosophy. Among recently trained science teachers, Kuhn's book may be the best-known work of a philosophical nature which is not addressed directly to the teaching of science. Of such works addressed directly to science teaching, those of Joseph Schwab may be the best known. Schwab's categories of "stable" and "fluid" science in The Teaching of Science as Enquiry (Cambridge: Harvard University Press, 1962) have been compared to Kuhn's categories of "normal" and "extraordinary" science. Schwab's work and the issues associated with that comparison are not treated here.

work as the expression of a new historiographic perspective which interprets rejected theories of science as coherent in their own time, not as "myths" from which a few lasting contributions have survived to the present. Accordingly, Kuhn rejects the view that science develops by an accumulation of true conclusions reached by following methods uniquely appropriate to scientific research. Kuhn argues that science develops by "revolutions" in which a community of scientists accepts a new "paradigm" as the basis for its further research.

The concept of "paradigm" plays two essential and quite different roles in Kuhn's argument. The second edition of The Structure of Scientific Revolutions contains a "postscript"<sup>1</sup> in which Kuhn explicitly distinguishes the two senses of "paradigm" by introducing the terms "exemplar" and "disciplinary matrix." The description of Kuhn's argument begins with a sketch of the major features of Kuhn's original perspective on the development of science. In that sketch, the term "paradigm" is used temporarily; its two senses are examined in the detailed analysis which follows.

#### An initial outline

Kuhn's interpretation of the historical development of science is based upon the identification of periods of "normal science," separated by periods of "extraordinary science." In periods of normal science, a community of scientists is united in the acceptance of a set of previous achievements as an adequate basis for its research. Normal science is regarded as "puzzle-solving." The shared paradigm suggests that nature will behave in certain ways which scientists seek to demonstrate. The three major puzzle-solving activities are determination of important facts, matching facts to theory, and further development of theory.<sup>2</sup>

Normal science, or the conduct of research according to a shared

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<sup>1</sup>Ibid., pp. 174-210.

<sup>2</sup>Ibid., pp. 22-34.

paradigm, is taken by Kuhn as a sign of maturity in a particular scientific field. The individual scientist faces research puzzles rather than debate over fundamentals. The paradigm represents accepted achievements which he may take for granted and use to guide his work, be it concerned with data, theory, or both.<sup>1</sup> The concept of paradigm draws together all the non-observational commitments shared by a community of scientists. These include laws, concepts, and theories; preferred types and uses of instrumentation; methodological commitments; and metaphysical commitments about the fundamental constituents of the universe.<sup>2</sup>

Kuhn argues that the puzzle-solving of normal science eventually and inevitably encounters anomalous phenomena which cannot be explained by the rules of the existing paradigm. The resulting "crisis" marks a period of "extraordinary science" in which the paradigm is called into question and new candidates for the status of paradigm are developed and compared as part of the effort to resolve the crisis. A "scientific revolution" occurs when a community of scientists accepts a new paradigm and thereby rejects the shared commitments which previously guided its research.

All crises begin with the blurring of a paradigm and the consequent loosening of the rules for normal research. In this respect research during crisis very much resembles research during the pre-paradigm period, except that in the former the locus of difference is both smaller and more clearly defined. And all crises close in one of three ways. Sometimes normal science ultimately proves able to handle the crisis-provoking problem despite the despair of those who have seen it as the end of an existing paradigm. On other occasions the problem resists even apparently radical new approaches. Then scientists may conclude that no solution will be forthcoming in the present state of their field. The problem is labelled and set aside for a future generation with more developed tools. Or, finally, the case that will most concern us here, a crisis may end with the emergence of a new candidate for paradigm and with the ensuing battle over its acceptance. . . .

The transition from a paradigm in crisis to a new one from which a new tradition of normal science can emerge is far from a cumulative process, one achieved by an articulation or extension of the old paradigm. Rather, it is a reconstruction of the field from new

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<sup>1</sup>Ibid., pp. 10-22.

<sup>2</sup>Ibid., pp. 40-42.

fundamentals, a reconstruction that changes some of the field's most elementary theoretical generalizations as well as many of its paradigm methods and applications.<sup>1</sup>

Kuhn suggests that different paradigms are comparable to different views of the world. They cannot be used to judge each other, and they can only be "tested" in competition for acceptance by a community as the basis for its subsequent research. Such testing does not seek to determine which paradigm is "right." A new paradigm may be favored if it is able to resolve the crisis, predict unexpected phenomena, or achieve some form of simplification.<sup>2</sup> Thus progress in science occurs as the result of professional decision within the insulated community which shares a paradigm. "The very existence of science depends upon vesting the power to choose between paradigms in the members of a special kind of community."<sup>3</sup>

Kuhn's argument is richly illustrated and buttressed with historical episodes which cannot be included in the present analysis. The reader is urged to consult Kuhn's text for the contribution of the historical evidence to understanding and evaluating his argument. Kuhn has followed a position in historiography to its logical implications for understanding the nature of science. He finds that normal science consists of solving puzzles identified in terms of a paradigm shared by a community of scientists. Such a community inevitably encounters crises in which unexpected phenomena seem inexplicable within the boundaries of the paradigm. Among the possible outcomes of a period of extraordinary science is a scientific revolution, in which the community accepts a new paradigm to guide its research.

Four topics require further analysis in the present examination of Kuhn's account of science. Closer scrutiny of three aspects of the original concept of paradigm precedes a statement of Kuhn's categorial framework. Following that statement, additional topics are examined to illustrate how important aspects of this position are related to the categorial framework. The additional topics are Kuhn's view of the logic of scientific inquiry and his interpretation of educational issues

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<sup>1</sup>Ibid., pp. 84-85.

<sup>2</sup>Ibid., pp. 153-155.

<sup>3</sup>Ibid., p. 167.

directly related to his account of science. The question of how a disciplinary matrix compares to Körner's concept of a categorial framework is also considered.

Kuhn's two distinct uses  
of the term "paradigm"

In the first edition of his work Kuhn used the term "paradigm" in a variety of different ways.<sup>1</sup> Kuhn maintains that two distinctly different uses of the term remain if stylistic variations are disregarded.<sup>2</sup> He proposes the term "disciplinary matrix" to identify his use of paradigm to refer to all the shared non-observational commitments of a scientific community, the totality of beliefs which may be revised when a new basis for research is accepted. He proposes the term "exemplar" to identify his use of paradigm to refer to that component of a disciplinary matrix which bears directly on the process of perception. Separate discussions of these two terms are followed by specific consideration of the relationship between a community of scientists and its disciplinary matrix.

Paradigm as disciplinary matrix

Kuhn suggests the term "disciplinary matrix" because it indicates that there are several types of commitments shared by the researchers in a particular area of specialization. The concept seems to involve what Körner refers to as a "unifying attribute." In this case, four separate particulars are unified by being shared by a community of scientists as a basis for research.

The first and most obvious type of commitment is a scientific

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<sup>1</sup>For an elaborate analysis of this variety of uses, see Margaret Masterman, "The Nature of a Paradigm," in Imre Lakatos and Alan Musgrave (eds.), Criticism and the Growth of Knowledge (Cambridge: Cambridge University Press, 1970), pp. 59-89.

<sup>2</sup>Kuhn, The Structure of Scientific Revolutions, pp. 181-182.

theory or group of theories--natural laws and the concepts associated with them. In his postscript, Kuhn speaks of symbolic generalizations as ". . . the formal or the readily formalizable components of the disciplinary matrix."<sup>1</sup> One important role of symbolic generalizations is to permit the use of logic and mathematics in the course of puzzle-solving. They also contribute to the identification of puzzles and to the acceptance of solutions. Kuhn sees these generalizations functioning not only as natural laws but also as definitions of some of their included symbols.<sup>2</sup>

The commitments which Kuhn originally described as metaphysical and methodological have subsequently been described as shared beliefs in particular models, either heuristic or ontological. Kuhn sees shared models as the source of a group's ". . . preferred or permissible analogies and metaphors."<sup>3</sup> As such, they also contribute to the identification of puzzles and the recognition of adequate solutions.<sup>4</sup>

The third type of shared commitment is the values which are used to judge predictions and theories. Here Kuhn is thinking of criteria such as accuracy, quantitative form, consistency, compatibility with other theories, and simplicity. These are commitments associated more with science in general than with particular scientific specialities. Hence values are likely to be shared across a number of communities of scientists. Values are particularly significant in the recognition of crisis and in the selection by a community of one disciplinary matrix over another. To explain the fact that these processes are not characterized by group unanimity, particularly in their initial stages, Kuhn points out that values can be shared by a group of individuals and yet lead to different individual judgments in their actual applications.<sup>5</sup>

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<sup>1</sup>Ibid., p. 182.

<sup>2</sup>Ibid., p. 40 and pp. 182-184.

<sup>3</sup>Ibid., p. 184.

<sup>4</sup>Ibid., pp. 41-42 and p. 184.

<sup>5</sup>Ibid., p. 42 and pp. 184-186.

The fourth component of a disciplinary matrix was originally indicated by the term "paradigm," as was the entire disciplinary matrix of which it is a part. With the term "exemplar" Kuhn refers to a "problem-solution" which illustrates how a symbolic generalization is applied to phenomena.

#### Paradigm as exemplar

Kuhn regards his concept of "exemplar," or "shared example," as one of the major contributions of his analysis of science. The concept reinterprets a particular characteristic of the education of scientists and indicates an important aspect of the way Kuhn views the process of perception. Kuhn contends that solutions to a variety of problems provide not practice in the application of theory already learned, as commonly thought, but rather additional scientific knowledge of a form which cannot be expressed in rules and criteria. At issue is the question of how a student of science learns ". . . how the scientists of the community attach the expression [of a symbolic generalization] to nature."<sup>1</sup> Kuhn's answer is that doing exemplary problems results in ". . . ability to see a variety of situations as like each other, as subjects for  $f = ma$  or some other symbolic generalization, . . ."<sup>2</sup> Having completed a number of exemplary problems, the student of science has come to share with other members of a community ". . . a time-tested and group-licensed way of seeing."<sup>3</sup>

Kuhn's broader point is that members of a community of scientists have learned, by means of exemplars, to see different situations ". . . as like each other, as subjects for the same scientific law or law-sketch."<sup>4</sup> In his original argument for the priority of paradigms (in the disciplinary matrix sense) over shared rules, Kuhn cites Wittgenstein's concept of a "family resemblance" and Polanyi's concept of "tacit knowledge" acquired by practice and not fully analyzable in terms of rules for practice.<sup>5</sup> In his postscript, Kuhn explicitly indicates

<sup>1</sup>Ibid., p. 188.

<sup>2</sup>Ibid., p. 189.

<sup>3</sup>Ibid.

<sup>4</sup>Ibid., p. 190.

<sup>5</sup>Ibid., pp. 44-45.

that he is dissatisfied with the position, descended from Descartes, that perception is an unconscious but interpretive process. Kuhn rejects the one-to-one identification of stimuli with sensations and argues that ". . . the route from stimulus to sensation is in part conditioned by education."<sup>1</sup> Kuhn takes the position that "the knowledge of nature embedded in the stimulus-to-sensation route" cannot be fully expressed in rules or generalizations, but otherwise has all the characteristics of knowledge. Such knowledge is transmitted by the study of the shared exemplars of a particular community.<sup>2</sup> ". . . what perception leaves for interpretation to complete depends drastically on the nature and amount of prior experience and learning."<sup>3</sup>

The relationship of a disciplinary matrix to a community of scientists

One further issue remains, concerning the relationship between a community of scientists and its disciplinary matrix. As Kuhn has pointed out, his original use of paradigm is circular, for a paradigm is shared by the members of a community of scientists and yet that community is said to be composed of those who share a paradigm.<sup>4</sup>

Breaking this circularity indicates the ontological status of these two particulars and the methods by which they are identified in the historical records of science. A community of scientists is ontologically fundamental in Kuhn's account. Identifying the disciplinary matrix of a particular community is dependent upon the prior isolation of the community which shared or shares the matrix. Engaging in puzzle-solving research is a constitutive attribute of a community of scientists. Kuhn suggests a number of characteristics which could serve as individuating attributes. Among these are area of research specialization, pattern of education and entrance into the scientific profession, technical literature, and formal and informal networks of communication.<sup>5</sup> Once a community of scientists has been identified,

<sup>1</sup>Ibid., p. 193.

<sup>2</sup>Ibid., p. 196.

<sup>3</sup>Ibid., p. 198.

historical reconstruction of its disciplinary matrix may proceed by studying that community to determine the relevant attributes of its research and its members' education.

Kuhn's categorial framework

Kuhn's analysis of science takes material objects, individuals, and communities of scientists as maximal kinds of independent particulars. The following internally incorrigible propositions express constitutive and individuating attributes associated with the maximal kinds employed by Kuhn.

1. A community of scientists shares a disciplinary matrix which serves as the basis for research, by providing individual members with criteria for identifying puzzles and evaluating proposed solutions.

2. A disciplinary matrix has four components, each of which contributes suggestions about the behavior of nature--the properties of material objects and the characteristics of their interactions.

- a. "the formalizable natural laws and their associated concepts," referred to as "symbolic generalizations"
- b. beliefs in particular heuristic and ontological models
- c. values used to judge predictions and theories
- d. "problem-solutions which illustrate how a symbolic generalization is applied to material objects," referred to as "exemplars"

3. Exemplars represent scientific knowledge not expressable in rules and criteria, and this knowledge conditions an individual's perception of phenomena.

4. The generation of alternative matrices by individuals occurs most actively when the currently-accepted matrix fails to permit a puzzle-solution.

5. A community of scientists selects from among competing matrices the one most adequate for its further research.

Classical logic is the primary logic underlying Kuhn's categorial framework.

Kuhn's view of the logic  
of scientific inquiry

From Kuhn's perspective, epistemological issues come to the fore during periods of crisis, the only times when it is either possible or appropriate to "test" paradigms. It is part of his concept of normal science that the members of a community agree not to challenge or criticize the disciplinary matrix upon which they have agreed, in order that puzzle-solving may proceed without restriction. Kuhn suggests that attempts to develop procedures of verification or falsification have failed to recognize a distinction which his account of science identifies: the distinction between anomaly and subsequent crisis on the one hand and matrix competition and selection on the other.

Kuhn rejects theories of verification, whether absolute or probabilistic, on the grounds that they require "pure or neutral observation languages" which he regards as unachievable.<sup>1</sup> This position is related to his thesis about perception, which rejects the view that sensations are fixed and neutral. Kuhn contends that any such language will contain some expectations about nature.<sup>2</sup>

Kuhn's argument against Popper's emphasis of the importance of falsification reflects the differences in their categorizations; only Kuhn takes communities of scientists as a maximal kind of particular. Kuhn sees a parallel between falsification and the anomalous experiences which can lead to crises, but he expresses doubt that falsifying experiences exist at all.<sup>3</sup> This is but one point in an extensive and continuing debate between Popper and Kuhn. One of their major disagreements concerns the place of criticism, which Kuhn limits to extraordinary science but which Popper maintains must continually be part of a scientist's attitude. Kuhn tends to argue that his account of science is the sociological counterpart of Popper's perspective, perhaps the other side of the same coin. Popper rejects such an interpretation on the grounds that there are fundamental differences which

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<sup>1</sup>Ibid., pp. 145-146.

<sup>2</sup>Ibid., pp. 126-127.

<sup>3</sup>Ibid., p. 146.

separate them.<sup>1</sup>

Kuhn suggests that elements of both verification and falsification are preserved in his account of extraordinary science and scientific revolutions. Anomalies, which may provoke crises and the generation of alternative disciplinary matrices, raise the issue of falsification of the current matrix. Then, the actual occurrence of a scientific revolution by a community's decision to reject one matrix and accept another could be viewed as an event involving both verification and falsification.<sup>2</sup> This posture suggests, correctly, that Kuhn does not wish to apply the concept of truth in the context of theory-competition. Similarly, Kuhn rejects the notion that scientific progress represents movement toward the true representation of "the real world." At the close of his original edition, he suggests that development might be better viewed as "evolution from" rather than "evolution toward."<sup>3</sup>

The educational issues in  
Kuhn's analysis of science

Kuhn's perspective on the nature and consequences of education is influenced by his attitude toward the process of perception and his thesis that a disciplinary matrix is shared by members of a community of scientists. Three related issues arise in the course of his argument: (1) that knowledge is embedded in exemplars suggests a reinterpretation of the function served by problem solutions, (2) most scientific textbooks mask scientific revolutions, and (3) existing patterns of education are well-suited to the training of scientists.

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<sup>1</sup>The debate between Popper and Kuhn and their respective adherents is well expressed in the essays included in Imre Lakatos and Alan Musgrave (eds.), Criticism and the Growth of Knowledge.

<sup>2</sup>Kuhn, The Structure of Scientific Revolutions, p. 147.

<sup>3</sup>Ibid., pp. 170-173. See also Kuhn's essay, "Reflections on my Critics," in Lakatos and Musgrave (eds.), Criticism and the Growth of Knowledge, pp. 264-265.

The first issue has already been discussed in some detail. Problem solutions are seen as giving empirical content to theories, not practice in the application of theories. Along with his rejection of attempts to demonstrate the verification of an individual theory (or disciplinary matrix), Kuhn rejects the idea that problem solutions in textbooks provide a student with evidence for a theory and reasons for believing it.

But science students accept theories on the authority of teacher and text, not because of evidence. What alternatives have they, or what competence? The applications given in texts are not there as evidence but because learning them is part of learning the paradigm at the base of current practice. If applications were set forth as evidence, then the very failure of texts to suggest alternative interpretations or to discuss problems for which scientists have failed to produce paradigm solutions would convict their authors of extreme bias. There is not the slightest reason for such an indictment.<sup>1</sup>

The topic of the influence of scientific textbooks is part of Kuhn's view that science develops by revolution, not by accumulation. Textbooks are credited with perpetuating the idea of accumulation so effectively that the revolutions Kuhn finds so numerous have gone unnoticed by historians and philosophers, who often relied upon textbooks. The task of transmitting the current disciplinary matrix, including exemplars, is well served by textbooks, and for that task of transmission there is no need to identify discarded matrices. One significant result is the neglect of evidence for revolutions.

Partly by selection and partly by distortion, the scientists of earlier ages are implicitly represented as having worked upon the same set of fixed problems and in accordance with the same set of fixed canons that the most recent revolution in scientific theory and method has made seem scientific. No wonder that textbooks and the historical tradition they imply have to be rewritten after each scientific revolution. And no wonder that, as they are rewritten, science once again comes to seem largely cumulative.<sup>2</sup>

The third issue follows directly from the second. Even though textbooks conceal the existence of revolutions, the use of textbooks in

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<sup>1</sup>Kuhn, The Structure of Scientific Revolutions, pp. 80-81.

<sup>2</sup>Ibid., p. 138.

the training of scientists has been highly effective. By implication, training-by-textbooks should continue, despite its rigidity and narrow scope. Most scientists engage in puzzle-solving, and it is not likely that one could train individuals to invent alternatives in the absence of anomaly and crisis. Thus Kuhn is permitted the luxury of condoning the use of textbooks which mask revolutions by his position that a crisis occurs in a community of scientists, inevitably and beyond the influence of individuals to bring it about intentionally.

One is left to speculate about what Kuhn expects scientists to make of his perspective on science and how he would have science taught to non-scientists. It seems that scientists are to continue as they always have, perhaps deriving some satisfaction from being told that crises must be expected to occur at intervals. It is clearly beyond Kuhn's task to speak directly to the question of general rather than professional education in science. Kuhn's analysis suggests that textbooks for professional education will not serve the needs of general education. The analysis also identifies many issues to be examined by those who seek to understand science rather than engage in scientific research.

Disciplinary matrix and categorial framework: a comparison

Kuhn describes a disciplinary matrix as the shared non-observational and non-experiential commitments in which the members of a scientific community believe. This is one of several features of his analysis which indicate the appropriateness of asking how a disciplinary matrix is different from a categorial framework. On brief reflection it seems reasonable that there should be significant similarities between the arguments made by Kuhn and by Körner. Both suggest that the individual experience of change at the levels with which they are concerned may be comparable to the experience of a Gestalt-switch and that the experience involves a change of beliefs.<sup>1</sup>

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<sup>1</sup>Kuhn, The Structure of Scientific Revolutions, pp. 111-112 and pp. 198-204, and Körner, Categorial Frameworks, p. 65.

Kuhn's remark that a model may have a status ranging from ontological to heuristic seems directly comparable to Körner's point that conflict between framework-principles may result in rejection of one or the other or in adoption of the less acceptable one as a heuristic principle.<sup>1</sup>

That there are and should be differences is suggested by comparison of the tasks addressed in the two studies. As noted earlier, Körner examines the relationships among an individual's classification of the objects of his experience, his standards of explanation, and his metaphysical beliefs. For that task he elaborates the concept of a categorial framework. Kuhn's interests, while similar, are directed specifically to science and the nature of its progress. The concepts of disciplinary matrix and exemplar emerge from his efforts to interpret the historical development of science and the influence of scientists' professional education.

Perhaps the most interesting and relevant divergence between Kuhn and Körner concerns the question of whether different belief systems are commensurable. For Kuhn they are not, yet for Körner they clearly are. Körner's concept of categorial framework is intended to permit the achievement of that possibility.

Kuhn's argument about incommensurability is closely related to his concept of exemplar and the associated thesis about perception. Dominant in his discussion is the claim that there are attributes which cannot be expressed in rules, that there are similarities which one can learn to recognize but which cannot be stated.<sup>2</sup> The following passage is indicative of the manner in which Kuhn frames the problem.

Two men who perceive the same situation differently but nevertheless employ the same vocabulary in its discussion must be using words differently. They speak, that is, from what I have called incommensurable viewpoints. How can they even hope to talk together much less to be persuasive. . .

The practice of normal science depends on the ability, acquired from exemplars, to group objects and situations into similarity sets

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<sup>1</sup>Körner, Categorial Frameworks, p. 66.

<sup>2</sup>Ibid., p. 200.

which are primitive in the sense that the grouping is done without an answer to the question "Similar with respect to what?" One central aspect of any revolution is, then, that some of the similarity relations change. Objects that were grouped in the same set before are grouped in different ones afterward and vice versa.<sup>1</sup>

Kuhn suggests that translation between language communities is an appropriate context from which to draw techniques for resolving the "breakdown" of communication associated with critically different exemplars, and this suggestion seems helpful. In the end, Kuhn clearly acknowledges that translation can overcome the difficulties imposed by the fact that standards of explanation are influenced by the beliefs expressed in different matrices or frameworks.

As translation proceeds, furthermore, some members of each community may also begin vicariously to understand how a statement previously opaque could seem an explanation to members of the opposing group.<sup>2</sup>

Kuhn is never clear about whether information is similarly influenced by differences between matrices. His thesis about perception seems to imply that it is.

As noted earlier, it is part of Körner's basic thesis that an individual's explanatory standards and his categorial framework are "intimately related." Körner distinguishes clearly between information and explanation and concludes that ". . . explanation is framework-bound whereas information is not."<sup>3</sup> He goes on to identify two possible errors associated with the false premise that there is no difference between information and explanation. Clearly, Kuhn is not suggesting that neither explanation nor information is framework-bound. Much less clear is whether Kuhn errs (from Körner's perspective) in the opposite direction of concluding that information is framework-bound. As Körner notes, that conclusion supports the position that users of different frameworks cannot understand each other.<sup>4</sup> This conclusion is a theme in Kuhn's discussions of the nature of scientific revolutions.

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<sup>1</sup>Ibid.

<sup>2</sup>Ibid., p. 203.

<sup>3</sup>Körner, Categorial Frameworks, p. 64.

<sup>4</sup>Ibid., p. 65.

Körner and Kuhn approach this question quite differently. Körner argues that "common informative content" is possible even when the propositions expressing it for each of two individuals are respectively incompatible with the framework of the other.<sup>1</sup> Kuhn argues that there are differences, which one cannot fully express in propositions, which can create differences at the level of information. The issue captures a fundamental difference between the two concepts, disciplinary matrix and categorial framework. Körner's perspective permits the observation that the difference is only internally but not externally incorrigible.

Dimensions of the Analytical Scheme:  
The Nature of Science

Three accounts of the nature of science, by Carnap, Popper, and Kuhn, have been described and analyzed in terms of Körner's concept of a categorial framework. While the results of the analysis are interesting in their own right, the analysis has been conducted for the purpose of generating a scheme which may be used to analyze the provision an argument makes for the development of views of the nature of science.

Following Körner, the categorization of objects by Carnap, Popper, and Kuhn has been the basic point of comparison. Five other issues have been predominant in the preceding analysis, and they appear appropriate for use as dimensions of the nature of science in the analytical scheme. The five issues are (1) demarcation of science from non-science, (2) how the empirical content of science increases, (3) how objectivity is achieved in science, (4) the relationship of science to truth, and (5) how progress is achieved in science.

The dimensions are presented in Table 1, preceded by the issue of categorization of objects. On each dimension, the positions taken by the three analysts of science have been stated concisely. Thus Table 1 serves both as a summary of the analysis of three accounts of the nature of science and as a statement of dimensions of the analytical scheme

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<sup>1</sup>Ibid., p. 64.

relevant to the nature of science. In Chapter IV, additional dimensions of the analytical scheme are constructed in terms of arguments which examine the concept of teaching.

TABLE 1

DIMENSIONS OF THE ANALYTICAL SCHEME: THE NATURE OF SCIENCE

Carnap

Popper

Kuhn

*Categorization of objects:* What are the highest categories for understanding science?

Objects of reference  
Elementary experience

Observable events  
(material objects)  
Individuals

Material objects  
Individuals  
Communities of scientists

*Demarcation of science:* How is science distinguished from non-science?

Scientific statements are  
verifiable, since each  
object can be constructed  
from relations among  
elementary experiences

Scientific hypotheses are  
falsifiable, since they  
prohibit at least one  
observable event

Scientists engage in solving  
puzzles identified in terms  
of a shared disciplinary  
matrix which includes  
natural laws and illustra-  
tions of their application  
to phenomena

*How empirical content increases:* By what process does the empirical content of science increase?

By justification, on the  
basis of elementary experi-  
ences, of purely empirical-  
rational statements about  
objects of reference

By intersubjective agreement  
concerning experiences which  
test deductive consequences  
of scientific hypotheses

By acceptance of solutions of  
puzzles in which the current  
disciplinary matrix is  
applied to phenomena

TABLE 1--continued

Carnap

Popper

Kuhn

*Objectivity of science:* In what way is objectivity achieved in science?

Purely structural definite descriptions eliminate reference to the "material"

All scientific statements must be intersubjectively testable. Logical relations among statements are objective, while psychological feelings of conviction about experiences are subjective.

Objectivity of either observation language or falsification procedures is not fully compatible with a view of competition between disciplinary matrices.

*Relationship of science to truth:* What place has the concept of truth in an account of science?

Scientific statements are those whose truth-value can be decided in principle, by correlating basic relations among elementary experiences

Although always tentative, better scientific hypotheses approach the truth more closely

Analysis of science does not require reference to the concept of truth. Matrix selection asks which one should guide research, not which one is true.

The existence and success of science can be accounted for in terms of evolution from a given state of knowledge

*Progress of science:* What activities of science constitute progress?

"... finding and ordering the true statements about the objects of cognition," by constructing objects of reference and investigating their non-constructual properties and relations

Increasing the truth-content of hypotheses, by achieving greater degrees of falsifiability and corroboration through continuous criticism

Adoption of a new disciplinary matrix by a community of scientists, which sets new criteria for identifying and solving puzzles



## CHAPTER IV

### DEVELOPMENT OF THREE PERSPECTIVES

#### ON THE CONCEPT OF TEACHING

##### Introduction

This chapter develops dimensions of the analytical scheme relevant to the concept of teaching, thereby completing the task begun in Chapter III. Application of the entire analytical scheme to assess its usefulness in the analysis of arguments about the teaching of science is carried out in Chapter V. The argument in this chapter has two distinct phases. In the first, descriptive phase, five analyses of the concept of teaching are reported in considerable detail. In the second, interpretive phase, perspectives on the concept of teaching are developed and then contrasted on various dimensions which constitute the portion of the analytical scheme relevant to the concept of teaching.

##### Selection of interpretations of teaching

The literature in which techniques of philosophical analysis are applied to educational concepts has grown rapidly in recent years, with some impressive achievements.<sup>1</sup> Within that literature the investigator has identified more than thirty papers which focus attention on the concept of teaching. From these, five have been selected for description and analysis in this chapter. Each of the five papers develops a clear and distinctive contribution to the analytic clarification of the concept of teaching.

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<sup>1</sup>This topic is considered in several of the essays by Israel Scheffler in Reason and Teaching (Indianapolis, Indiana: The Bobbs-Merrill Company, Inc., 1973). That collection of essays illustrates the intellectual development of one important contributor to philosophical analysis of educational concepts and issues.

As with the preceding analysis of the nature of science, it seems neither necessary nor appropriate to survey the extensive history of philosophical analysis of the aims and techniques of education.<sup>1</sup> However, it is appropriate to identify the type of analysis to which the concept of teaching is being subjected. In contrast to the divergence of the three accounts of the nature of science examined in Chapter III, the interpretations of teaching which are examined here have a great deal in common.

This analysis of the concept of teaching emphasizes one of several possible perspectives on education. Reference to two different ways of categorizing perspectives on the nature of education facilitates identification of the perspective being emphasized. Eisner and Vallance examined recent literature in the field of curriculum and developed a set of five categories to identify different, somewhat conflicting sets of assumptions which writers tend to take for granted in their arguments.<sup>2</sup> Curriculum is alternately viewed in terms of (1) development of cognitive processes, (2) technology, (3) self-actualization, (4) social relevance or reconstruction, or (5) academic rationalism. These labels effectively indicate the general nature of the divergent perspectives recognized by Eisner and Vallance; elaboration of the categories is unnecessary for present purposes.

A related but shorter list of perspectives is presented by Crittenden in a paper which explores the relationship of assumptions about the social context and the processes of education to the conduct

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<sup>1</sup>One valuable source of information on the historical development of the concept of teaching is Harry S. Broudy and John R. Palmer, Exemplars of Teaching Method (Chicago: Rand McNally & Company, 1965).

<sup>2</sup>Elliot W. Eisner and Elizabeth Vallance, "Five Conceptions of Curriculum: Their Roots and Implications for Curriculum Planning," in Conflicting Conceptions of Curriculum, ed. by Elliot W. Eisner and Elizabeth Vallance (Berkeley, California: McCutchan Publishing Corporation, 1974), pp. 1-18.

of teacher education.<sup>1</sup> Crittenden discusses interpretations of education as (1) "a process of socialization," (2) "growth through the satisfaction of felt need and interests," and (3) "initiation into public traditions of human understanding." These interpretations seem to correspond respectively to the categories of social relevance or reconstruction, self-actualization, and academic rationalism in the Eisner and Vallance analysis.

The following analysis of the concept of teaching is dominated by the perspective of academic rationalism or "initiation into public traditions of human understanding." This perspective is most complementary to the preceding analysis of the nature of science. It is also the perspective which provides strongest support for philosophical analysis of the concept of teaching and accordingly occurs more than the others in arguments seeking analytic clarification of the concept. Because conflicting views on teaching are discussed within each of the five arguments selected for examination, it is possible to develop alternative positions from arguments which share a common perspective on the nature of education.

#### Overview of the analysis of the concept of teaching

Consistent with the study's focus on teacher education, the analysis of the concept of teaching assumes the perspective of the teacher and considers both ends and means--what the teacher is trying to achieve and how he goes about it. The nature of knowledge and the position of the learner or pupil are related to the role of a teacher within the general school setting.

The sequence in which the five interpretations are presented is quite deliberate. Michael Oakeshott's essay, "Learning and Teaching,"<sup>2</sup>

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<sup>1</sup>Brian Crittenden, "Some Prior Questions in the Reform of Teacher Education," Interchange, IV, 2/3 (1973), 1-11.

<sup>2</sup>Michael Oakeshott, "Learning and Teaching," in The Concept of Education, ed. by R. S. Peters (London: Routledge & Kegan Paul, 1967), pp. 156-176.

provides an initial, general discussion of those two activities when knowledge is viewed as an inheritance of distinctively human achievements, combining information and judgment. Israel Scheffler's essay, "Philosophical Models of Teaching,"<sup>1</sup> develops similar points within a specific focus on the concept of teaching. Three models are sketched; two have shortcomings which are remedied in the third. Douglas Roberts and Dolores Silva reach compatible conclusions in a paper titled "Curriculum Design, Teaching Styles, and Consequences for Pupils."<sup>2</sup> From a perspective of alternate schemes for representing and explaining observations, they consider the consequences of different teaching styles.

The discussion by Roberts and Silva of the different prerogatives of teacher and pupil introduces the broad topic of authority which is explored in detail by R. S. Peters in his essay, "Authority and Education."<sup>3</sup> In the last of the five papers, titled "Socratic Method, Platonic Method, and Authority,"<sup>4</sup> James Ogilvy explores the relationship between teaching style and authority and develops yet another important dimension of the concept of teaching.

Each of the five interpretations provides a significant perspective which is used in the subsequent construction of a "composite" interpretation of the concept of teaching. Körner's concept of a categorical framework is employed in the analysis of two alternate ways of deviating from the composite interpretation. The chapter closes with presentation of the teaching dimensions of the analytical scheme.

<sup>1</sup>Israel Scheffler, "Philosophical Models of Teaching," Harvard Educational Review, XXXV, 2 (Spring 1965), 131-143.

<sup>2</sup>Douglas A. Roberts and Dolores Silva, "Curriculum Design, Teaching Styles, and Consequences for Pupils," Samplings [Journal of the Future Schools Study Project, Albuquerque, New Mexico] I, 4 (July 1968), 16-28.

<sup>3</sup>R. S. Peters, Ethics and Education (London: George Allen & Unwin Ltd, 1966), pp. 237-265.

<sup>4</sup>James A. Ogilvy, "Socratic Method, Platonic Method, and Authority," Educational Theory, XXI, 1 (Winter 1971), 3-16.

Oakeshott: Knowledge as an Inheritance  
of Human Achievements

The theme of Michael Oakeshott's essay, "Learning and Teaching," is that the interpretation of knowledge as "a manifold of different 'abilities'," each a conjunction of information and judgment, has significant consequences for one's understanding of learning and teaching. Specifically, Oakeshott argues that teaching must be understood to involve two different forms of communication--"instructing," or communicating information; and "imparting," or communicating judgment. The two aspects of knowledge can be communicated and acquired, but not in the same manner and not on separate occasions.<sup>1</sup>

Basic premises of the argument

Oakeshott begins by identifying what may be regarded as his basic premises about learning and teaching and about the general nature of teacher and pupil roles. This is a useful exercise in which Oakeshott declares his stand with respect to some familiar metaphors and issues.

Oakeshott regards learning as ". . . an activity possible only to an intelligence capable of choice and self-direction in relation to his own impulses and to the world around him."<sup>2</sup> His claim is that an activity of which "understanding and being able to explain" can be a part is different in all respects from an activity of which they cannot be a part.<sup>3</sup> Two basic points are made about teaching. "The counterpart of the teacher is not the learner in general, but the pupil."<sup>4</sup> This statement indicates that attention is focused upon learning which occurs in response to teaching. Oakeshott also specifies his concept of what a

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<sup>1</sup>Michael Oakeshott, "Learning and Teaching," in The Concept of Education, ed. by Peters, pp. 170-176.

<sup>2</sup>Ibid., p. 156.

<sup>3</sup>Ibid., p. 157.

<sup>4</sup>Ibid.

teacher communicates to a pupil. "Every human being is born an heir to an inheritance of human achievements, of 'expressions' of human minds to which he can succeed only in a process of learning."<sup>1</sup>

With these and related remarks Oakeshott makes it quite clear that he regards teaching and learning as concepts to be understood from consideration of the nature of knowledge developed by preceding generations. He maintains that teaching involves planned rather than accidental communication, in the presence of a pupil regarded as ready to learn what is communicated to him.<sup>2</sup> "Teaching is the deliberate and intentional initiation of a pupil into the world of human achievement, or some part of it."<sup>3</sup> Specifically, Oakeshott maintains ". . . that a teacher is one who studies his pupil, that the initiation he undertakes is one which has a deliberated order and arrangement, and that, as well as knowing what he designs to transmit, he has considered the manner of transmission."<sup>4</sup>

Oakeshott completes his opening statement of premises by indicating his understanding of the nature of the "inheritance" which a teacher communicates to his pupil. The inherited achievements are seen as contingent, not necessary, and neither finished nor unfinished. They are more likely to be confusing than clear, and they suggest rather than dictate ways of thinking. Oakeshott recognizes that a teacher may desire some guarantee of the value and permanence of the inheritance, but he maintains that such security is not available from any source.<sup>5</sup>

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<sup>1</sup>Ibid., p. 158.

<sup>2</sup>Further developments of this point are available in B. Paul Komisar, "Teaching: Act and Enterprise," in Concepts of Teaching: Philosophical Essays, ed. by C. J. B. Macmillan and Thomas W. Nelson (Chicago: Rand McNally & Company, 1968), pp. 63-88, and in Paul Hirst, "What is Teaching?", Journal of Curriculum Studies, III, 1 (May 1971), 5-18.

<sup>3</sup>Oakeshott, "Learning and Teaching," p. 159.

<sup>4</sup>Ibid., p. 160.

<sup>5</sup>Ibid., p. 162.

Knowledge as a conjunction of  
information and judgment

The detailed accounting of the introduction to Oakeshott's argument in "Learning and Teaching" serves to indicate both the assumptions of his perspective and his careful attention to consistency and comprehensiveness. Against this background, his main argument can be described more concisely. It has been noted that Oakeshott considers what is known in terms of abilities comprised of both information and judgment.

This conjunction, in a concept of 'abilities', of what we know and the use we make of it, is not designed to prove anything, but merely to indicate the way in which we carry about with us what we may be said to know. . . . What we know constitutes an equipment which we possess in terms of what it enables us to do or to understand.<sup>1</sup>

Information, "the explicit ingredient of knowledge," is composed of facts which provide ". . . rules or rule-like propositions relating to abilities."<sup>2</sup> These rules represent either information which is required for doing something or criteria for recognizing that something has been done incorrectly. Information which explains a performance is a third type of rule-like proposition, but this type of information ". . . is never a component of the knowledge which constitutes the performance."<sup>3</sup>

Judgment, in Oakeshott's view, is the "implicit" ingredient of knowledge, since it cannot be specified in propositions. "Before any concrete skill or ability can appear, information must be partnered by 'judgment,' 'knowing how' must be added to the 'knowing what' of information."<sup>4</sup>

. . . , I do not think we can avoid recognizing what I have called 'judgment' as a partner, not only in those abilities we call skills, but in all abilities whatever, and, indeed, more particularly in those abilities which are almost exclusively concerned with mental operations.<sup>5</sup>

<sup>1</sup>Ibid., p. 164.

<sup>2</sup>Ibid., pp. 164-165.

<sup>3</sup>Ibid., pp. 164-167.

<sup>4</sup>Ibid., p. 167.

<sup>5</sup>Ibid., p. 168.

In short, in every 'ability' there is an ingredient of knowledge which cannot be resolved into information, and in some skills this may be the greater part of the knowledge required for their practice.<sup>1</sup>

#### Implications for teaching and learning

From his premises about the concern of teacher and learner with knowledge as an inheritance of human achievement, and from his view of knowledge as abilities in which information and judgment are united, Oakeshott derives implications for understanding the activities of teaching and learning. Both activities are regarded as twofold.

. . . teaching may be said to be a twofold activity of communicating 'information' (which I shall call 'instructing') and communicating 'judgment' (which I shall call 'imparting'); and learning may be said to be a twofold activity of acquiring 'information' and coming to possess 'judgment'.<sup>2</sup>

The information-communicating aspect of teaching is a familiar one. Oakeshott's contribution to the analysis of this aspect of teaching derives from his earlier premises. It is a teacher's responsibility to select the information to be communicated and to organize the information to reveal its "rule-like character." The teacher must also order the information to be communicated and provide exercises by which pupils will come to recognize the information in other forms and recall it in appropriate contexts.<sup>3</sup> These are familiar aspects of the activity of teaching which Oakeshott has given coherence with his view of information as part of a pupil's inheritance of human achievements, into which a teacher strives to initiate him.

Oakeshott's greater contribution to the analysis of teaching is revealed in his discussion of the judgment-communicating aspect of teaching. In the following passage he extends his earlier discussion of judgment, pointing out that one must learn to think in particular ways, but that this is not done in the same manner as one learns information.

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<sup>1</sup>Ibid., p. 169.

<sup>2</sup>Ibid., p. 170.

<sup>3</sup>Ibid., p. 172.

'Judgment', then, is that which when united with information, generates knowledge or 'ability' to do, to make, or to understand and explain. It is being able to think--not to think in no manner in particular, but to think with an appreciation of the considerations which belong to different modes of thought. This, of course is something which must be learned; it does not belong to the pupil by the light of nature, and it is as much a part of our civilized inheritance as the information which is its counterpart. But since learning to think is not acquiring information it cannot be pursued in the same way as we add to our stock of information.<sup>1</sup>

Judgment is an ability learned in the course of acquiring information, and it can only be imparted by a teacher as he is instructing. It is by the ability of judgment that one moves from information to permitted or prohibited conclusions. Thus judgment may be most clearly imparted at moments when pupils become aware of "concrete situations" in which facts are not simply displayed but organized by being used in an example or argument.<sup>2</sup> Oakeshott sees the acquiring of judgment not only as learning to interpret and use information but also as "learning to recognize and enjoy the intellectual virtues" and acquiring "the ability to detect the individual intelligence which is at work in every utterance, even in those which convey impersonal information."<sup>3</sup>

The difficulties associated with identifying and describing the concept of judgment account for Oakeshott's rather elaborate preparations for these conclusions about how teaching and learning may be understood. These remarks about learning are restricted to learning which is the counterpart of teaching. The two activities of learning and teaching are discussed with reference to knowledge viewed as a contingent inheritance of human achievements, against which a pupil comes to see himself as uniquely human, and into a portion of which a teacher strives to initiate his pupils. From the view of knowledge as abilities comprised of information and judgment, Oakeshott argues that teaching simultaneously includes instructing in information and imparting judgment.

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<sup>1</sup>Ibid., p. 173.

<sup>2</sup>Ibid., pp. 175-176.

<sup>3</sup>Ibid., p. 174.

Oakeshott's argument is firmly rooted in the perspective of academic rationalism. To some, aspects of his position will seem unduly neglectful of pupils' personal experiences. His argument is particularly valuable for the contribution he discusses of judgment makes to understanding important aspects of teaching, ranging from differences among modes of thought to critical characteristics of different styles of teaching. Attention shifts now to the second interpretation of teaching, developed by Scheffler in a quite different manner. Scheffler's position is compatible with Oakeshott's, particularly in terms of viewing knowledge as an inheritance and teaching as an activity concerned with communicating simultaneously both information and judgment.

Scheffler: A Metaphor of  
Principled Deliberation

In "Philosophical Models of Teaching," Israel Scheffler sets out to provide an "indirect" response to normative, epistemological, and empirical questions about teaching. His technique is to present and criticize three "philosophical models" of teaching, designated the impression, insight, and rule models. As the argument unfolds, it becomes clear that the models are not regarded as equally defensible. The rule model is deemed most appropriate because it best captures certain essential features of knowledge.

In his argument Scheffler suggests that the insight model is an improvement upon the impression model, and the rule model in turn an improvement upon the insight model. This suggestion is convenient to the "inductive" development of the claims being made, but it is not essential to the validity of the argument. Here it is more valuable to consider the impression and insight models for their contributions to understanding the rule model. In the subsequent derivation of the teaching dimensions of the analytical scheme, the impression and insight models are interpreted as attempts to simplify the concept of teaching by overemphasizing some features and neglecting others which are preserved and balanced in the rule model.

Scheffler associates each of the three models with a particular philosopher, in an attempt to indicate more clearly some of the unique

features of each model. Unfortunately, these associations cannot be regarded as indicative of the historical roots of each model, and the associations generate some problems as they resolve others. The investigator here reports those details of the three models which are most relevant to the present task of examining distinctive analyses of the concept of teaching.

Scheffler opens his argument with a definition which expresses his view that teaching is an intentional activity which must respect the learner's own judgments. "Teaching may be characterized as an activity aimed at the achievement of learning, and practiced in such manner as to respect the student's intellectual integrity and capacity for independent judgment."<sup>1</sup> Yet this definition does not indicate for a teacher what learning he should try to achieve, what constitutes such learning, and how one should go about trying to achieve it. Presentation of the three models is intended to develop answers to these questions.

#### The impression model of teaching

Scheffler's first model of teaching regards knowledge as something to be transmitted by a teacher for storage by a pupil.

The impression model is perhaps the simplest and most widespread of the three, picturing the mind essentially as sifting and storing the external impressions to which it is receptive. The desired end result of teaching is an accumulation in the learner of basic elements fed in from without, organized and processed in standard ways, but, in any event, not generated by the learner himself.<sup>2</sup>

Scheffler presents two versions of this model. One is termed "empiricist" and associated with Locke. The second is termed "verbal" because it recognizes that ". . . not only sense experience but language, and, moreover, accepted theory"<sup>3</sup> are to be impressed on the mind. In both cases, knowledge is construed as the "stored accumulation" of whatever is presented to the learner.

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<sup>1</sup>Israel Scheffler, "Philosophical Models of Teaching," p. 131.

<sup>2</sup>Ibid., p. 132.

<sup>3</sup>Ibid., p. 134.

Scheffler credits the impression model with recognizing the importance of experience, yet he sees the model as misdirected. Its suggestion that the learner need only store and accumulate what is presented fails to recognize that the learner must be able to use what he learns. It also fails to recognize the possibility and importance of "innovation" by the learner.<sup>1</sup>

#### The insight model of teaching

The second model of teaching is based upon a view of knowledge as "vision" or "insight into meaning."

. . . the "insight model" . . . represents a radically different approach. Where the impression model supposes the teacher to be conveying ideas or bits of knowledge into the student's mental treasury, the insight model denies the very possibility of such conveyance. Knowledge, it insists, is a matter of vision, and vision cannot be dissected into elementary sensory or verbal units that can be conveyed from one person to another.<sup>2</sup>

The teacher can only "prompt" or "stimulate;" if such learning does occur, it goes beyond what the teacher has done. And it is this "insight into meaning" which is required for understanding and using knowledge, in contrast to storing it for recall.<sup>3</sup>

Scheffler analyzes the prompting theory in St. Augustine's dialogue, "The Teacher," and subsequently makes a distinction between information and knowledge. To know is not only to understand and accept information but also ". . . to have earned the right, through one's own effort or position, to an assurance of its truth."<sup>4</sup> Ultimately, Scheffler finds that the insight model has called attention to important points yet, like the impression model, it is incomplete. The impression model stresses "conservation" of knowledge in its public, collective sense. The insight model stresses "innovation" and accounts for creativity by marking the importance of the individual learner's efforts to personally come to know. Yet, Scheffler explains, "vision of reality" is not the right metaphor for truths other than those based upon observation or introspection. For propositions in the sciences, politics,

<sup>1</sup>Ibid.

<sup>2</sup>Ibid., p. 135.

<sup>3</sup>Ibid.

<sup>4</sup>Ibid., p. 137.

history, or law, "principled deliberation" seems a better metaphor, permitting reference to reasons, evidence, principles, and decisions in coming to understand what is distinctive about knowledge.<sup>1</sup>

Beyond the cognitive insight, lies the fundamental commitment to principles by which insights are to be criticized and assessed, in the light of publicly available evidence or reasons. In sum, then, the shortcoming of the insight model may be said to lie in the fact that it provides no role for the concept of principles, and the associated concept of reasons.<sup>2</sup>

### The rule model of teaching

The third model of teaching interprets knowledge through the metaphor of principled deliberation, tempering individual insight with adherence to rules which exist within traditions of scholarship.

In contrast to the insight model, the rule model clearly emphasizes the role of principles in the exercise of cognitive judgment. The strong point of the insight model can thus be preserved: The knower must indeed satisfy a further condition beyond the mere receiving and storing of a bit of information. But this condition need not, as in the insight model, be taken to involve simply the vision of an underlying reality; rather, it generally involves the capacity for a principled assessment of reasons bearing on justification of the belief in question. The knower, in short, must typically earn the right to confidence in his belief by acquiring the capacity to make a reasonable case for the belief in question.<sup>3</sup>

Scheffler associates the rule model with Kant's emphasis on reason and the adherence to rules or principles. The rule model, he argues, recognizes and respects the autonomous judgment of the learner or knower, who has a ". . . right to seek reasons in support of claims upon his credibilities and loyalties, and [a] correlative obligation to deal with such reasons in a principled manner."<sup>4</sup>

Ultimately, Scheffler makes explicit a point which is implicit throughout his argument. The impression and insight models have both strengths and shortcomings in their conceptions of knowledge and the nature of teaching and learning. The rule model can be regarded as

<sup>1</sup>Ibid., p. 138.

<sup>2</sup>Ibid., p. 139.

<sup>3</sup>Ibid., p. 140.

<sup>4</sup>Ibid., p. 141.

providing a supplement to those points which were appropriately stressed by each of the other two models. Scheffler expresses this feature of the rule model in the following way.

. . . , intermediate between the public treasury of accumulated lore mirrored by the impression model, and the personal and intuitive grasp of the student mirrored by the insight model, it places general principles of rational judgment capable of linking them<sup>1</sup>.

Thus Scheffler's rule model of teaching indicates that a teacher's task, in its fullest development, is to make it possible for a learner to enter into living traditions of scholarship. Knowledge must be preserved, yet each learner must make it his own. He can do so only by respecting the tradition of principles from which the knowledge has emerged.

By a different route, Scheffler reaches conclusions which are consistent with the position developed by Oakeshott. Scheffler moves through several metaphors and philosophical positions to a stance which reflects the same concept of "inheritance" with which Oakeshott begins his argument. The parallels between information and impressions on the one hand, and between judgment and vision on the other, are not coincidental. Scheffler's account concludes with a synthesizing metaphor expressing the position Oakeshott argued from the start. Scheffler's argument gives fuller attention to conceptions of teaching which stress either information or judgment at the expense of the other.

The idea of an inheritance of human achievements and evolving traditions of public scholarship which pervades the first two interpretations of teaching is also prominent in the third, developed by Roberts and Silva. Their argument presents an epistemological position at the outset, as Oakeshott's did, and it later identifies two unsatisfactory "teaching styles" which parallel Scheffler's impression and insight models of teaching.

Roberts and Silva: Representations  
and Explanations of Phenomena

The third interpretation of teaching is expressed in a discussion of curriculum-planning considerations, titled "Curriculum Design,

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<sup>1</sup>Ibid.

Teaching Styles, and Consequences for Pupils." Douglas Roberts and Dolores Silva have selected a title which indicates their awareness that reorganization of part of a school's curriculum requires information not only about what experiences are considered desirable for pupils but also about the "teaching style" required to achieve the intended outcomes for pupils. Roberts and Silva use the phrase "teaching style" to characterize ". . . a teacher's unique way of patterning teaching acts that are predictable under specified conditions."<sup>1</sup>

Ordering schemes and  
consequences for pupils

The authors' epistemological position is indicated in their discussion of consequences for pupils. They approach the school curriculum from the perspective that there is something intellectual which is worthwhile for pupils. They are specifically interested in ". . . cognitive capacities and processes, . . . interpreted in terms of human capacity to order diverse observations and the function of these ordering processes in the human search for order and meaningfulness."<sup>2</sup> Their concern is with the diversity of observations which are experienced by individuals and in which individuals seek order and meaning by selecting observations and developing "representations and/or explanations."

In discussing certain aspects inherent in curriculum building, we believe that it is useful to view human history, at least in part, as a record of the invention and use of ordering schemes for representing and/or explaining diverse observations.<sup>3</sup>

The end which Roberts and Silva have in view is a curriculum which permits the student to learn ". . . responsible freedom of choice for how he thinks."<sup>4</sup> They argue that pupil experiences appropriate to that end would include ordering diverse observations, becoming aware that they are doing so, learning that there are alternative ways to order the same observations, and realizing that particular consequences

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<sup>1</sup>Douglas A. Roberts and Dolores Silva, "Curriculum Design, Teaching Styles, and Consequences for Pupils," p, 16.

<sup>2</sup>Ibid., pp. 17-18.

<sup>3</sup>Ibid., p. 18.

<sup>4</sup>Ibid., p. 19.

follow from each choice of a way to order observations.<sup>1</sup> Particularly interesting is the manner in which the authors express the view that a teacher's task is to introduce pupils to knowledge developed by their predecessors, knowledge which includes both information and judgment.

We view pupils as having a great deal of experience to process in the course of a lifetime, and the human race as having a great deal to offer for use in that task. At the heart of our ideology is the notion of choice among alternatives, but responsible choice. . . . The task of the school, according to our position, is to be sure the pupil is aware of alternative representational and explanatory schemes, and of a set of criteria for choosing among these based on informed judgment of the consequences and implications of each to the individual pupil and to others.<sup>2</sup>

When that task has been achieved, the final and personal decision among alternatives is left to the pupil.<sup>3</sup>

### Teaching styles

After examining in detail how the content of such a curriculum might be organized, Roberts and Silva discuss the teaching style which they regard as appropriate for achieving the goals of that curriculum. Their model involves information processing, communication, and the prerogatives of teacher and pupil in both. In what they term the "trialogue" style, both teacher and pupils have access to the "domain of observable phenomena."<sup>4</sup> The authors present a very useful statement of the different prerogatives which teacher and pupil must retain in the teaching-learning interaction.

On the one hand, the teacher has greater expertise than the pupil at representing and/or explaining observations by virtue of his longer study of what the human race has available for that purpose. As the teacher receives observations from the domain of observable phenomena, he has a substantial arsenal of representations and/or explanations for those, and he must retain the prerogative of insisting that the pupil try them when it is appropriate. On the other hand, the pupil is in the position of knowing which observations he has made within the domain, and thus he knows better than the teacher which observations need to be represented and/or explained in his

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<sup>1</sup>Ibid.

<sup>2</sup>Ibid., pp. 19-20.

<sup>3</sup>Ibid., p. 20.

<sup>4</sup>Ibid., p. 23.

personal experience. It remains the pupil's prerogative, then, to make use of representations and/or explanations, according to whether or not they are relevant to his growth of personal knowledge.<sup>1</sup>

In the triologue teaching style, communication between teacher and pupil involves a mutual exchange of observations and representations and/or explanations. Respect is maintained both for the teacher's prerogative to introduce the achievements of the human race and for the pupil's prerogative to make his own attempts to process information in achieving personal knowledge.

To emphasize the features of the triologue style, which is considered appropriate for achieving the curricular consequences they describe, Roberts and Silva sketch two other teaching styles and explain why they are regarded as inappropriate. They characterize an "imposition" style as one which denies pupils access to the domain of observable phenomena while the teacher communicates to pupils the representations and/or explanations developed by the human race.<sup>2</sup> More generally, even if pupils were granted access to the domain of observable phenomena, the teacher's prerogative would be overemphasized if he refused to consider pupils' attempts to represent and explain phenomena relevant to their own experiences.

A second inappropriate teaching style is termed an "abandonment" style. It overemphasizes the pupil's prerogative to represent and explain what is relevant to his experience, ignoring the potential contribution of the teacher's expertise to that task. Denied his basic prerogative, the teacher is in an unsatisfying position, while the pupil is "abandoned" to retrace on his own the ordering achievements by which his predecessors developed what is now known.<sup>3</sup>

The imposition and abandonment styles indicate the inadequate alternatives to which one can be led by failure to respect and balance both teacher and pupil prerogatives in the teaching-learning situation. The triologue teaching style attempts to preserve that respect and balance, in order to achieve certain pupil outcomes associated with the existence of alternative ways to represent and explain observations.

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<sup>1</sup>Ibid., pp. 23-24.

<sup>2</sup>Ibid., p. 25.

<sup>3</sup>Ibid., pp. 25-26.

An Interim Summary

In the three interpretations of teaching just examined, the position is taken that teaching and learning cannot be understood properly and adequately without reference to the intellectual achievements which are preserved and extended in various forms of knowledge and associated style of inquiry. Oakeshott casts this knowledge as an inheritance of human achievements, interpreted as abilities blending information and judgment. Scheffler speaks of ongoing traditions of rationality to which learners must be introduced. Roberts and Silva emphasize the finding of order and meaning in observations by the invention of ways to represent and/or explain phenomena. The three accounts complement each other as ways to interpret knowledge. They jointly maintain that what teacher and pupil seek to achieve and how they go about it must be based upon an adequate conceptualization of knowledge.

Roberts and Silva give the most explicit attention to teaching style, although Scheffler and Oakeshott also offer clear suggestions for how a teacher should go about achieving the initiation of a pupil into an inherited tradition of knowledge. There are important parallels between the inappropriate teaching styles sketched by Roberts and Silva and the inadequate models of teaching described by Scheffler. The imposition style corresponds to the impression model and an emphasis on what Oakeshott called "instructing." The abandonment style corresponds to the insight model in certain respects. Later in this chapter, these parallels are examined further in the derivation of dimensions of the analytical scheme relevant to the concept of teaching.

Roberts and Silva go beyond epistemological considerations to introduce the concept of teacher and pupil prerogatives in teaching-learning communication. They carefully note that these prerogatives are not equal. Only the teacher, who has already developed expertise in the knowledge to be communicated to his pupils, can make certain decisions which influence the overall course of teacher-learner interaction. This fundamental feature of the concept of teaching gives rise to the issue of authority, to which the discussion now turns.

That students currently tend to react quite negatively to behavior which they perceive to be "authoritarian" reminds one that there are a host of other considerations besides "initiation into an inheritance" which can in fact dominate the teaching-learning situation and obscure that essential feature discussed above. One purpose of this exploration of the concept of teaching is to establish a perspective from which logically distinctive characteristics of the activity of teaching may be recognized.

Peters: The Teacher as  
an Authority in Authority

The two remaining interpretations of teaching are developed with specific reference to the concept of authority. The first is developed by R. S. Peters in the essay, "Authority and Education," in his book titled Ethics and Education. Peters' essay is particularly valuable for its analysis of several general types of authority, in an attempt to be very clear about the several ways in which the concept bears on the activity of teaching.

Two applications of the  
concept of authority

Peters begins his analysis by noting that ". . . the concept of authority is inseparably connected with a rule-governed form of life."<sup>1</sup> The concept is most frequently encountered in systems of social control, where it is appropriate to speak of an individual being in authority and thereby being "authorized" to make decisions involving the application of some set of rules. The concept of authority also has application outside the context of social control. In the domain of knowledge we may properly speak of an individual being an authority.

There are two essential differences between these two applications of the concept of authority. With respect to social control, one is in authority by appointment and the appeal is to rules. With

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<sup>1</sup>R. S. Peters, "Authority and Education," p. 238.

respect to knowledge, one is an authority by prior training and success, and the appeal is to reasons and evidence.<sup>1</sup>

Authority is a particularly significant concept for the activity of teaching, because in our modern educational context, ". . . the teacher is an authority figure in both the above senses."<sup>2</sup>

He is put in authority to do a certain job for the community and to maintain social control in the school while he is doing it. He must also be an authority on some aspect of the culture which he is employed to transmit. It is also expected that, to a certain extent, he will be an expert on the behaviour and development of the children over whom he is in authority, and on methods of teaching them.<sup>3</sup>

There is a further distinction about authority which Peters is careful to note at the outset, the distinction between formal and actual authority. In every situation of a formal appointment to authority, there are associated expectations related to the actual exercise of that authority.<sup>4</sup> Teachers are not excepted from the significance of this distinction, and it may be that they are particularly subject to its significance in times when authoritarian behavior tends to be resented.

#### Authority as analyzed by Weber

Peters' discussion retraces the analysis of authority by Max Weber, who distinguished between authority based on tradition and that based on a legal-rational system. A traditional base of authority typically confers status in all contexts and is regarded as unquestionable by those who recognize it. In contrast, a legal-rational base of authority confers status only within the individual's "sphere of competence" and it reflects a belief in the legality of the rules by which persons are placed in positions of exercising authority.<sup>5</sup> Outside the context of social control, in the area of knowledge, one can be recognized as

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<sup>1</sup>Ibid., pp. 238-240.

<sup>2</sup>Ibid., p. 240.

<sup>3</sup>Ibid.

<sup>4</sup>Ibid., p. 241.

<sup>5</sup>Ibid., pp. 242-243.

an authority without the support of either inherited status or legal appointment. In our present educational context, a teacher is typically appointed legally on evidence of being an authority in some field of knowledge.<sup>1</sup>

Peters reports that Weber was particularly interested in the phenomenon of "charismatic" authority, which blends being an authority with being in actual authority, and perhaps in formal authority as well. The position of teacher represents an instance in which one who is an authority is placed in authority for the purpose of transmitting to others the valued knowledge on which he is an authority. The concept of "charisma" may be associated with teachers who, in addition, are singularly effective in the actual exercise of authority.<sup>2</sup>

These several distinctions about authority are relevant and necessary because Western culture in particular has experienced over several centuries a replacement of traditional authority by rational authority in various aspects of life. This replacement brings with it the notion that authority is something which requires justification. Peters notes that authority in the adult-child and teacher-pupil relationships no longer rests on a traditional base. He concludes that ". . . the case for authority in the sphere of knowledge . . . must be regarded at best as a provisional expedient."<sup>3</sup> The final appeal in matters of knowledge can never be to an individual but only to reasons and evidence and public procedures for criticizing them. Provisional authority in matters of knowledge is granted so that knowledge may be applied to matters of everyday life and so that it can be transmitted to succeeding generations. For this latter purpose the institution of the school has been established.<sup>4</sup>

### Three senses of authority for a teacher

Peters concludes his analysis by discussing the authority of a teacher in three senses already mentioned. A teacher is given formal authority to achieve certain educational goals. Then, in the actual

<sup>1</sup>Ibid., p. 244.

<sup>2</sup>Ibid., pp. 245-247.

<sup>3</sup>Ibid., p. 250.

<sup>4</sup>Ibid., pp. 250-251.

exercise of authority, the teacher must maintain social control while he is initiating his pupils into the area of knowledge in which he has expertise. It is at this point that Peters blends ideals with practical concerns in an analysis which raises a number of issues associated with the various senses of a teacher's authority.

#### Formal authority by appointment

Peters suggests that there are several purposes for which a teacher is formally appointed to authority. In addition to the primary purpose of initiating others into what the community regards as intrinsically worthwhile, he can also contribute to the instrumental functions of training and selecting individuals for the various types of work required in the society as a whole. Peters' comparison of American and English systems of education in terms of weighting of these two purposes raises some interesting questions. Fundamentally, Peters asks whether the authorizing community regards teachers as "experts on means" of transmitting the culture or as "authorities on ends" valued by the community.<sup>1</sup> His discussion is valuable for pointing out that it is possible, in practice, to appoint a teacher to a position of authority for reasons which neglect or minimize the authority of expertise in some field of knowledge. It has been argued that this latter authority is logically associated with the concept of teaching in schools.

#### Actual authority: knowledge

Peters returns to the primary sense of a teacher as an authority when he considers the actual authority of a teacher. Noting that pupils have no say in selecting teachers, and noting that pupils are required to attend school, Peters sees a clear challenge for the teacher. "The task is basically to get the pupils to identify themselves with the aim of the school, to share the teacher's concern for what is being handed on."<sup>2</sup> Coercion may lead to alienation, while extrinsic values may fall short of the mark. ". . . what is intrinsic to the activities and forms of awareness must be vividly intimated with arrogance."<sup>3</sup>

<sup>1</sup>Ibid., pp. 252-258.

<sup>2</sup>Ibid., p. 258.

<sup>3</sup>Ibid., p. 259.

That one is never more than a provisional authority with respect to knowledge provides another reason why a teacher must guard against being perceived as authoritarian. His pupils must not only come to see the world in terms of a particular form of knowledge but also become able to criticize the associated assumptions.

Paradoxically enough a teacher must both be an authority and teach in such a way that pupils become capable of showing him where he is wrong. The teacher is an agent of<sup>1</sup> change and challenge as well as of cultural conservation.

Actual authority: social control

Finally, on the matter of social control, Peters explains that the task of the teacher in authority ". . . is complicated to a varying degree by the necessity of preserving conditions of order which are necessary conditions of its performance."<sup>2</sup> Peters is careful to observe that one need not abandon authority in general because one reacts strongly against the repressive use of authority. A teacher in authority is neither a prison warden nor a "benign child-minder" who simply appeals to the interest of children.<sup>3</sup>

Peters argues that authority in social control must be rationalized, not abandoned. Eventually, constraints put up by the teacher are to be internalized by pupils. This internalization requires that the exercise of authority be rational and "task-oriented." Authority which appears to have a traditional base will be rejected, quite rightly, by pupils. "In brief, teachers and parents have to learn to be in authority without being authoritarian."<sup>4</sup>

Thus it is Peters' position that a teacher is an authority who is placed in authority for the basic purpose of transmitting the knowledge on which he is an authority. When a teacher exercises the authority of the position to which he has been appointed, he does so for its

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<sup>1</sup>Ibid., p. 261.

<sup>2</sup>Ibid., p. 263.

<sup>3</sup>Ibid.

<sup>4</sup>Ibid., p. 265.

contribution to enabling pupils to move toward becoming authorities themselves.<sup>1</sup>

Peters' general analysis of authority in the context of education is complemented by the specific analysis of authority and teaching methods in the fifth interpretation of teaching. Ogilvy's interpretation is consistent with the views of knowledge drawn by Oakeshott and Scheffler, and it portrays the teacher and pupil prerogatives discussed by Roberts and Silva in a context complementary to that established by Peters.

Ogilvy: An Incomplete Theory  
as the Best Question

In his paper titled "Socratic Method, Platonic Method, and Authority," James Ogilvy examines closely the teaching techniques of Socrates and Plato, to forge a construct which can illuminate the contemporary issue of authority in teaching. He develops a characterization of teaching method which specifically recognizes that a teacher's expertise is to be used in a way which permits each learner to rely upon his own intellectual resources. Ogilvy ultimately argues for a clear distinction between educational authority and political authority.

Socratic method and the  
learner experience

Ogilvy begins his analysis by posing a perceptive question: "Why is the Socratic method praised so much more than it is practiced?"<sup>2</sup> Noting that one frequently hears a "Socratic technique" spoken of as an

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<sup>1</sup>The distinction between authority of knowledge and authority of position has been incorporated into a classroom observation procedure by Greta Morine, Robert S. Spaulding, and Selma Greenberg in their book titled Discovering New Dimensions in the Teaching Process (Scranton, Pennsylvania: International Textbook Company, 1971). On pages 110-114 they discuss seven teacher roles: intellectual authority, guide, or arbiter; social authority, guide, or arbiter; and clerical worker.

<sup>2</sup>James A. Ogilvy, "Socratic Method, Platonic Method, and Authority," p. 3.

appropriate teaching method, Ogilvy points out that such a method of teaching can be characterized superficially, adopted without being fully understood, and then rejected because it did not achieve the anticipated goals, even though one cannot explain the failure. Taken to extremes, a superficial characterization of the Socratic method can suggest that the teacher is superfluous (because any "midwife" can draw out the knowledge already present in the learner's mind) and that there is no professional expertise in education (which would, if it existed, speak against "participatory democracy" in educational decision-making).<sup>1</sup>

To develop characterizations which are not superficial, Ogilvy returns to the works of Socrates and Plato. In particular, he explores the apparent shift in Plato's later dialogues away from the "Socratic" characteristics of his early dialogues. The Socratic teaching technique was quite specifically one of questioning in a one-to-one relationship which permitted the teacher to adapt the dialogue to the individual characteristics of the learner, in an effort to bring about a particular kind of learner experience. Ogilvy observes that Plato's early dialogues try to create Socratic dialogue in writing. Ogilvy suggests that in the medium of writing rather than speech, this dialogue form generates attempts to understand the dialogue itself. Quite different is the learner's experience within the actual dialogue, an experience typically involving discovery of one's ignorance.<sup>2</sup>

Citing the analogy of adapting a literary work to the different media of film or theater, Ogilvy points out that the goal is to achieve the same effect as the original work, not to be slavishly true to it. He suggests that Plato faced the similar task of achieving in writing rather than speech the same learner experience as the spoken Socratic dialogue. The task is twofold. What is written must require the learner to employ his own "intellectual resources" yet it must also "speak differently" to different readers, to respect each learner's particular characteristics. Ogilvy suggests that it was Plato's remarkable solution, in the later dialogues, to introduce "complex but incompletely worked out

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<sup>1</sup>Ibid., pp. 3-5.

<sup>2</sup>Ibid., pp. 5-6.

theories."<sup>1</sup> These require each learner to be active, yet they permit each to respond differently.

Plato's later dialogues are successful surrogates for Socrates because Plato saw that an appealing, genuinely intriguing theory is the best counterpart for oral questioning. In the written medium, an incomplete theory is the best question. In its openendedness, an incomplete theory flexes to the intellectual resources of each reader.<sup>2</sup>

A third alternative for  
the classroom teacher

With this insight into the potential value of an "incomplete theory," Ogilvy turns to the situation of the classroom teacher. Dealing with many pupils at once, not in succession, a teacher who wishes to use the "maieutic" method shares Plato's problem of making the same words "speak differently to different students." If a teacher uses questions to bring out different responses from various pupils, he is authoritarian in a sense if he "guides" the course of his questioning to conclusions he had in mind at the start. In dialogues like the Meno, Socrates was able to avoid this authoritarian imposition of the teacher's views because of the one-to-one relationship. Guided questioning seems authoritarian and un-Socratic because pupils are not able to arrive at conclusions on their own.<sup>3</sup>

Like Peters, Ogilvy is sensitive to the fact that pupils have reason to ". . . resent an authority who acts like an authority but will not own up to being an authority."<sup>4</sup> Placed in such a dilemma and having failed to achieve the "maieutic" goals, many teachers turn to the only other alternative they recognize--the completely structured (and authoritarian) style of the lecturer. Ogilvy submits that teachers may find a viable "middle ground" in the Platonic form of the maieutic method.

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<sup>1</sup>Ibid., p. 9.

<sup>2</sup>Ibid., p. 10.

<sup>3</sup>Ibid., p. 12.

<sup>4</sup>Ibid. Here Ogilvy uses "an authority" in the sense of one who is in a position to control the interaction. This is the in-authority sense in Peters' interpretation.

According to the Platonic method, an interesting and engaging theory serves as the best question. If a teacher takes the time and effort to 'lay something on the table' the way Plato does in his later dialogues, then inquiry and education may proceed neither in the vacuum created by a totally unstructured situation, nor in the highly structured Procrustean bed of a lecture or guided series of questions and answers.<sup>1</sup>

Such a method may permit a teacher to respect the importance of the learner experience without rejecting the fact that his subject-matter expertise gives him more to "lay on the table" than anyone else in the classroom. A teacher maintaining the authoritarian stance of a lecturer would expect what he says to be repeated by his pupils in their work; a teacher attempting to use the Platonic method would expect pupils to examine and criticize what he says.<sup>2</sup>

#### Educational and political authority

Ogilvy concludes his essay by outlining his own "interesting and engaging theory" about the nature of educational authority. He speculates that the Platonic method may provide an other-than-political way to view the relationship of one teacher to a group of pupils. "In terms of the Platonic method, legitimate educational authority will depend on an ability to practice the maieutic method in a one-to-many relationship."<sup>3</sup> From this point of view, subject matter is more important at the university level not because the subject matter is placed above the intellectual development of the learner but because it is essential to the task of challenging students who have reached the university level "toward further personal and intellectual growth."<sup>4</sup> Noting the high calibre of Plato's intellect, Ogilvy remarks that "the theories he introduced succeed as questions only to the extent that their intrinsic plausibility elicits attempts to answer the questions they raise."<sup>5</sup>

By relating subject-matter expertise to the ability to achieve a particular kind of learner experience, Ogilvy's construct of a

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<sup>1</sup>Ibid., p. 13.

<sup>2</sup>Ibid.

<sup>3</sup>Ibid., p. 14.

<sup>4</sup>Ibid.

<sup>5</sup>Ibid.

"Platonic method" permits the authority associated with subject-matter competence to be viewed as educationally rather than politically significant. Ogilvy further suggests that this perspective on the contribution of scholarship to the teaching-learning situation might help both faculty and students to avoid making political responses to strictly educational issues. On this view, "participatory democracy" is not a viable alternative to the exercise of authority for educational purposes by those who have achieved scholarly competence.<sup>1</sup>

Ogilvy's particular contribution in this paper is the isolation of the importance of the "learner experience" and the suggestion that there is a method by which a teacher may strive to achieve that type of experience for all the pupils in his classroom. Subject-matter expertise does not licence authoritarian behavior, yet its educational significance cannot be denied. Ogilvy has described a teaching method by which expertise may be interpreted in terms of its contribution to achieving uniquely educational goals.

#### Derivation of an Analytical Scheme for the Concept of Teaching

To this point, the investigator has described significant characteristics of five analyses of the concept of teaching, and indicated their general compatibility. In the remainder of the chapter, the discourse is interpretive rather than descriptive. From the common core of the five analyses, a "composite perspective" on the concept of teaching can be seen. It is viewed by the investigator as embodying a comprehensive set of categories for thought about teaching.

Each of the five analyses has suggested that there are two ways of deviating from a teaching strategy consistent with the composite perspective. That is, the five arguments described seem to have been written, in part, as attempts to resolve a conflict between an overemphasis on accumulated public knowledge, on the one hand, and on overemphasis on the development of personal judgment, on the other.

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<sup>1</sup>Ibid., pp. 14-16.

Thus two alternate perspectives are also suggested by the analyses themselves, as discussed below.

The portion of the analytical scheme relevant to the concept of teaching is developed by contrasting the three perspectives on teaching (the composite perspective and the two alternates) according to six dimensions which capture important features of the arguments described above.

### Perspectives on teaching and models of teaching

Before presenting the three perspectives on teaching which make it possible to develop additional dimensions of the analytical scheme, it is appropriate to clarify what, if any, relationship the three perspectives have to models of teaching. The phrase "model(s) of teaching" has been used in this study in a number of different ways.

In Chapter I, the phrase "models of teaching" appears in the report of how Nuthall and Snook have categorized research on teaching. The three models--behavior-control, discovery-learning, and rational--are "conceptual structures" which have guided research on teaching. In Chapter II, the phrase "model of teaching" appears in the reports by Belanger and Cogan of a new perspective on teacher education. The word "model" is used to refer to an individual's conceptual framework for planning and interpreting classroom events, and it includes knowledge and beliefs about teaching and learning. Then, earlier in this chapter, the phrase "philosophical models of teaching" appears in the description of an argument by Scheffler. The three models--impression, insight, and rule--consist of different sets of assumptions about the nature of knowledge, reflected in teachers' goals, behaviors, and achievements.

Possibly more familiar than any of these is a fourth use of the phrase "model of teaching," to refer to a complete prescription for teacher behavior derived from a selected theoretical position, frequently but not exclusively psychological. Many models of this type are

described and compared in Models of Teaching,<sup>1</sup> by Joyce and Weil. This use of "model" is similar to the term "method" of teaching--a general technique reflecting accumulated experiences of the profession--in the sense that models and methods are rather complete guides for how one should behave as a teacher.

Each of the four is an appropriate use of the word "model," as a conceptual framework which can guide behavior, yet there are some significant differences among the four. The perspectives on teaching described below bear little resemblance to a model of teaching which guides research (Nuthall and Snook) or prescribes teaching behaviors (Joyce and Weil). It is not necessarily the case that any of the perspectives actually exists as a model of teaching in someone's head (Belanger and Cogan). The greatest similarity is between the perspectives described below and philosophical models of teaching (Scheffler): both are intended to facilitate the evolution of an individual's model of teaching (Belanger and Cogan).

The following discussion uses Körner's concept of a "categorical framework" to interpret the five analyses of the concept of teaching. The term "perspective," rather than "model," marks the focus on categories available for thought about teaching, based on analytical rather than empirical findings. The dimensions of teaching presented below, in the second portion of the analytical scheme, identify three alternatives on different elements of a teaching strategy. Thus a dimension is narrower than a method or model (Joyce and Weil) of teaching, and it is intended to stimulate thought and alternative actions rather than to prescribe actions. The three perspectives on teaching serve as bases for generating the alternative positions on each of the dimensions included in the analytical scheme.

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<sup>1</sup>Bruce Joyce and Marsha Weil, Models of Teaching (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1972).

A composite perspective on  
the concept of teaching

The composite perspective seen in the five analyses of the concept of teaching can be described in terms of the maximal kinds of particulars which it provides for the categorization of experience. It is convenient to identify at the same time the sense in which each of the five analyses of teaching argues for a balance which is more comprehensive than either of the two positions it seeks to unite.

Oakeshott stresses the significance of judgment as a component of knowledge which must be communicated while communicating information, but in a different way. Scheffler presents the rule model of teaching as a synthesis of models stressing accumulated information and individual judgment, a synthesis achieved by including deliberation according to principles of traditions of inquiry. Roberts and Silva describe a triialogue teaching style which balances teacher and pupil prerogatives in communication by recognizing the different relation of each to phenomena and to representations and explanations of phenomena.

Peters maintains that a teacher must be "an authority in authority" without being authoritarian. This is possible when a teacher employs his expertise in the service of pupils' development, a conclusion also reached by Ogilvy. To the classroom teacher who has limited himself to a choice between the Socratic method (inadequately understood) and the lecture, Ogilvy offers a "Platonic" method more adequate than either one alone.

The common core of these analyses of teaching can be expressed by reference to five maximal kinds of particulars--objects of experience, individuals, communities of inquirers, personal categorial frameworks, and disciplinary frameworks. The attributes of these maximal kinds are indicated in the following statements.

1. Individuals can develop the ability to exercise judgment in the use of information. In so doing, they develop and apply personal frameworks for the interpretation of experience.

2. A community of inquirers shares a disciplinary framework which it preserves and extends by applying the framework to theoretical and/or practical problems in the interpretation of objects of experience.

3. The attributes of a personal framework are those associated with Körner's concept of a categorial framework. A disciplinary framework is taken as the categorial framework which is shared by a community of inquirers.

This formulation reflects the use in Chapter III of Körner's concept of a categorial framework and Kuhn's concept of a community of inquirers. No suggestion is intended that the five analyses of teaching presuppose Körner's and Kuhn's arguments. Rather, those arguments are seen as contributing suggestions to one possible expression of a comprehensive perspective drawn from the five analyses.

Teaching and the counterpart activity of learning are here regarded as activities which are most comprehensively understood in terms of the five maximal kinds identified above. A teacher is a member of a community of inquirers in the sense that he has achieved expertise in a particular tradition of deliberative principles and explanatory standards. In teaching, his objectives include using that expertise to enable learners to develop personal frameworks. Thus a learner is seen as an individual whose goal is to achieve knowledge<sup>1</sup> and thereby develop a personal framework in the light of frameworks developed individually and collectively by his predecessors. Both teacher and learner have personal frameworks and the potential to contribute to the development and application of disciplinary frameworks. The role of teacher emphasizes individual expertise in a particular disciplinary framework and the ability to bring that expertise to bear on the personal development of learners. The role of learner emphasizes development of a personal categorial framework for interpreting experience, in the light of first many and later several or perhaps a single disciplinary framework, if the learner aspires to membership in a community of inquirers.

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<sup>1</sup>It seems unfortunate that the terms "knowledge" and "information" have come to be used interchangeably in educational discourse. Here "knowledge" is used in the sense expressed by Oakeshott, Scheffler, and Roberts and Silva.

Two limited perspectives on  
the concept of teaching

Failure to include all five maximal kinds available in the composite perspective generates a limited perspective on the concept of teaching. Two such perspectives, with limitations identified below, are quite familiar. One overemphasizes the development of personal frameworks by learners, while the other overemphasizes the preservation of disciplinary frameworks. These two interdependent aspects of teaching are balanced in the composite perspective. The term "information emphasis" is used to identify the overemphasis of public disciplinary frameworks, often inadequately portrayed as collections of information. The term "insight emphasis" is used to identify the overemphasis of individual development, often inadequately portrayed with little or no reference to disciplinary frameworks.

The information emphasis

Teaching based upon the information emphasis would be likely to stress unduly the task of the teacher to transmit what he knows to his pupils. The fact that teachers must communicate with many pupils generates a number of problems which may be minimized, but not resolved, by this emphasis. Teaching by lecture is associated with this emphasis. Teaching problems tend to fall into such areas as devising appropriate sequences for the presentation of information and maintaining order and attention during presentation. The number of pupils seems to prohibit investigating the unique responses of each. Knowledge may come to be viewed as an accumulation of publicly accepted facts which are preserved by having new generations commit them to memory. Teaching behaviors patterned on this emphasis could appear authoritarian in two senses, as the teacher controls both the content and the process of communication.

This familiar interpretation of teaching is now the subject of widespread criticism. Certainly it is rigid and authoritarian. It may never be implemented in the extreme, for a teacher is not likely to neglect completely the personal development of all his pupils. Teaching patterned on this emphasis can be said to work in the sense that it can achieve certain minimum levels of effectiveness in transmitting basic skills and content. This emphasis is associated with "information" in

Oakeshott's discussion, Scheffler's impression model, the imposition style described by Roberts and Silva, Peters' reference to the complete authority of a prison warden, and Ogilvy's reference to the political authority suggested by the lecture method.

#### The insight emphasis

The familiar alternative, widely acclaimed in recent years, is a concept of teaching which seems to be based on the insight emphasis. This view stresses the task of the teacher to consider the characteristics and behaviors of each individual pupil and to stimulate pupils to make their own judgments and thereby achieve insights into the nature of their experiences. When linked with phrases such as "Socratic method" and "discovery," these goals may be interpreted as ones attainable without reference to formal disciplines of knowledge. Problems tend to focus on stimulating pupils without actually telling them what they are to learn. What pupils do learn is likely to be personally relevant, and it is unlikely that the behavior of the teacher would be interpreted as authoritarian.

In its extreme form, also rare and improbable, teaching patterned on the insight emphasis would become an exchange of opinions among equals. If recognized at all, the expertise of a teacher viewed as lacking authority only becomes available to pupils by request. Teaching patterned on this emphasis can be said to work in the sense that pupils are able to learn to some extent when encouraged to explore a rich environment.

Roberts and Silva use the term "abandonment" to capture the sense of withholding from pupils the achievements of the past. Similarly, Peters spoke of the "benign child-minder." Ogilvy noted that this emphasis on insight suggests the political alternative of participatory democracy and denies that expertise can enter into educational decision-making.

#### Maximal kinds of particulars in the information and insight emphases

The perspective on teaching suggested by the information emphasis

seems to reflect only three maximal kinds--objects of experience, individuals, and a categorial framework to be shared by all individuals. The perspective suggested by the insight emphasis also seems to reflect only three maximal kinds--objects of experience, individuals, and personal categorial frameworks. As noted earlier, the composite perspective also includes communities of inquirers and disciplinary frameworks.

Comparison of the three perspectives in terms of included maximal kinds helps to explain some of their differences. Neither the information emphasis nor the insight emphasis recognizes adequately the significance of communities of inquirers. Accordingly, both fail to distinguish the two senses--personal and disciplinary--in which categorial frameworks may be recognized. The information emphasis tends to stress shared frameworks while failing to recognize the diversity of such frameworks. The insight emphasis tends to stress personal frameworks. The arguments by Oakeshott, Scheffler, Roberts and Silva, Peters, and Ogilvy are interpreted here as alternative ways of indicating the need to recognize the significance for the concept of teaching of communities of inquirers and the related distinction between personal and shared categorial frameworks.

Before stating formally the teaching dimensions of the analytical scheme, it is worth noting that this analysis permits one to account for the shortcomings of a familiar attempt to resolve the information-insight tension. A teaching strategy which may be termed "guided discovery" turns the teacher's statements into questions to achieve pupil participation. Ogilvy described this variation as Socratic questioning which the teacher guides by accepting only those answers which are "right."<sup>1</sup> It can be satisfying to both teacher and pupils to achieve more pupil involvement than is likely in a lecture. Yet the maximal kinds of particulars remain those of the information emphasis, as recognized by the alternative label some use for this strategy, namely "substitute lecture." Pupil involvement is not of the kind achieved by the insight

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<sup>1</sup>Ogilvy, "Socratic Method, Platonic Method, and Authority," p. 12.

emphasis. As Ogilvy noted, pupils rightly resent a pretense of non-authority by a teacher who effectively controls the content and process of communication, as in the information emphasis.

The teaching component of  
the analytical scheme

Three perspectives on the concept of teaching have been developed. The composite perspective provides the most comprehensive set of categories for thought about teaching. The composite perspective is regarded as a synthesis of the information and insight emphases in the sense that it includes the maximal kinds of both. The composite synthesis is more comprehensive than the simple sum of the two, however, because it is achieved by incorporating maximal kinds not adequately recognized in either the information or the insight emphasis.

The composite perspective is not a solution to the search for one best teaching method or style. Yet by providing a greater number of categories for thought about teaching, it comprehends a greater number of teaching methods, including ones not available within the information emphasis, the insight emphasis, or some simple combination of the two. Scheffler's rule model, the triologue style constructed by Roberts and Silva, and Ogilvy's Platonic method are all taken as examples of teaching styles which can only be interpreted fully with the categorization included in the composite perspective on teaching.

Six dimensions are used in the teaching component of the analytical scheme to contrast the three perspectives on the concept of teaching. The three interdependent categories of "knowledge," "learning," and "teaching" provide comparisons related to the objectives of teaching. Three other dimensions, designated by the terms "communication," "authority," and "use of expertise" provide comparisons related to the conduct of teaching. The six dimensions are set out in Table 2.

TABLE 2

DIMENSIONS OF THE ANALYTICAL SCHEME: THE CONCEPT OF TEACHING

<u>Information Emphasis</u>	<u>Insight Emphasis</u>	<u>Composite Perspective</u>
<i>Categorisation of objects:</i> What are the highest categories for understanding teaching? Objects of experience Individuals One shared categorial framework	Objects of experience Individuals Personal categorial frameworks	Objects of experience Individuals Communities of inquirers Personal categorial frameworks Disciplinary frameworks
<i>Nature of knowledge:</i> What is knowledge? Public information which increases over time by the accumulation of information	Personally achieved insight or judgment	An inheritance of human achievements, set in various modes of thought which include standards for publicly assessing personal insights
<i>Nature of learning:</i> What is the nature of the activity of learning? Individually accumulating public information and storing it for future use	Creating one's own insights into the nature of personal experience or reality	Acquiring information and coming to possess judgment by which information is used, in accord with public standards
<i>Nature of teaching:</i> What is the nature of the activity of teaching? Transmitting information to preserve what has been accumulated and to make it available to pupils for their personal use	Stimulating pupils to achieve personal insight or to exercise personal judgment	Communicating both information and judgment simultaneously but differently, to introduce pupils to traditions of human understanding while respecting their independence of judgment

TABLE 2--continued

Composite Perspective

Insight Emphasis

Information Emphasis

*Communication:* What is the relationship between teacher and pupil, in the processing of information?

Emphasis is given to the teacher's prerogative to share his expertise in processing information

Emphasis is given to the pupil's prerogative to process information from his personal experience

Balance is maintained for both teacher and pupil prerogatives in their information-processing communication

*Authority:* What is the nature of the teacher's authority?

The teacher acknowledges being in authority over his pupils, but he does not distinguish between types of authority

The teacher excludes all forms of authority from his relationship with his pupils

The teacher acknowledges being an authority, and he accepts being in authority for the purpose of enabling many pupils to learn at the same time

*Use of expertise:* How does the teacher use his expertise?

Expertise is imposed by the teacher; structure is considerable or complete

Expertise is made available to pupils by the teacher; structure is minimal or absent

Expertise is used by the teacher to provide enough structure to indicate what is known while providing enough freedom to allow pupils to respond individually

CHAPTER V  
AN ASSESSMENT OF THE APPLICABILITY  
OF THE ANALYTICAL SCHEME

Introduction

This chapter presents the second phase of the investigation, an assessment of the applicability of the analytical scheme developed in Chapters III and IV. Passages selected from four textbooks on the teaching of science are analyzed for content and structure, using the dimensions of the analytical scheme supplemented by Toulmin's concept of an "argument-pattern", described below. The general question asked in this chapter is "What information does application of the analytical scheme provide about the scheme's acceptability for examining arguments about the teaching of science?"

Three topics are discussed in preparation for the analysis. First the procedure used to select the four passages is described. Then Toulmin's concept of the pattern of an argument is introduced and its relevance to the analysis is explained. Finally, a short example of analysis of an argument is presented and discussed, to make the reader familiar with the format of the full analysis of four separate passages.

The chapter concludes with a summary of the results of the analysis and a discussion of their implications for assessing the applicability of the analytical scheme. The following questions are of particular interest.

1. Is each of the dimensions of the scheme relevant to some portion of at least one of the selected passages? If not, is this a reflection on the analytical scheme?
2. Are the range and detail of each dimension adequate for use in analysis of arguments? Are modifications to dimensions required or suggested?
3. Does analysis of an argument according to dimensions of the analytical scheme permit one to determine whether issues are addressed clearly, distinctly, and comprehensively in the argument?
4. Does analysis of an argument according to dimensions of the

analytical scheme facilitate identification of the authority upon which the argument rests?

5. Do significant issues arise in the selected passages which cannot be analyzed in terms of dimensions of the analytical scheme? Are additional dimensions required or suggested?

#### Selection of Data for Analysis

The investigator has identified a set of textbooks on methods of teaching science, for use as sources of data in this initial assessment of the analytical scheme. Ultimately, the analytical scheme may prove useful in the analysis of how science teachers think about science teaching, as indicated in their teaching, in their talk about their teaching, and in preservice and inservice training. However, printed materials offer certain advantages over transcriptions of conversations and instructional discourse, in an initial assessment. In some respects data collection is simpler, and the analysis of printed materials does not involve certain types of inference about the context and intention of speech. Finally, textbooks on methods of teaching science provide an element of generality. They are a regular feature of science teacher education programs, regardless of the variations one would expect among programs at different universities.

#### Identification of textbooks

In May, 1973, the investigator surveyed the individuals responsible for teaching curriculum and instruction courses for preservice secondary-school science teachers at the three locations in Ontario<sup>1</sup> where such courses are offered. Of the twenty-eight methods textbooks in use or cited on reading lists, eight were reported so much more frequently than the others that they were obviously central. This sample was accepted as being large enough to insure diversity yet small enough to permit analysis of some portion of each book. The eight textbooks are listed in Table 3. The decision to examine books in use in Ontario

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<sup>1</sup>The Faculties of Education at Queen's University, the University of Toronto, and the University of Western Ontario.

TABLE 3

SCIENCE METHODS TEXTBOOKS IDENTIFIED  
AS SOURCES OF DATA FOR ANALYSIS

- Andersen, Hans O., and Koutnik, Paul G. Toward More Effective Science Instruction in Secondary Education. New York: The Macmillan Company, 1972.
- Brandwein, Paul F.; Watson, Fletcher G.; and Blackwood, Paul E. Teaching High School Science: A Book of Methods. New York: Harcourt, Brace & World, Inc., 1958.
- Collette, A.T. Science Teaching in the Secondary School. Boston: Allyn and Bacon, 1973.
- Massey, Norman Bland. Patterns for the Teaching of Science. Revised ed. Toronto: The Macmillan Company of Canada Limited, 1969.
- Romey, William D. Inquiry Techniques for Teaching Science. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968.
- Sund, Robert B., and Trowbridge, Leslie W. Teaching Science by Inquiry in the Secondary School. Columbus, Ohio: Charles E. Merrill Books, Inc., 1967.
- Thurber, W.A., and Collette, A.T. Teaching Science in Today's Secondary Schools. 3rd ed. Boston: Allyn and Bacon, 1968.
- Washton, Nathan S. Teaching Science Creatively in the Secondary Schools. Philadelphia: W.B. Saunders Company, 1967.

is solely one of convenience for isolation of a sample. No claims are made about the books themselves, individually or collectively.

#### Selection of passages

After completing the initial development of the analytical scheme, the investigator surveyed the contents of each of the eight textbooks and selected two passages from each--one relevant to the nature of science and another more concerned with how science is taught. After estimating the potential offered by the sixteen passages for application of the analytical scheme, the investigator selected eight passages with the greatest potential. One was selected from each textbook. The sample is approximately balanced between a focus on science and a focus on teaching.

The eight passages, labeled as Selections A to H, were analyzed in detail. Four selections (B, D, E, and G) which illustrate most broadly the application of the analytical scheme were chosen for use in the main body of the investigation. The remaining four selections (A, C, F, and H) are presented in Appendix A. Their analysis corroborates the findings in the main body of the investigation. No claim is made, or intended, to the effect that one selection is in any way representative of an entire textbook. To maintain the focus on assessment of the scheme's applicability, the authorship of a selection is identified only in the opening comments of each analysis, when the context in which the passage was written is described.

#### A Procedure for Examining the Structure of An Argument

As explained in Chapter I, the investigation is concerned with the provision made for science teachers to accept arguments on rational authority, as well as with the provision made for teachers to understand the significance of any particular characteristic of science or teaching. Both the content and structure of arguments are of interest and relevance. The various dimensions of the analytical scheme are to be tested for their contributions to recognizing the significance of content, but alone they cannot deal fully with the structure of an argument.

To permit a more complete analysis of arguments, the investigator has adopted Toulmin's procedure for determining the pattern of an argument. This procedure also serves two other purposes. It provides a common format for the analysis of arguments in each of the four selected passages. It also "opens" each argument to analysis by helping to clarify just what is at issue, before specific issues are examined in detail.

#### Toulmin's argument-pattern

Toulmin has suggested, in The Uses of Argument,<sup>1</sup> that six argument-elements provide an adequate basis for scrutinizing arguments in any field of inquiry. Toulmin's is an analysis of rational arguments in general, using the field of jurisprudence as a guide. His interests include the different functions of propositions used in arguments and the relevance of different criticisms of arguments. In one part of his study, Toulmin develops a pattern for the analysis of arguments, and this pattern can serve as a basis for assessing the structure of an argument.

The six elements of Toulmin's argument-pattern are Data, Warrant, Conclusion or Claim, Backing, Qualifier, and conditions of Rebuttal.<sup>2</sup> Data support the Conclusion (or Claim) of an argument by virtue of the Warrant which permits the inference from Data to Conclusion (or Claim). A Warrant derives its Backing (or its authority) from a particular position characteristic of the field within which the argument is made. When present in an argument, a Qualifier indicates the strength of the Conclusion (or Claim), while conditions of Rebuttal indicate when the Conclusion (or Claim) may be set aside because the Warrant lacks authority in the circumstances of that particular argument.<sup>3</sup> Toulmin expresses the pattern of rational arguments by linking the six elements as shown in Figure 1.

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<sup>1</sup>Stephen Toulmin, The Uses of Argument (Cambridge: Cambridge University Press, 1958).

<sup>2</sup>Capitalization of these six terms is used in the analyses which follow to signal that the words are being used in this sense of Toulmin's.

<sup>3</sup>Toulmin, The Uses of Argument, pp. 97-107.

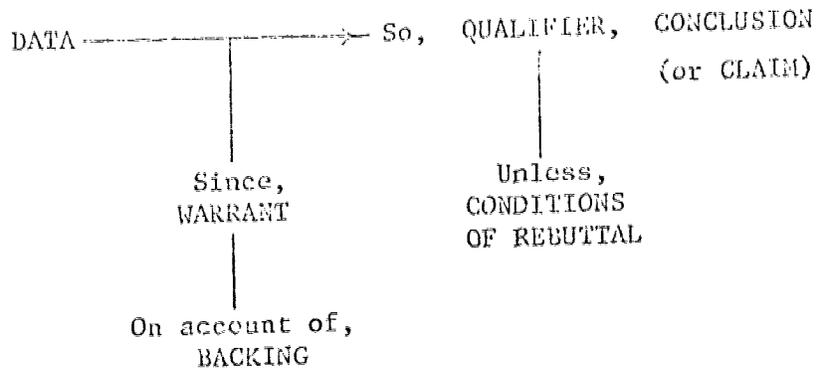


Fig. 1.--Toulmin's argument-pattern<sup>1</sup>

This pattern is applicable both to Warrant-using arguments, in which Data and Warrant permit a particular Claim, and to Warrant-establishing arguments, in which known Conclusions are used to support a new way of drawing inferences from Data.<sup>2</sup> The category of Backing refers to the general grounds on which a Warrant is acceptable and relevant. Often taken for granted or regarded as self-evident by the person who makes an argument, the Backing for the Warrant is particularly relevant to a critical assessment of an argument.

A brief illustration adds to the meaning of these remarks about the relationship of Backing to Warrant. Toulmin cites three Warrants of classification which are authorized by very different Backings.

1. "A whale will be a mammal."
2. "A Bermudan will be a Briton."
3. "A Saudi Arabian will be a Muslim."

The first Warrant is supported by a scheme of taxonomic classification, the second is based upon a set of legal statutes, while the third is backed by statistics relating nationality and religious beliefs.<sup>3</sup> These

<sup>1</sup>Ibid., p. 104.

<sup>2</sup>Ibid., pp. 120-122. "Warrant-using" and "Warrant-establishing" are Toulmin's terms. The investigator has found it convenient to use the term "Claim" in the pattern of a Warrant-using argument and the term "Conclusion" in the pattern of a Warrant-establishing argument. This differentiation helps one to keep in mind which type of argument one is analyzing.

<sup>3</sup>Toulmin, The Uses of Argument, pp. 103-104.

differences at the level of Backing contribute to recognizing the particular field of inquiry to which each Warrant belongs.

#### Use of the argument-pattern

What is the specific contribution of Toulmin's argument-pattern to analysis of the manner in which an argument is expressed? For purposes of the analyses which follow, the contribution is two-fold. When analyzing a portion of an argument in which a position about science or teaching is expressed, it is helpful to know the particular role that portion plays in the argument as a whole. Prior identification of elements of the argument makes the information available. Also, the argument-pattern can be used to determine whether an argument is complete, since the pattern described by Toulmin indicates what elements may be expected in a rational argument. Data, Warrant, Conclusion (or Claim), and Backing are regarded as essential elements of all rational arguments; Qualifiers and conditions of Rebuttal may or may not be required, according to the content of the argument.

The distinction between elements which are always required and those which are required according to the content of an argument can be anticipated logically from the definitions of the elements. Not all Conclusions (or Claims) require explicit Qualifiers, not do all Warrants require explicit conditions of Rebuttal. That this is the case has been demonstrated in an earlier study in which the investigator analyzed arguments presented to students by science teachers.<sup>1</sup>

The analyses of Selections A to H are conducted from the position that making provision for a reader to accept an argument on rational authority requires making available all the elements required for the argument in question. This position assumes that acceptance of an argument on rational authority must always be preceded by a critical assessment of the complete argument by the individual contemplating acceptance.

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<sup>1</sup>Thomas L. Russell, "Toward Understanding the Use of Argument and Authority in Science Teaching," Background Paper No. 7 for the Explanatory Modes Project (Toronto: The Ontario Institute for Studies in Education, Department of Curriculum, 1973).

The first step in meeting these conditions is providing a complete argument; the second step involves developing the argument in a manner which will meet the standards of the assessment.

An Illustration of the Format  
of the Analysis

Each analysis of a selection has three parts: initial analysis, detailed analysis, and a commentary on the analysis. The initial analysis identifies argument-pattern elements and suggests potentially relevant dimensions of the analytical scheme. Initial analysis is presented with the text of the selection, using a two-column format.

The first paragraph of Selection F is presented to illustrate the format. Line numbers in the left margin are used during the analysis to refer to particular portions of a selection.

TEXT<sup>1</sup>

INITIAL ANALYSIS

THE GOALS OF SCIENCE

Theories and Scientific

Principles

(Three paragraphs omitted)

Theories are based on facts which are derived from observation and experimentation. As our experimentation progresses  
5 and reveals new information, theories often have to be modified. Scientists search for theories and principles which are true and unchanging,  
10 but the history of science has shown that there is no certainty in science but only probability. Because theories evolve and are modified as our  
15 knowledge of nature increases, the goals [sic] of science in formulating broad, encompassing

The discussion of science in lines 1-21 focuses on the unending nature of theory-building. In lines 1-9, four distinct categories are indicated: phenomena, facts, theories, and individuals who experiment and theorize. The Conclusion that theory development has no end in science (lines 16-19) relies on the Warrant that theories are modified as new information demands (lines 3-7 and 13-15). Data are drawn from the history of science (lines 7-13). The *Progress of science* dimension is relevant to the account of theory

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<sup>1</sup>Robert B. Sund and Leslie W. Trowbridge, Teaching Science by Inquiry in the Secondary School (Columbus, Ohio: Charles E. Merrill Books, Inc., 1967), p. 10.

ideas of knowledge--theories--  
never ends. There is always  
20 an assignment for the next  
generation.

modification (lines 3-7), while  
the *Relationship of science to  
truth* dimension seems relevant to  
the choice between certainty and  
probability (lines 7-13).

The detailed analysis of a selection presents the patterns of  
major arguments in a selection, before undertaking the basic task of  
analysis: examining the relationship between the content of each argu-  
ment and the analytical scheme, according to dimensions noted in the  
initial analysis. As an illustration, the argument-pattern of the  
preceding excerpt from Selection F is presented.

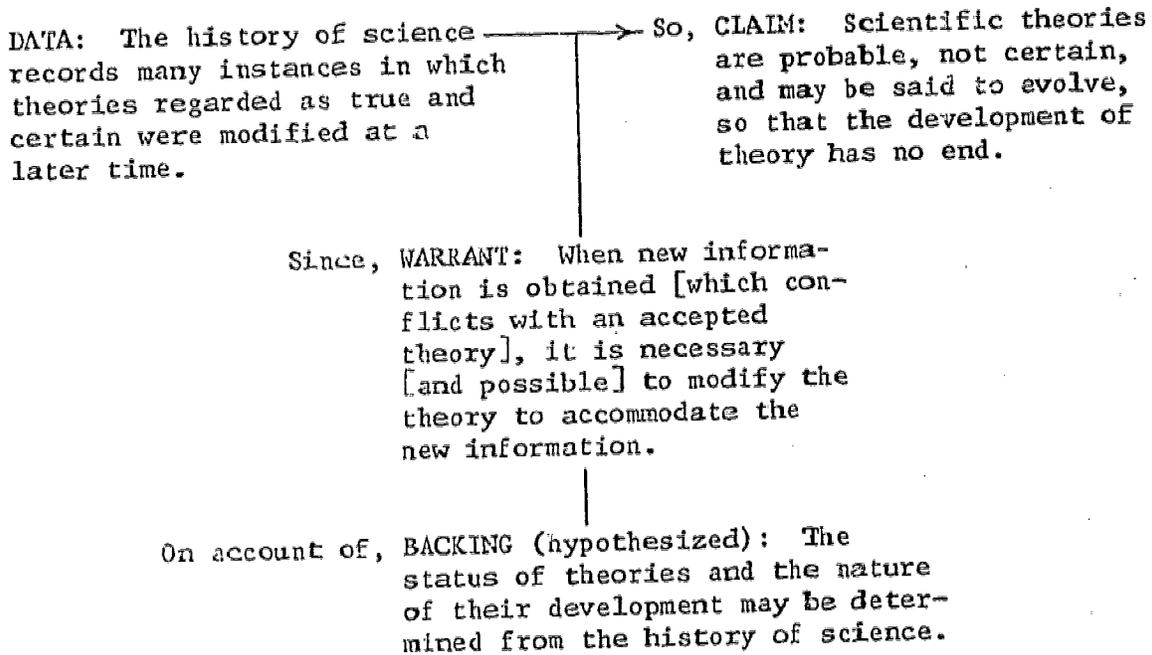


Fig. 2.--The argument-pattern of the first major argument of Selection F, with Warrant expanded and Backing hypothesized.

Finally, a commentary on the analysis is provided to summarize the detailed analysis and to note some of the more significant results of application of the analytical scheme.

Notes on the use of  
the argument-pattern

The actual process of determining the pattern of an argument is not as straightforward as the preceding discussion might suggest. The

results are probably dependent to some extent on the person performing the analysis. Once a tentative identification of pattern-elements has been made, reviewing the required relationships may indicate that the argument could be interpreted in alternative ways. It is not unusual to make several adjustments in the representation of an argument's pattern, before a "best fit" is achieved.

The argument in the preceding excerpt from Selection F does not include any statements which may be regarded as Backing. For purposes of presenting the argument's pattern, the investigator has hypothesized what the Backing might have been, had it been provided by the authors. This practice is followed when important elements appear to be absent.

The simplest criterion of provision for acceptance of an argument on rational authority, rather than the personal authority of the author(s), is the presence of all necessary elements. In the case of the example above, the absence of Backing is sufficient to conclude that provision has not been made for a reader to accept the argument on rational authority. Detailed analysis proceeds in such instances, to capitalize on the opportunity to assess the applicability of the analytical scheme.

A second criterion is the clear and correct indication of the relationships of elements of the argument to each other. This is a more difficult criterion to apply, since there is no single or best way to indicate relationships or to present the elements of an argument. Notice, in the text above, that the Warrant (lines 3 to 7) is given before the Data (lines 7 to 13) and repeated (lines 13 to 15) before the Claim is stated (lines 16 to 19). The contrast between the need to modify theories (lines 6 and 7) and the search for theories which are unchanging (lines 7 to 9) could be regarded as initiating a second argument, but it has been interpreted here as raising a second issue--the relationship of science to truth. In lines 3 to 13, there are no clues to differentiate the Warrant from the Data. The word "because" in line 13 does signal correctly the presentation of the Warrant of the argument.

Notes on the use of the analytical scheme

The ways in which a dimension of the analytical scheme can be

relevant to an argument are functions of both the dimension and the argument. The detailed analysis of a selected passage is intended to determine as fully as possible what a relevant dimension can indicate about an argument and what that application can indicate about the dimension. Normally, one would be interested only in what the dimensions of the scheme indicate about the argument being made. Here the primary interest is in bringing out as much information as possible about the applicability of dimensions of the analytical scheme.

As noted earlier, dimensions of the scheme are intended to serve as criteria for assessing those portions of arguments in which positions about science and teaching are expressed. Examination of the applicability of the analytical scheme involves at least three general issues: (1) the relevance and adequacy of each dimension, (2) the general usefulness of the scheme across arguments, and (3) the capacity of the scheme to address all issues raised within arguments to which it is appropriately applied.

With respect to the illustrative text and analysis above, it is possible at this point only to note, not to confirm, that two different dimensions of the nature of science appear to be relevant to the content of the text, and that no issues are raised which cannot be related to dimensions available within the analytical scheme. Detailed analysis tests the actual relevance and the adequacy of the dimensions, while comparison across selections tests the general usefulness of the scheme.

It is possible to anticipate the argument-elements to which application of the analytical scheme will be of most significance in an overall assessment of an argument. In a Warrant-using argument, which ends in a Claim, it is the adequacy of the Data and Backing which are of greatest importance. In a Warrant-establishing argument, which ends in a Warrant, the adequacy of Data, Conclusion, and Backing are of particular interest.

#### Application of the Analytical Scheme to Four Selected Passages

The analytical scheme is now applied to four of the eight passages selected from eight textbooks on the teaching of science. Application of the scheme to the remaining four passages is presented in Appendix A, as

noted earlier. The results of the following application of the scheme are summarized and interpreted in the final section of the present chapter. Comments about the subsidiary analysis of four passages in Appendix A also appear in that section.

### Selection B

Initial inspection of Teaching High School Science: A Book of Methods, by Brandwein, Watson, and Blackwood, suggested that it would be particularly appropriate to analyze the first chapter, "Ways of the Scientist."<sup>1</sup> The chapter discusses many aspects of the work of scientists and it offers several opportunities to test the applicability of science dimensions of the analytical scheme.

Identifying a convenient selection from the chapter proved to be more complex in this case than in most others. Because the entire chapter forms one argument, it is necessary to include the opening and closing paragraphs as well as one full section of the chapter.<sup>2</sup> This is the longest of the eight selections. As the following analysis reveals, individual arguments are elaborated quite fully.

#### TEXT

A note at the beginning: We have at hand 42 syllabuses, from 37 states, for general science, biology, physics, chemistry, 5 earth science, and physical science courses. They have one thing in common; all propose to teach the scientific method. Forty-one of them seem 10 to deal with the "empirical approach", the slowest, least effective way of "problem solving."

#### INITIAL ANALYSIS

This first paragraph of the three-paragraph introductory note (lines 1-48) provides Data for an argument which spans the entire chapter. The last sentence (lines 9-13) foreshadows the argument's Claim, which appears in lines 249-275 of the text, below.

<sup>1</sup>Paul G. Brandwein, Fletcher G. Watson, and Paul E. Blackwood, Teaching High School Science: A Book of Methods (New York: Harcourt, Brace & World, Inc., 1958), pp. 11-35.

<sup>2</sup>Ibid., pp. 11, 28-30, and 32.

Actually the word "science"  
 15 stands for such a complex variety of information, abilities, and operations that none of the many published definitions seems wholly adequate. We hesitate to  
 20 add one more effort to compress the grandeur of science and scientific work into a brief pattern of words. However, perhaps we can clarify what  
 25 science isn't, and suggest explicitly what it involves. Many eminent scientists and philosophers have written about the nature of science; those readers  
 30 who wish to go beyond our discussion may find the books listed at the end of the chapter helpful.

One peculiarity of ours will  
 35 certainly not escape you: we tend to think of science more as a verb than as a noun; we tend to think of the way a scientist works rather than what science  
 40 is. We think that science is more concerned with the process by which a body of reliable knowledge is obtained than with the resulting body of knowledge  
 45 itself. Consequently when we talk of science, we shall really be talking about ways in which scientists seek concepts.

(Five sections of chapter omitted)

50 Concept seeking--the way of the scientist and the way of his world

Science, it seems, is more than empiricism, more than  
 55 problem solving, certainly more than a method, or methods, even more than an attitude; it is a use of intelligence in a very complex, and at present little understood, cerebration in an  
 60 attempt to make sense of this world. Its patterns of inves-

The second and third paragraphs provide some indication of the approach the authors take to the analysis of science. They are reluctant to create another definition of science (lines 14-16). Also, they are more inclined to consider what scientists do, not what they obtain by their efforts (lines 34-45). This view is consistent with the earlier reference to "the scientific method" (lines 8-9).

These statements of basic perspective are indicative of the Backing for the argument. It is important to note that the reader is advised of the availability of a substantial body of literature (lines 26-33), with which he could compare the Backing or basic assumptions of the authors. The last sentence (lines 45-48) announces a basic theme of the chapter, one which is closely related to Conant's analysis of science, upon which the authors rely heavily.

The first paragraph (lines 52-77) of the chapter section chosen for analysis repeats several themes developed in preceding sections, particularly the immediately preceding one.

The *Demarcation of science* dimension may be relevant to lines 52-65. The remainder of the para-

tigation and its operations in investigation are an attempt to discover the regularities, if  
 65 any, of nature. The way of the scientist is designed to determine the way the world works. "Sciencing," as Bridgman has it, is a total operation. It  
 70 really has no beginning as such and no end as such. It is, in a sense, the seeking of concepts--concepts and conceptual schemes which man builds to  
 75 help him understand man and the universe. One concept leads but to another.

In On Understanding Science, Conant emphasized the cumulative nature of science in contrast to other fields of creative effort. Suppose Michelangelo, Raphael, Chardin, and Rembrandt were to come on  
 85 the present scene to answer the question, "Has painting advanced since our times?" We could visualize some interesting discussions, but hardly agreement.  
 90 And what might Beethoven, Bach, Brahms, Schumann, and Wagner say of modern music?

What, however, would Newton, Galileo, Archimedes, Dalton,  
 95 Vesalius, Grew, and Mendel say of modern science? Surely they would agree that science had advanced. And in analyzing why this advance might be so palpably clear, Conant derives what to him appears a consistently clear characteristic of scientific accomplishment:  
 100 Science is both cumulative and self-correcting.  
 105

In examining the work of research scientists and in analyzing their reports, Conant observes that the end result of a  
 110 scientist's work, if indeed, the word "result" may be used, is but another problem or several,

graph (lines 65-77) indicates a compatibility between Bridgman's position, previously presented, and that of Conant. The following sentence appeared in the previous section: "This is what Conant meant when he defined science as 'a series of concepts or conceptual schemes (theories) arising out of experiment or observation and leading to new experiments and observations.'" This appears to be the source of the position expressed in lines 71 to 77.

The first argument of this section of the chapter appears in lines 78-105. As Data, the reader is asked to hypothesize that great individuals in three creative fields--painting, music, and science--could examine their respective fields at the present time and comment on whether the changes they note constitute advances (lines 78-96).

As stated, the Claim that (only) the scientists would recognize advances seems to be regarded as self-evident. (See lines 87-92 and 96-98.) However, the next sentence (lines 98-105) indicates that there is a Warrant for this Claim, one which takes Conant's analysis of science as Backing. The Warrant expresses two characteristics of science.

First to be explained is the Warrant that science is cumulative. The Data for the argument appear to be the starting points and end results identifiable in the work and reports of research scientists. Comparison supports

not a conclusion or a "new"  
discovery, but a breathing space  
115 on the way to another concept.  
The scientist's way is an unending  
quest, unending conceptualization,  
or unending concept attainment;  
120 science is truly an "endless frontier."

(One paragraph omitted)

The scientist's aim, conscious  
or otherwise, is a hunt for the  
conceptual scheme, for a spatial  
125 pattern in the infinite jigsaw  
puzzle of how the world works.  
A few such schemes (each based  
on many discrete facts, principles,  
and concepts) are given by  
way of illustration:

130 The earth is surrounded by an  
ocean of air.

Some diseases are caused by  
microorganisms.

135 Existing organisms are the  
result of evolutionary changes  
during the earth's history.

These conceptual schemes,  
which we admire and use, re-  
sulted from observation and  
140 experiment, interwoven with  
creative mental effort. If  
observations and experiments  
are to lead to conceptual  
schemes which are to be a useful  
145 picture of the real world, they  
need to be reliable. But since  
man is not always reliable, the  
investigations must somehow be  
self-correcting. How is this  
150 self-correction by unremitting  
investigation built into the  
scientist's way of work?

All men are fallible, even  
scientists. They, however, are  
155 acutely aware of their falli-  
bility, as the quotation from  
Bridgman has shown. A major  
question then is how scientists  
dealing with incomplete and im-  
160 perfect data are able to estab-

the Conclusion that solving  
problems always generates new  
ones (lines 106-115). Thus the  
Warrant is established that the  
work of a scientist is unending  
and science is cumulative. That  
the *Progress of science* is relevant  
is clear from the Claim of the  
previous argument (lines 96-98).

A subsequent paragraph extends  
this point by providing illustrative  
examples of conceptual schemes  
of science (lines 121-136).  
The use of Conant's terminology  
suggests that Conant's definition  
of science (reported above, opposite  
lines 67-73 of text) may be regarded  
as Backing for the Warrant.

The transition to the Warrant  
that science is self-correcting  
is begun by citing a previously  
established Claim about the  
activities which result in conceptual  
schemes (lines 138-141).  
Usefulness is said to require  
reliability, which must be  
achieved by self-correction  
"since man is not always reliable"  
(lines 141-149). This position  
may be regarded as part of the  
Backing for the Warrant about to  
be explained.

The argument for the Warrant  
that science is self-correcting  
is achieved by citing both Data  
and Conclusions. Included in the  
Data are the facts that all men  
are fallible, that scientists are  
"acutely aware of their falli-  
bility" and inherently skeptical

lish general statements on which they put great reliance. This is accomplished because scientists, conscious of their  
 165 limitations, are inherently skeptical, in the best sense of the word, of their own work and that of others. Any single scientist's work must be con-  
 170 firmed. This open-endedness of an investigation, the realization that conclusions are not final, always provides opportunity for reconsideration of a  
 175 result when new data become available. (New tools may play a major role in providing such new data.) The scientist must accept some ambiguity in  
 180 his knowledge even as he strives to lessen the ambiguity.

Bridgman has stressed the importance of using the correct operation in making observa-  
 185 tions. This involves the appropriate choice and arrangement of tools. We would all agree that a ruler is appropriate for measuring height, but not for  
 190 measuring intelligence. What constitutes the "correct" operation is always somewhat in doubt; one does the best he can and leaves to his colleagues now  
 195 and later the task of criticism.

Thus scientific work is never ended; it can always be extended and improved. For instance, Piltown Man, long a debatable  
 200 construct of the anthropologist, is now recognized as a classic hoax. How the fraud was finally exposed is a fine example of the self-correcting nature of scien-  
 205 tific study. The original papers are worth reading. They would serve well to illustrate many aspects of how the scientist works. They also  
 210 illustrate how the scientist is constantly scrutinizing his "operations," "concepts," and

of their work, and that their investigations are open-ended (lines 153-157, 163-173). (In the quotation, Bridgman discusses "scientific method" and raises the topics of truth, verification, and objectivity. He concludes, in part, that "science is what scientists do.") The relevant Conclusions are that one scientist's work must be confirmed by others, that there are always opportunities for reconsidering results, and that some ambiguity always remains in scientific knowledge (lines 168-170, 173-181). These points appear to be regarded as sufficient to establish the Warrant that science is self-correcting.

The parenthetical remark in lines 176-178 is expanded in a brief reference to Bridgman's position that instruments of observation have significance for scientists' work. Apparently, one aspect of self-correction involves agreement that the instrumentation was correct, and development of new instrumentation, if it seems to be needed.

An example is provided of a situation in which science was self-correcting (lines 198-202). The reader is referred to documents which provide detailed evidence. As one would expect, the documents are said to illustrate the scientist's self-scrutiny, which can be associated with the inherent skepticism previously mentioned (lines 163-168). Indication is given that the history of science is a good source of evidence relevant to this Warrant concerning self-correction (lines 218-226).

"conceptual schemes." He is constantly asking:  
 215 What do we know?  
 How do we know it?  
 How well do we know it?  
 As a scientist consistently asks questions of this nature,  
 220 he introduces a self-correcting element into his ways of work. Scientists, we repeat, can and do make mistakes. Anyone who is familiar with the history of  
 225 science can cite chapter and verse. But the scientist's way is self-correcting mainly because confirmation of observation is made by many others who  
 230 are free, to a reasonable extent, of the personal bias which may have influenced the original statement. In science, too many cooks do not spoil the  
 235 broth. The meal is prepared by many cooks working in many different kitchens. Hence, any conclusion, confirmed as it is by different men, with different  
 240 intent and in different situations, tends to approximate the "truth." And hence, when the conditions are better known and the operation is appropriate,  
 245 future results are increasingly predictable.

(One paragraph and one section of the chapter omitted)

Teaching the ways of the scientist

We began this chapter with a  
 250 mention of 42 syllabuses at hand. Only one of them implies that there are many methods of science; 41 of them clearly imply that the scientific method  
 255 is what we have called here "the empirical" or "try it and see" approach. Some of the syllabuses call this approach "problem solving." This tendency to  
 260 simplify a complex subject, to seek a single approach to sci-

The self-correcting aspect of a scientist's method is said to depend most heavily on the fact that other scientists must confirm observations. The reference to elimination of personal bias (lines 230-233) suggests that the *Objectivity of science* dimension may be relevant. The authors seem to regard it as self-evident that scientific conclusions tend to approximate the "truth." The *Relationship of science to truth* dimension may be relevant. The double use of "Hence" (lines 237 and 242) implies a direct logical link from confirmation by others through approximation of the truth to increasing powers of prediction.

The concluding paragraph of the overall argument of the chapter is cited to complete the context provided by lines 1-48, above. The Claim of the overall argument is given in lines 263-270, while the initial Data are referred to in lines 249-259. The reference to concept seeking (lines 270-275), introduced by the phrase "of course," is again indicative of the Backing which the authors adopt from Conant's work. The

ence, is understandable but it can be very misleading. Actually, as we have seen, the  
 265 highly empirical way of problem solving is but one approach of the scientist, and it is a very slow one, used as a last resort when we have no better guides to  
 270 action. And, of course, scientists seek and solve problems in order to find concepts, science might better be considered as concept seeking, rather than  
 275 problem solving.

(One paragraph omitted)

reduction of the many methods of science to one is regarded by the authors as potentially "misleading" (lines 259-263).

#### Detailed analysis

Preparing argument-patterns of the arguments in Selection B is a rather involved process, but it does help to indicate the inter-relationships of the arguments. Figures 3 and 4 refer, respectively, to the argument of the entire chapter and to the arguments in the section selected for complete analysis. The Warrant in Figure 3 is established within sections of the chapter which precede the section analyzed here. Once established, the Warrant can be used to reach the indicated Claim.

DATA: Forty-two science syllabuses propose to teach the scientific method--the empirical approach to problem-solving. Only one syllabus implies that there are many methods of science.

So, CLAIM: Empirical problem-solving is but one approach used by research scientists.

Since, WARRANT: There are many methods of science, which have been described and discussed.

On account of, BACKING: What scientists do when doing research, as reported and interpreted by Conant and Bridgman.

*Argument B-1<sup>1</sup>*

Fig. 3.--The argument-pattern of the chapter from which Selection B is taken.

<sup>1</sup>Each argument in a selection is assigned a number to facilitate later references to the argument.

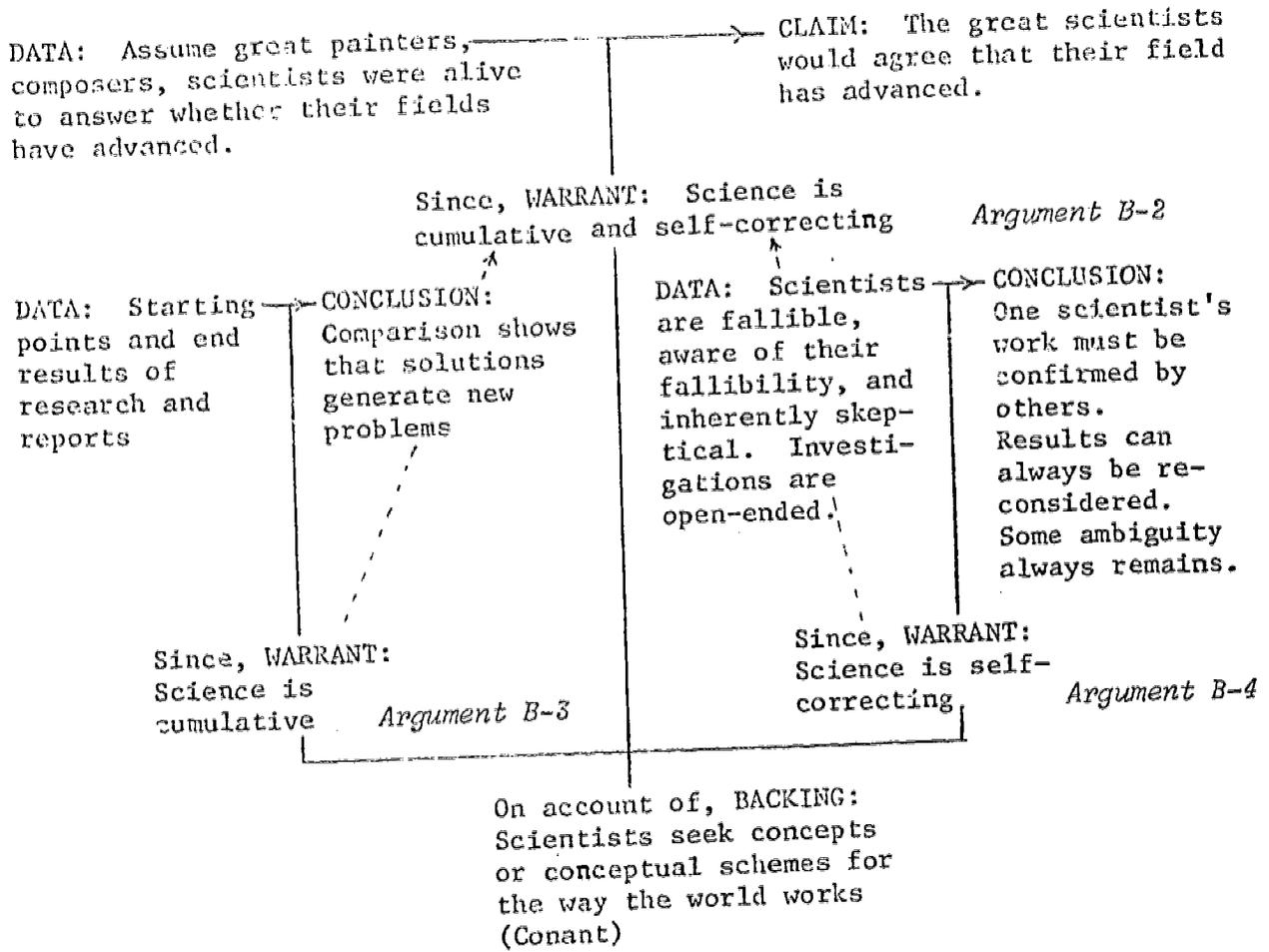


Fig. 4.--The arguments in the main portion of Selection B, shown in their inter-relationship

Perhaps the most important of the relationships revealed by these diagrams is the fact that the arguments in Figure 4 elaborate the Backing for the overall argument in Figure 3. Specifically, the Warrant that science is cumulative and self-correcting is developed from Conant's analysis of scientists' research patterns. As the dotted lines in Figure 4 indicate, a Warrant about science is obtained by uniting two separate Warrant-establishing arguments. That Warrant is used to justify a Claim (to the effect that former scientists would recognize an advance in modern science) which seems intended to generate interest in the subsequent explanation of how the two Warrants were established.

In the initial analysis, four science dimensions are cited as potentially applicable to Selection B. The possible application of the

*Demarcation of science* dimension to lines 52 to 65 is suggested by the form of the sentences: "Science, it seems, is . . .," and "Its patterns . . . and its operations . . . are . . . ." Essentially, the authors seem to say that science is an attempt to discover regularities in nature, by a complex and incompletely understood use of intelligence. Then science is described in Conant's terms, as the seeking of concepts and conceptual schemes.

The differences among the three positions on the *Demarcation of science* dimension do lend support to the view that science is not completely understood. Beyond that, the authors' view of science as the seeking of conceptual schemes which express regularities is not as carefully detailed as the positions on this dimension of the analytical scheme. The authors describe a process, rather than a result, so their statement has closer affinity to the form in which Kuhn's position is expressed.

The argument for the Warrant that science is cumulative (B-3; lines 106 to 136) readily suggests comparison with positions on the *Progress of science* dimension. The most significant content of the argument is the Conclusion that ending work on one problem generates work on one or more additional problems. There is nothing in the argument to suggest that the authors do not see accumulation as a continuous process. While the authors' position could be compatible with either Carnap's or Popper's position, the criteria provided in the argument itself are not specific enough to permit one to recognize one of the positions on this dimension.

In the argument that science is self-correcting, (B-4; lines 137 to 246) the phrase "self-correcting" is suggestive of both objectivity and truth. The relevance of the dimensions of *Objectivity of science* and *Relationship of science to truth* becomes most apparent in the closing statements of the argument (lines 226 to 246). With respect to the *Objectivity of science*, the authors stress that personal bias is avoided by having others confirm the findings of any one scientist (lines 226 to 233). Inter-subjectivity is an element of Popper's position, but his analysis stresses the form of scientific statements, not the form of scientists' actions. The other Claims (lines 170 to 181) made by the authors in this argument suggest application of the *Relationship of science to truth* dimension.

The references to open-endedness and ambiguity show similarity to Popper's position, with one important difference. The statement in lines 237 to 242 suggests that a position with respect to objectivity leads directly to a position about the relationship of science to truth. The analyses of science by Carnap, Popper, and Kuhn do not suggest that one dimension is a sub-dimension of the other, as the authors' argument does. Greater detail would be required in this argument to make further comparisons with positions on either of these dimensions of the analytical scheme.

#### Commentary on the analysis

Analysis of Selection B indicates that the authors have attempted to present their arguments fully and to identify for readers the basic principles underlying their position. They acknowledge their dependence upon Conant's view of science as the seeking of concepts and conceptual schemes. They also point out that it is possible to go beyond their discussion, and they identify some of the resources available for doing so.

Application of the analytical scheme is made to the Data and Conclusions of two Warrant-establishing arguments, in which the authors elaborate the Backing of a Warrant-using argument to the effect that great scientists of the past would interpret modern science as advance over the science of their times. These arguments, which are outlined in Figure 4, serve in turn to elaborate the Backing of the argument which is outlined in Figure 3, and which spans an entire chapter.

Four dimensions of the nature of science are relevant to the arguments in Selection B. In general, application of the analytical scheme to these arguments indicates that the authors do not provide a degree of detail comparable to that which is available within the sources for the dimensions of the scheme. Thus complete comparison is not possible. The authors raise a number of significant issues and discuss them at some length, yet details of their position are lacking and they do not illustrate the possibility of alternative interpretations.

One specific comparison can be made. With the Warrant that science is self-correcting, the authors appear to treat simultaneously the topics of scientific objectivity and the relationship of science to

truth. In contrast, construction of the analytical scheme has indicated that there is value in treating these issues separately. The pattern of this argument, shown in Figure 4, provides clues for explaining how the two issues came to be merged. In the Data, fallibility and skepticism are grouped together as characteristics of scientists, while in the Conclusions, intersubjective confirmation and the acceptance of some ambiguity in results are similarly grouped as characteristics of scientists' work. The failure to treat these two issues separately may arise from these groupings or, more simply, from the decision to use the single term, "self-correcting." The simultaneous treatment of two important issues is regarded as a limitation of the argument, identified by application of the analytical scheme.

#### Selection D

In contrast to Selection B, in which the arguments focus on the nature of science, the argument in Selection D is related to the concept of teaching. The selection is from Massey's text, Patterns for the Teaching of Science. As its title, "The Hidden Nine-Tenths,"<sup>1</sup> suggests, the chapter stresses the importance of a teacher's before-class planning, planning of which pupils remain largely unaware. Part of the chapter identifies different aspects of planning and provides some practical suggestions. The portion titled "Before Beginning to Plan"<sup>2</sup> describes three teaching patterns, or approaches. It seems an obvious choice for analysis because the patterns refer directly to several of the teaching dimensions of the analytical scheme.

Presentation of three teaching patterns constitutes the larger portion of the excerpted passage. The balance contains statements about conditions bearing on a teacher's adoption and practice of a philosophy of education. The point of the passage seems to be to identify three basic alternatives available to a teacher, with the recommendation that a beginning teacher should select one of them. Dimensions of the

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<sup>1</sup>Norman Bland Massey, Patterns for the Teaching of Science (Revised ed.; Toronto: The Macmillan Company of Canada Limited, 1969), pp. 34-37.

<sup>2</sup>Ibid., pp. 34-35.

analytical scheme can be used to analyze the three teaching patterns, which constitute the Data of the argument.

## TEXT

## INITIAL ANALYSIS

## Before Beginning to Plan

Before a teacher can begin to plan lessons, he must, of course, have decided on a teaching method, and this will depend on his philosophy of education. This may to some extent be controlled by the philosophy of the school in which he is teaching, as well as by the philosophy of the school system, but it is largely the teacher who determines how he will teach the students in his classroom. The nature of his role is, to a great extent, of his own making. Will he choose the more traditional pattern, in which the teacher is the central, dominant figure, deciding, with the help of the syllabus, what will be taught and how it will be taught? Or will he adopt a more modern, or 'progressive', approach, that views the classroom as pupil-centred, and the teacher as a guide to assist the pupils in the investigations they themselves have initiated? In the former the emphasis is on the teaching; in the latter it is on the learning. With the traditional approach the teacher has the advantage of thorough planning and a fair degree of predictability of his success. The modern approach does not permit this to any great extent, for the class is largely allowed to follow its own interest. If the class, or part of the class, becomes

The opening statements (lines 1-17) establish a context. Part of the first sentence (lines 1-4) provides the Warrant for the implied Claim that a beginning science teacher should personally select one of three possible teaching approaches. The rest of the first sentence (lines 4-6) indicates that selection is made according to one's philosophy. The balance of the introduction (lines 6-17) provides a Qualifier on the Claim that a teacher should make a completely personal choice of teaching approach.

An initial description (lines 17-30) of the "traditional" and "progressive" approaches is followed by elaboration of these two patterns. The phrases "Will he choose . . . ?" (line 17) and "Or will he adopt . . . ?" (lines 23-24) suggest the apparent Claim of the argument, that a teacher should select from among the three approaches which constitute the Data (lines 17-54 and 63-95) of the argument.

The *Communication and Use of expertise* dimensions are relevant to the presentation of the first two teaching approaches. In lines 30-33, special uses of words are introduced; the *Nature of learning* and *Nature of teaching* dimensions are relevant. In lines 33-54, additional Data about the two approaches are provided from experience. Thorough planning and predictability for the teacher are set in opposition to following interests

interested in micrometeorology;  
 45 for example, it can study this  
 aspect in some depth. Because  
 careful planning is not ordi-  
 narily possible under these  
 circumstances, the teacher must  
 50 have a good background knowl-  
 edge of his subject and be con-  
 stantly alert to opportunities  
 for learning, if his guidance  
 is to be effective. The  
 55 following chapters contain  
 many elements of the tradition-  
 al type of teaching, for this  
 is the method adopted by most  
 teachers at the beginning of  
 60 their careers, but the possi-  
 bilities of the other approach  
 are not overlooked.

In recent years there has  
 been an increasing emphasis on  
 65 the scholarly aspect of science.  
 Pupils have been made acquaint-  
 ed with the actual way in which  
 scientists work. They have be-  
 come aware of the existence of  
 70 the various disciplines of  
 science, of the scientist's  
 methods, and of the structure  
 of scientific knowledge. Sci-  
 ence classes have become places  
 75 where the pupils can investi-  
 gate some of the phenomena of  
 this world in more or less the  
 same fashion as the research  
 scientist. Some of these in-  
 80 vestigation might be original;  
 some of the problems might not  
 even be capable of solution.  
 Others might be designed to  
 lead the young student along  
 85 the same path of discovery  
 that some famous scientist once  
 followed. The aim of this  
 approach is, in part, to give  
 students a realistic apprecia-  
 90 tion of the role of the re-  
 search scientist and to en-  
 courage young people to con-  
 sider science as a career. It  
 is essentially an academically

of pupils. The example in lines  
 42-46 suggests that control of  
 subject-matter content is a  
 basic consideration.

In lines 46-54, a rationale is  
 given to explain why the "pro-  
 gressive" approach requires more  
 background knowledge. The *Nature  
 of teaching* and *Use of expertise*  
 dimensions are relevant to this,  
 and the preceding point.

In lines 54-62, subsidiary Data  
 are provided about the method  
 chosen by most beginning teachers  
 and about the appearance of the  
 two approaches in subsequent  
 chapters of the book.

Discussion of a third teaching  
 approach in lines 63-95 completes  
 the presentation of Data. The  
 third approach is referred to as  
 an "academically centred  
 approach" (lines 94-95).

It seems most appropriate to  
 interpret each teaching approach  
 as a Warrant for a teacher to use  
 in planning and interpreting  
 classroom events. One's philoso-  
 phy of education would be the  
 Backing for the Warrant. This  
 third teaching approach is de-  
 scribed indirectly at first  
 (lines 66-73), by reporting some  
 outcomes pupils have achieved  
 with the pattern. Emphasis is  
 on how scientists work and on the  
 structure of scientific knowledge.  
 These general phrases suggest  
 comparison with the *Nature of  
 knowledge*, *Nature of learning*,  
 and *Nature of teaching*  
 dimensions.

The discussion in lines 73-87  
 is more directly indicative of  
 the characteristics of the  
 "academically centred approach."  
 Lines 87-93 extend the indirect  
 description in lines 66-73.  
 Lines 95-98 provide additional

95 centred approach. Some elements of this way of teaching science are also to be found in this book.

100 Although the teacher must have some philosophy of science education before he can undertake any lesson planning, this philosophy will, no doubt, be changed as his teaching career advances. It will be modified by other school of thought and probably it will become a composite of the traditional, the progressive, and the  
110 academic.

Whatever the approach adopted, however, the teacher will only succeed if he learns to respect his pupils as individuals. We must trust each of them, expect a measure of success from each of them, and recognize the personal worth of each of them, if he is to  
120 establish a basis for the practice of his philosophy in the classroom.

subsidiary Data about subsequent chapters.

Upon completion of the presentation of Data, the discussion returns to the remainder of the argument. The Warrant is repeated (lines 99-102) and then extended to include probable development subsequent to the use of an initial teaching approach.

The final paragraph (lines 111-122) seems to offer Conditions of Rebuttal relevant to all arguments which predict success for any teaching pattern or approach.

#### Detailed analysis:

As the initial analysis indicates, it seems appropriate to treat this passage as a single argument which is supplemented by related Claims and Data. This is a Warrant-using argument for the Claim that a beginning science teacher should select one of three approaches available for teaching science. Diagrammatically, the argument may be summarized in the following way.

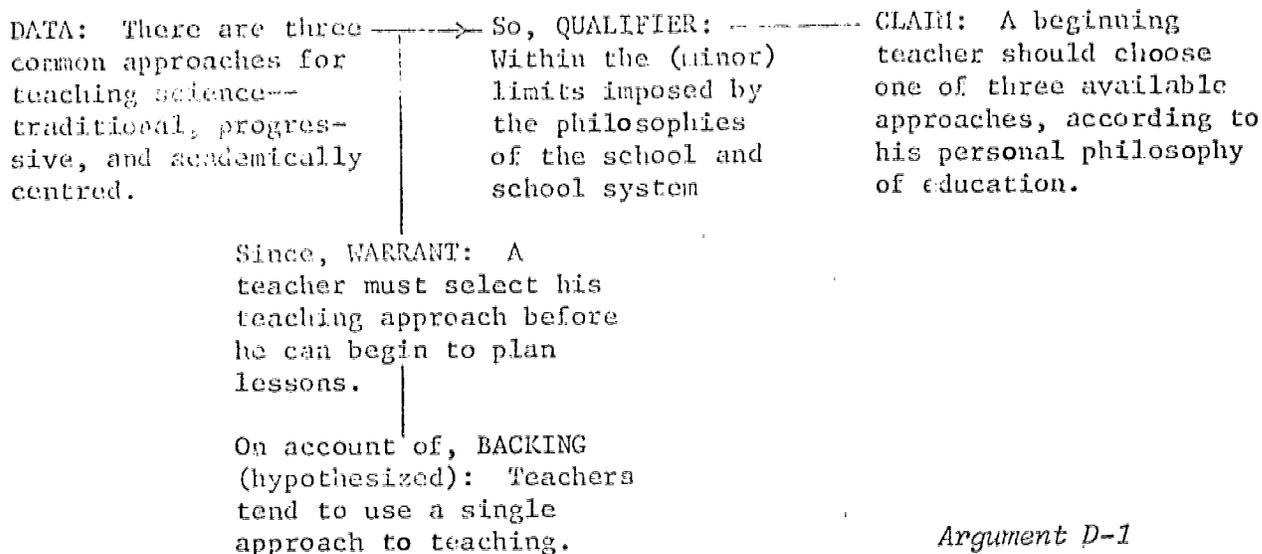


Fig. 5.--The argument-pattern of Selection D, with Backing hypothesized.

The argument provides a context within which the author can present three approaches to teaching science. The actual presentation of the approaches is the major purpose of this passage, if the proportion of space devoted to the presentation is indicative of its importance. The Claim of the argument may provide motivation for intended readers to consider them carefully.

Many of the concept-of-teaching dimensions of the analytical scheme can be applied to the presentation of three patterns of teaching, here interpreted as the Data of the argument. The content of lines 19 to 46 suggests that the "traditional" approach corresponds closely to what has been termed an information emphasis, while the "progressive" approach corresponds to the insight emphasis in the analytical scheme. The dimensions of *Communication* and *Use of expertise* are most clearly indicative of this correspondence. Reference in lines 19 to 23 to the teacher's being dominant--making decisions about what and how to teach--corresponds to the information emphasis on those dimensions. Reference in lines 27 to 30 to pupils initiating investigations which they pursue with the teacher's guidance corresponds to the insight emphasis.

Both the *Nature of Learning* and the *Nature of teaching* dimensions apply to the Claim, made in lines 30 to 33, that the traditional

approach emphasizes teaching while the progressive approach emphasizes learning. This Claim restricts excessively the meanings of the words "teaching" and "learning". Such a simplistic approach is avoided by using the information and insight emphases to develop the portion of the analytical scheme which relates to the concept of teaching.

The reference in lines 33 to 38 to thorough planning and predictable success suggests the considerable or complete structure of the information emphasis. The points developed in lines 38 to 54 seem to indicate a departure from the correspondence between the progressive (or "modern") approach and the insight emphasis. This portion of the Data corresponds more closely to the composite perspective on the *Use of expertise* dimension. That is, the author clearly indicates that a teacher must be prepared to use his knowledge of a subject to guide his efforts to make learning possible. In short, these shifting meanings could be quite confusing for a reader.

The terms used to describe the "academically centred" approach seem to correspond closely to certain features of the composite perspective. References to how scientists work, in lines 66 to 68 and 75 to 79, are suggestive of, but not as complete as, the composite perspective position on the *Nature of teaching* dimension. The composite perspective position on the *Nature of knowledge* dimension is suggested by the reference to disciplines of science in lines 70 and 71. Finally, into the reference to methods and structure of knowledge in lines 71 to 73, one may read the combination of information and judgment expressed in the composite perspective position on the *Nature of learning and Nature of teaching* dimensions.

#### Commentary on the analysis

With the exception of the *Authority* dimension, all dimensions of the concept of teaching are relevant to analysis of this selection. All of the issues raised within the presentation of three approaches to science teaching can be interpreted adequately by application of the analytical scheme.

Use of the scheme to analyze the content of this argument raises two points particularly relevant to an assessment of the applicability

of the scheme. In lines 30 to 33, the words "teaching" and "learning" are used quite differently than elsewhere in the argument--almost in a slogan sense. Application of the analytical scheme readily identifies this different usage. The analytical scheme enables one to identify the traditional and progressive approaches with the information and insight emphases in a straightforward manner.

A second comment on the applicability of the analytical scheme emerges from the use of the *Communication and Use of expertise* dimensions to analyze lines 19 to 42. While both dimensions do seem relevant to that portion of the argument, there is some ambiguity in distinguishing the applicability of one dimension from that of the other. The differences between the two dimensions need to be expressed more clearly; modifications to the scheme are suggested at the end of the chapter.

As noted previously, the analytical scheme is applicable only to the Data of the argument in Selection D. Application of the scheme suggests that the traditional, progressive, and academically centred approaches show some correspondence to the information emphasis, the insight emphasis, and the composite perspective. The correspondence is a limited one. Points of opposition between the traditional and progressive approaches appear more as differences of opinion than as systematic differences. The various dimensions of the analytical scheme represent different and explicit ways of comparing the three perspectives on teaching.

A variety of limitations have been identified in the presentation of the Data. Backing for the Warrant is not made available. Accordingly, it is judged that the argument falls short of making provision for acceptance on rational authority.

### Selection E

The opening section in Romey's Inquiry Techniques for Teaching Science is titled, "What is Science?"<sup>1</sup> The passage combines discussions of what science is and how science is and should be taught, to reach the

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<sup>1</sup>William D. Romey, Inquiry Techniques for Teaching Science (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968), pp. 3-4.

conclusion that science teaching should emphasize the processes and methods of scientists, continuously and from an early age.

Application of Toulmin's concept of an argument-pattern suggests that parts of twelve different arguments appear in this selection, with Conclusions of some arguments serving as Data for succeeding ones. When reading the passage, it is significant to note that six of the arguments employ or generate pairs of mutually exclusive alternatives. Once these alternatives have been established, the overall Claim appears to be reached by an implicit Warrant to the effect that when one of two alternatives has many shortcomings, one should proceed according to the other.

Because so many arguments appear in a short space, the initial analysis accompanying the selected passage is somewhat sketchy. More complete analysis follows.

## TEXT

## INITIAL ANALYSIS

What is Science?

Books about methods of teaching science invariably begin with a section that defines "science." Perhaps this is the best place to begin.

If you should examine most college science courses, you might have to conclude that science is primarily a large body of knowledge. College teachers seem willing to accept without any objection the original meaning of the Latin word scientia; knowledge. Forators believe that beginning teachers generally imitate the person they consider to have been their own best teacher. This often leads to a series of lectures supported by a small amount of laboratory work and group discussion. In such a framework the teacher becomes a figure of authority, whose main function is to dispense knowledge. Teaching is then a matter of the teacher's

The preferred definition of science appears in lines 99-104. It is contrasted with the definition in line 14, to create one alternative relevant to the overall Claim of the passage.

The first argument (lines 6-14) seems to use an implicit Warrant that a teacher's teaching reflects his understanding of his subject. The *Nature of knowledge* and *Demarcation of science* dimensions are relevant. The second argument (lines 15-22) seems intended to explain why beginning teachers lecture, in preference to laboratory work and discussion. The *Nature of teaching* dimension is relevant. The *Authority* dimension applies to the third argument (lines 22-26), which extends the first two. In turn, it is extended by the fourth argument (lines 26-29). The arguments in lines 22-29 seem to use implicit Warrants concerning popular perceptions of specific

demonstrating to his students how much he knows.

30 A number of years ago, after the author had handed in a mediocre report in field geology, the course instructor informed the author that geology  
35 was more an art than a science. However, as the author continued graduate study he found that the courses he took emphasized more and more the facts  
40 of geology and the conclusions of other geologists. As do most students in science courses, he had to memorize factual information and then  
45 reproduce it on examinations.

Then the author found he had to work on a thesis project for which there was no authority with a set of neatly prepared  
50 answers. Most of the knowledge he had gained in his courses was useful only as a tool to find answers to problems. He had to discover even the problems themselves. How much  
55 mental strife might have been avoided had his training in course work been aimed more at the recognition of problems,  
60 the formulation of hypotheses, the gathering and analysis of data, and the arrival at conclusions.

In a sense, the teaching of  
65 science can be compared to the teaching of art. Some art schools stress the history of art, whereas others are more concerned with studio art;  
70 actual painting or sculpture. The difference between the two approaches is that one produces art historians whereas the other produces artists. The  
75 same is true of science. At present, many of our secondary schools and colleges are teaching the history of science

behaviors. The *Use of expertise* dimension is relevant to the fourth argument.

The fifth argument (lines 30-63) builds on Data from the author's experience as a graduate student. The argument develops a contrast between an emphasis on facts and memorization and an emphasis on the identification and solution of problems. The fifth argument is interrupted by the sixth, for which only the Claim is presented (lines 41-45). No Data beyond the author's own experiences are presented. The fifth argument seems to use an implicit Warrant to the effect that prior training could reduce the "mental strife" associated with not knowing what to do in an unfamiliar situation. The Claim is made (lines 41-45) that the author could have avoided much mental strife had he been trained in particular (scientific) processes. The *Demarcation of science* and *How empirical content increases* dimensions appear to be relevant.

On the Backing of the author's opinion, the seventh argument (lines 64-79) relies upon a Warrant (lines 64-66 and 74-75) that art teaching and science teaching are comparable in the types of outcomes achieved by different instructional patterns. A contrast is set up between the history and the actual practice of a discipline. The *Nature of teaching* dimension is relevant.

In lines 79-84, only the Claim of the eighth argument is presented, extending the history-

rather than science itself. We  
 80 burden students with factual  
 knowledge, but few students get  
 to do science until they reach  
 the level where they must write  
 a master's or doctor's thesis.  
 85 Asking a highschool or college  
 undergraduate to learn science  
 from a book or from a set of  
 lectures is a little like asking  
 a music student to learn  
 90 the notes to a composition for  
 the piano before he has been  
 taught how to play the instru-

ment.  
 Recent curriculum studies  
 95 make it clear that young  
 children, even at the elemen-  
 tary school level, are capable  
 of doing simple scientific  
 work. The word "scientific"  
 100 comes from the two Latin words  
scientia, knowledge, and  
facere, to make. "Scientific"  
 refers to the creating  
 of knowledge. Students need  
 105 not wait until graduate school  
 to do scientific work in  
 science classes. On the con-  
 trary, emphasis on the process-  
 es and methods of scientists  
 110 should begin in the elementary  
 school and continue throughout  
 the student's academic career.

The main problem with which  
 this book deals is how to make  
 115 the teaching of science more  
 scientific.

practice contrast and attributing  
 a disadvantage to an emphasis on  
 facts. The *Use of expertise* and  
*Nature of learning* dimensions are  
 relevant to this and the next  
 argument.

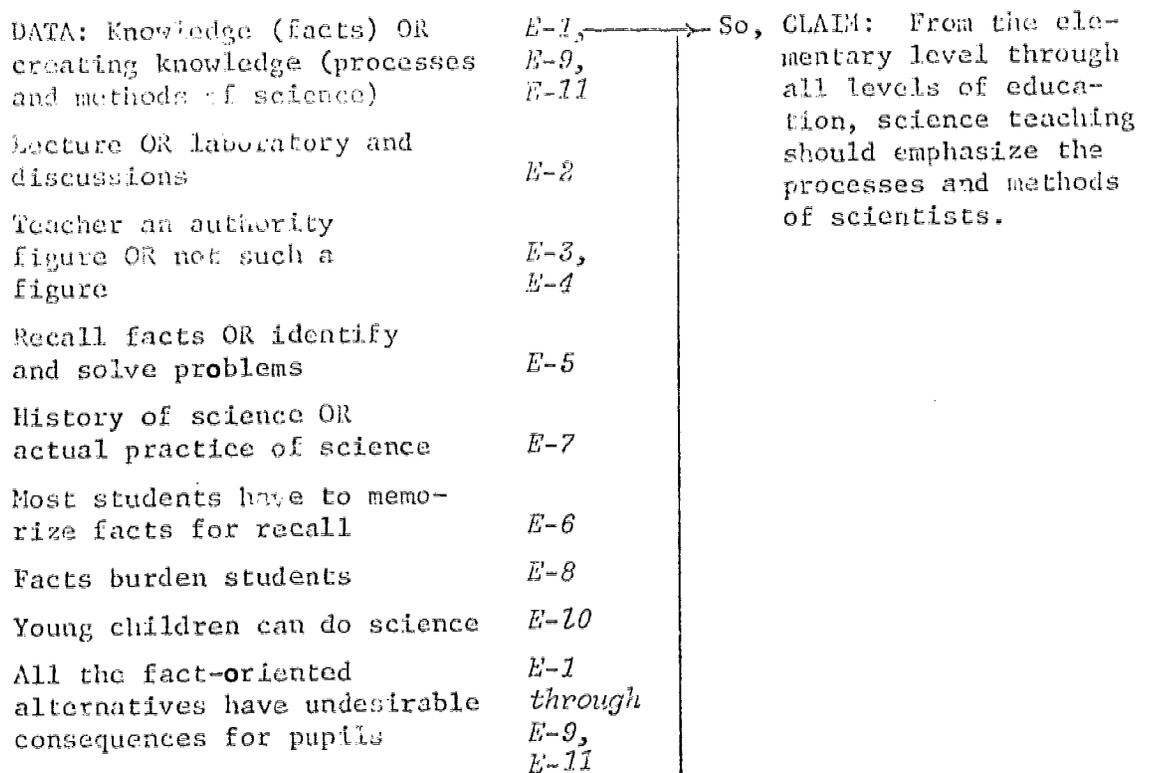
The ninth argument (lines 87-  
 93) uses a Warrant that teaching  
 music and teaching science are  
 slightly similar, again on the  
 Backing of the author's personal  
 belief. Implicit is a Claim that  
 it is absurd to learn science as  
 facts from books and lectures.

The tenth argument (lines 94-  
 99) reports a Claim for which  
 "recent curriculum studies" are  
 the source of Data, Warrant, and  
 Backing. The eleventh argument  
 (lines 99-104) provides a Claim  
 which contrasts with that of the  
 first argument, again using a  
 Warrant that meanings may be  
 derived from Latin roots. The  
*Demarcation of science* and *Pro-*  
*gress of science* dimensions may  
 be helpful in examining this  
 argument.

The twelfth argument takes all  
 the preceding arguments as Data  
 and moves to the Claim expressed  
 in lines 104-112, with an impli-  
 cit Warrant that the better al-  
 ternative is the one without  
 disadvantages. Again, the  
 Backing seems to be the author's  
 own opinions about how science  
 may be defined and how it should  
 be taught.

#### Detailed analysis

Twelve different arguments are identified in the initial analysis. Each of eleven arguments contributes to the passage's overall Claim, which is taken to be part of a twelfth argument. All of the arguments appear to be Warrant-using arguments, contributing Claims which serve as Data for the final Claim that science teaching should always stress the processes and methods of scientists, from the elementary level on. The



Since, WARRANT (hypothesized): When one of two clear alternatives has many disadvantages, select the other.

On account of, BACKING (hypothesized): The author's experience indicates it is appropriate to conceptualize science and teaching in dichotomous terms.

*Argument E-12*

Fig. 6.--The argument-pattern for the overall argument of Selection E, with Warrant and Backing hypothesized.

In the first, fifth, and eleventh arguments, the author of Selection E refers in several ways to a difference between knowledge itself and the processes by which knowledge is created. In the first and eleventh arguments (lines 6 to 14 and 99 to 104), the question of Latin roots of "science" and "scientific" is raised. Since the author

appears to be examining whether knowledge or the processes by which it is achieved is indicative of the unique nature of science, the *Demarcation of science* dimension appears relevant. That reference to Latin roots is not found in the three positions on this dimension of the analytical scheme is not as significant as the fact that the author seems to force a choice between looking at scientific statements and looking at scientists' actions. Despite the obvious and important differences between the positions expressed by Carnap, Popper, and Kuhn, each position expresses a way to relate what scientists do to the acceptance or rejection of scientific statements. In this sense the author's approach to the demarcation of science appears to be inadequate.

The fifth argument (lines 30 to 63) adds nothing new to analysis of the demarcation of science, but it does raise the question of how scientists seek, and can be trained to seek, knowledge. When one considers the possible relevance of the dimension *How empirical content increases*, the processes cited by the author as a focus for training (lines 59 to 63) are found to be unrelated to the issues raised by Carnap, Popper, and Kuhn. The processes mentioned by the author are broad and general, and suggestive of a "method" of research, while this dimension of the analytical scheme raises specific questions about how additional knowledge is incorporated into science.

The author's phrase, "the creating of knowledge" (lines 103 to 104), suggests the possibility of reference to the *Progress of science* dimension. Here again it is evident that the three available positions relate scientists' methods to scientific statements, while the author appears to be seeking a sharp distinction between processes and results in his analysis of science.

Thus, with each of three relevant dimensions concerning the nature of science, similar results are obtained: it seems that the author is presenting an unusual position without developing in detail whatever support may be available for his position.

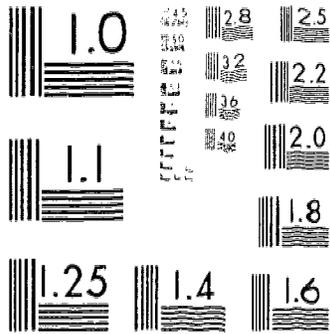
Of the dimensions of the concept of teaching, the *Nature of knowledge* dimension is the first to which the content of Selection E may be compared. This dimension is relevant to the argument in lines 6 to 14

(E-1), where the author suggests that college teachers accept a position close to the information emphasis position. The same dimension is relevant to the argument in lines 79 to 104 (E-11), where it is not possible to distinguish clearly between the positions of the insight emphasis and the composite perspective. In argument E-11, associated remarks about the capabilities of young children (lines 94 to 99) and about the time for beginning to do scientific work (lines 104 to 107) do seem to stress what individuals do on their own. Thus it seems more likely that the insight emphasis position on the *Nature of knowledge* dimension would be suggested.

The discussion in lines 15 to 29 is clearly indicative of the information emphasis, on the dimensions of *Nature of teaching*, *Authority*, and *Use of expertise*. The same position on the *Nature of learning* dimension is suggested in lines 36 to 45. The author is critical of these positions, and the overall argument seems to be intended to achieve a rejection of the information emphasis by a reader.

It is not as easy to determine whether the insight emphasis or the composite perspective is to be regarded as the desirable alternative. The *Authority* dimension of the scheme is relevant to the statement in lines 46 to 50, where the wording suggests the complete unavailability of authority in the sense associated with the information emphasis. The statement in lines 55 to 63 is difficult to interpret on the *Nature of learning* dimension, for the author does not provide sufficient criteria to permit distinguishing what one is able to do personally from what one may be able to do with the support of a discipline.

The argument continues to be less than definitive in lines 64 to 93, where the *Nature of learning*, *Nature of teaching*, and *Use of expertise* dimensions are relevant. In particular, the author fails to consider what a teacher must do to enable a pupil to "do science" (line 82). Rejection of teaching the history of a discipline suggests that the passage is more likely to be associated with the insight emphasis than with the composite perspective. To the investigator, these points and the presentation of pairs of mutually exclusive alternatives in arguments about how science should and should not be taught (lines 15 to 29 and 36 to 93) indicate that the passage as a whole is likely to suggest positions on the insight emphasis.



MICROCOPY RESOLUTION TEST CHART  
NATIONAL BUREAU OF STANDARDS 1963-A

Commentary on the analysis

Because the overall argument in Selection E is interpreted as a Warrant-using argument, one must consider the Data, Backing, and Warrant of the argument in assessing the provision made for acceptance on rational authority. The analysis identifies several points at which parts of the eleven arguments providing Data are omitted, and so one could argue immediately that there are shortcomings in this argument. Similarly, because the Warrant of the argument had to be hypothesized and because the Backing does not appear to go beyond the author's own experiences, this argument appears to rely heavily upon the personal authority of the author.

Application of the analytical scheme to Selection E, which involves both nature-of-science and concept-of-teaching dimensions, provides an assessment of the acceptability of the Data of the argument. Although limitations of the argument's provision for acceptance on rational authority have been identified above, there is value in reviewing the results of the detailed analysis. Reference to three science dimensions indicates that the author is attempting to view science only in terms of the methods of scientists, without reference to the nature of scientific knowledge. Various dimensions of the concept of teaching indicate rejection of the information emphasis, with apparent acceptance of the insight emphasis as the only desirable alternative.

The dimensions of the concept of teaching are more clearly and extensively applicable to the Data of the argument. Of particular significance is the close correspondence between the author's expressed views of science and the insight emphasis on the *Nature of knowledge* dimension--"personally achieved insight or judgment." Given the clear rejection of an emphasis on "factual information" and the clear expression of an "either-or" posture characteristic of the tension between information and insight emphases, it seems possible that a reader could view the analysis of science as dependent upon the analysis of teaching. Thus the assessment of the Data by reference to dimensions of the analytical scheme suggests that even if other, more obvious, shortcomings were resolved, it would still not be possible to accept the argument on rational authority.

Selection C

A passage concerned with how science should be taught has been selected from a chapter titled "How Boys and Girls Learn Science,"<sup>1</sup> in Teaching Science in Today's Secondary Schools, by Thurber and Collette. There are two arguments in Selection C, and both appear to be warrant-establishing arguments. In these arguments, taken from a section headed "Teaching Principles and Generalizations," the scientific method of reasoning and the nature of scientific theories are related to the teaching of science.<sup>2</sup>

## TEXT

The scientific method. Inductive and deductive reasoning as such do not require the testing of conclusions. Armchair philosophers, including some well-known scientists, have made valuable contributions and also interesting mistakes by depending upon these types of reasoning alone.

The scientific method of reasoning involves elements of both the inductive and deductive processes and demands in addition careful checking of conclusions. The method is not limited to science or to scientists, nor does it have a stereotyped pattern. All careful thinkers use it.

(An example in which science students studied the phototropic behavior of one type of fly is omitted.)

Unconsciously, this class was making use of the scientific method. The pupils had a

## INITIAL ANALYSIS

The first two paragraphs (lines 1-20) develop the Data of the first argument. The scientific method is described as a method of reasoning, in which testing of conclusions is added to inductive and deductive reasoning. The comments about this method, in lines 16-20, seem more likely to form part of the Backing. The dimension *How empirical content increases* may be relevant to the Data.

The discussion in lines 21-33 provides an example which seems to serve two functions. It adds

<sup>1</sup>W.A. Thurber and A.T. Collette, Teaching Science in Today's Secondary Schools (3rd ed.; Boston: Allyn and Bacon, 1968), pp. 38-70.

<sup>2</sup>Ibid., pp. 58-59.

25 problem and they proposed some solutions. They gathered pertinent information, in this case by experiments, and arrived at a tentative conclusion that was tested by further observations. Continued testing caused them to modify the final statement to one that seemed satisfactory to everyone.

35 The scientific method of reasoning as a procedure in teaching has much to commend it. Although it demands adequate time for satisfactory development, the resulting learnings are sound. Pupils know the exact meaning of the general statement, they know its applications, and they know its limitations.

45 Although the scientific method of reasoning is little more than applied common sense, it is not something that can be taught by a lecture or a single illustration at the beginning of the year. The scientific method demands extensive practice in a wide variety of situations. It need not be formalized by listing it in sequential steps; indeed such formalization may interfere with the thinking of pupils. Pupils are generally intelligent enough to work out satisfactory procedures for each particular situation without reference to a formal list.

The teaching of theories.  
Theories are generalizations that have been formulated to explain a set of conditions. Some theories are widely accepted and some are in dispute. All theories are susceptible to modification and even to abandonment. The thinking person may accept a theory but he always does so with reservations. Many of the great contributions

detail to the previous description of the scientific method. It also identifies what is likely to be meant by the suggestion in lines 35-36 that this method may be regarded as a teaching procedure.

The sentence in lines 34-37 is interpreted as stating the Warrant being established in the argument. It is immediately followed by the Conclusion, in lines 37-44, that this teaching procedure produces sound "learnings." The *Nature of Learning* dimension may be relevant to the remarks in lines 40-44.

The final paragraph (lines 45-62) of the first argument seems to provide several items which are relevant at the level of Backing, rather than Data. Three points refer to the scientific method, and a fourth refers to pupils' ability to apply the scientific method. In this interpretation, all comments about the scientific method are regarded as Backing for the Warrant; only the description of what the authors take that method to be is regarded as providing Data.

The second argument begins with presentation of Data. In lines 64-78, several characteristics of theories are set out. The *Relationship of science to truth* dimension may be relevant.

7) to science have been made by men who refused to accept blindly the theories prevailing at the time.

80 No part of the science program needs more careful treatment than the teaching of theories. It is all too easy to influence young minds into accepting theories as facts--  
85 either closing the minds permanently or making it difficult for the minds to be changed.

Pupils should be conscious of the theories dealt with in  
90 the science program. They should be shown why the theory was proposed, they should be given the data that was used in its formulation, and they  
95 should know the evidence that has accumulated in its support and any modifications that the theory has undergone. The limitations of the theory  
100 should be made clear.

Pupils trained to evaluate theories carefully have open  
105 minds. They can accept change. They realize that little is known in the field of science. They understand the challenge of science. They may be tomorrow's Kepplers [sic] and Darwins and Einsteins.

110 Unfortunately, teachers must do a good deal of sifting to isolate theories from facts. Far too many authors and teachers ignore the distinction.  
115 Books commonly use the expression, "The Molecular Theory," without pointing out in the slightest how the accompanying information differs from fact-  
120 ual material presented in other portions of the book.

The statements which follow the Data seem to express considerations at the level of Backing (lines 79-87). They indicate why it is important to develop a position on the teaching of theories.

The statements in lines 88-100 are interpreted as providing the Warrant being established. The meaning of the first sentence (lines 88-90) is expanded by the second and third sentences (lines 90-100). The *Communication* dimension may be relevant to this Warrant for the teaching of theories.

Lines 101-107 provide the Conclusion which is intended to support the Warrant already presented (lines 88-100). Four desirable characteristics are associated with pupils trained to evaluate theories. The last sentence (lines 107-109) seems to be intended to enhance the value of the preceding characteristics.

The last paragraph included in this selection (lines 110-121) identifies a practical problem associated with the application of the Warrant. The point is related to the Backing already indicated (lines 82-87).

Detailed analysis

The authors of Selection G have provided the four basic elements for each of the two arguments. In both instances, comments about the Data seem best interpreted as part of the Backing for the Warrant being established. The two Warrants speak to how science should be taught, and the comments interpreted as Backing indicate the significance of characteristics of science for a science teacher. These features are displayed in the argument-patterns in Figures 7 and 8.

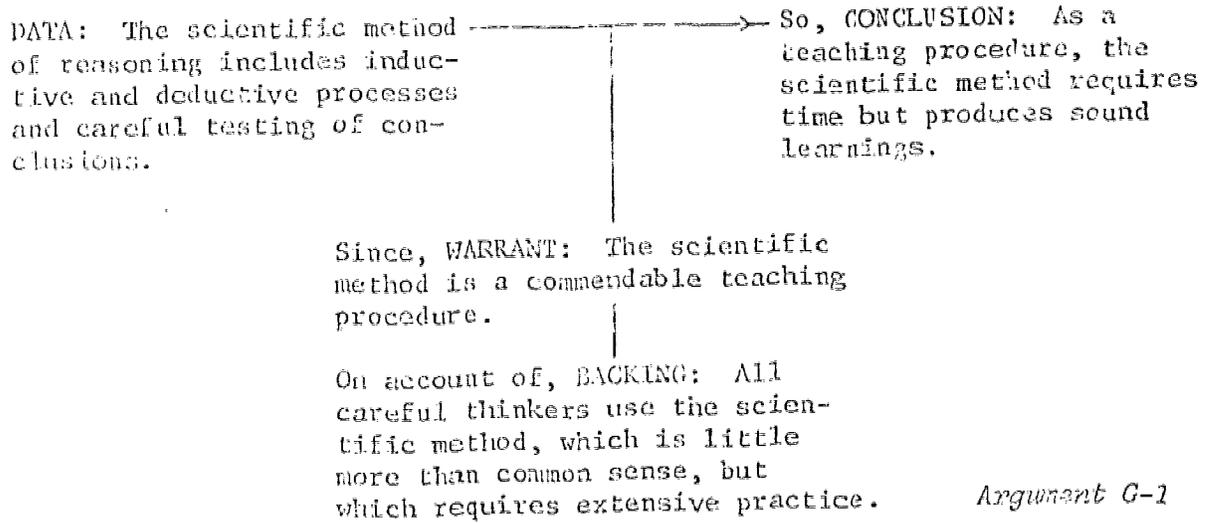


Fig. 7.--The argument-pattern of the first argument in Selection G.

and limitations.

On account of, BACKING: Theories  
are easily accepted as facts, with  
undesirable results for students.  
How theories are taught requires  
careful treatment.

Argument G-2

Fig. 8.--The argument-pattern of the second  
argument in Selection G.

The discussion of the "scientific method" introduces the Data of argument G-1. The authors' description of the scientific method (lines 11 to 33) is a general one--problem, hypotheses, experimental data, tentative conclusion, and modification by continued testing. It seems appropriate to come to an understanding of this method with reference to science before interpreting it as a method of teaching. When one reviews the titles of the dimensions relevant to the nature of science, the dimension *How empirical content increases* seems likely to be relevant. Positions on this dimension speak specifically and in detail to the acceptance of conclusions into the body of scientific knowledge. Positions on the *Progress of science* dimension relate to the issue of continued testing, while questions of whether and in what sense a conclusion is tentative are addressed by the dimension *Relationship of science to truth*.

Two results may be drawn from this comparison between the text and the analytical scheme. The authors touch on a number of issues in their references to the scientific method, and they do not examine these issues in detail sufficient to permit their positions to be compared to those on the several relevant dimensions. The impression that significant

issues are not being developed by the authors is borne out by their subsequent expression of the view that "the scientific method of reasoning is little more than common sense" (lines 45 to 47). Reference to the analytical scheme permits one to conclude that several issues associated with the Data of the argument have not been identified explicitly or addressed comprehensively.

The several characteristics of theories which serve as Data in argument G-2 suggest that comparison to positions on the *Relationship of science to truth* dimension would be appropriate. Even though the authors do not mention the concept of truth explicitly, the references to modification, abandonment, and acceptance with reservations indicate that this dimension is relevant to the content of the argument. The authors' position shows more similarity to Kuhn's than to the positions of Carnap and Popper. However, the position is not developed to an extent which would permit close comparison. The authors do express particular interest in the differences between theories and facts (lines 84 and 110 to 114), but they appear to regard the differences more as self-explanatory than as deserving of study. Reference to the analytical scheme confirms that the authors have not developed these differences as they could have.

The Conclusion of the first argument and the Warrant of the second argument are expressed in terms which hint at issues associated with two dimensions of the concept of teaching. The evidence is limited and inconclusive, but the possible application deserves brief consideration. In lines 40 to 44, the authors expand their reference in line 40 to "sound" learnings. Pupils are said to "know" exact meanings, applications, and limitations of what they learn. These characteristics could be associated with the composite perspective on the *Nature of learning* dimension. However, the position has been asserted, not supported empirically. In the second argument, in lines 90 to 100, the verbs used to expand the meaning of being "conscious of the theories" (lines 88 and 89) convey a message about how a teacher relates to students. The passive mode of expression (lines 91, 92 and 93, and 100) seems closest to the information emphasis on the *Communication* dimension. In both instances, the evidence is limited and the identification of a position is only

tentative. Reference to these two dimensions does suggest that issues are raised which merit further examination for full understanding of the authors' position.

Finally, in concluding the detailed analysis, it is interesting to note that the same order of presentation of argument-elements occurs in both arguments. The elements of Data and Backing precede the Warrant being established, and the Warrant is followed by the known Conclusion. One might speculate about whether such a sequence invites the careful scrutiny a reader might be expected to give the arguments if he is to accept them on rational authority.

#### Commentary on the analysis

Three dimensions of the nature of science contribute to analysis of the Data of the two Warrant-establishing arguments in Selection G. Two dimensions of the concept of teaching appear relevant to the manner in which other elements of the arguments are stated.

The issues raised by the discussions of the scientific method and the nature of theories can be interpreted adequately by reference to the analytical scheme. Application of the scheme demonstrates that the scheme does have the capability to permit one to recognize that issues associated with the nature of science are not being addressed clearly or comprehensively.

The authors do appear to provide the elements required for complete arguments. However, significant issues associated with the Data presented in each argument are not developed for the reader. Support for the Conclusions about how children learn is not provided in these Warrant-establishing arguments. Thus the authors cannot be said to make provision for acceptance of the arguments on rational authority.

#### Interpretation of the Results of Application of the Analytical Scheme

In this final section of the chapter, the various kinds of information obtained in the preceding analysis are summarized and interpreted. The five questions posed in the introduction to the chapter serve as a guide. Attention is given to both the content and the structure of

arguments. Later in the section, comments are included about the subsidiary analysis of additional textbook passages, presented in Appendix A.

Several broad generalizations provide points of reference for examining the results first in terms of dimensions of the scheme and then across all four selections to which the scheme has been applied. Application of dimensions of the nature of science has often produced a conclusion that an issue is not presented in detail sufficient to permit a satisfactory comparison between a position in an argument and the positions on a relevant dimension. At times the detail is sufficient to permit recognition of similarities, but positions within the dimensions are never clearly identifiable in the analyzed passages. In contrast, application of dimensions of the concept of teaching has frequently resulted in recognition within arguments of positions expressed within relevant dimensions. However, positions associated with the composite perspective are never fully expressed in the analyzed passages. In the two selections which discuss extensively how science is taught (D and E), development of arguments involves the contrast between the information and insight emphases of various dimensions.

Results of analysis, by  
individual dimensions

1. *Is each of the dimensions of the scheme relevant to some portion of at least one of the selected passages? If not, is this a reflection on the analytical scheme?*

Within the sample of Selections B, D, E, and G, each dimension of the analytical scheme is relevant at least once, and most dimensions are applicable to more than one argument. Table 4 summarizes the results relevant to this question by indicating the particular arguments to which each dimension has been found to be applicable.

2. *Are the range and detail of each dimension adequate for use in analysis of arguments? Are modifications to dimensions required or suggested?*

The most appropriate means for dealing with this question is to summarize the results on a dimension-by-dimension basis.

The *Demarcation of science* dimension is relevant to arguments B-1, E-1, E-5, and E-11. In both Selection B and Selection E, the authors appear

TABLE 4

ARGUMENTS RELEVANT TO EACH DIMENSION  
OF THE ANALYTICAL SCHEME  
(Selections L, D, E, and G)

<i>Demarcation of science</i>	B-1	E-1, E-5, and E-11	
<i>How empirical content increases</i>		E-5	G-1
<i>Objectivity of science</i>	B-4		
<i>Relationship of science to truth</i>	B-4		G-1, G-2
<i>Progress of science</i>	B-3	E-11	G-1
<i>Nature of knowledge</i>	D-1	E-1	
<i>Nature of learning</i>	D-1	E-8, E-9	G-1
<i>Nature of teaching</i>	D-1	E-2, E-7	
<i>Communication</i>	D-1		G-2
<i>Authority</i>		E-3	
<i>Use of expertise</i>	D-1	E-4, E-8, and E-9	

to be developing a position about characteristics unique to science. The authors' positions are not well developed, when compared to positions on this dimension of the analytical scheme. Thus there is no reason to consider altering this dimension of the scheme.

Arguments E-5 and G-1 afford opportunities to apply the dimension *How empirical content increases*, which is regarded by the investigator as the most appropriate dimension for analysis of discussions of a "scientific method." In these two arguments, no direct comparisons are possible. Because the concept of a "scientific method" tends not to be regarded as philosophically productive, this result is not regarded as an indication that the range of positions might be inadequate.

The *Objectivity of science* dimension is applied only once. In argument B-4, a position similar to one of the positions on this dimension is developed. The *Relationship of science to truth* dimension is applicable to the content of arguments B-4, G-1, and G-2. In the first, some similarity to Popper's position on this dimension is found; in the last, a slight similarity to Kuhn's position is identifiable. In these instances of similarity to one position on a dimension, there is no reason to regard the range of available positions as inadequate.

Arguments B-3, E-11, and G-1 provide opportunities to apply the scheme's final dimension of the nature of science, *Progress of science*. The content of these arguments does not appear to challenge the range of available positions. Argument E-11 deserves special note: there a position is suggested (though not developed) which separates the processes of science from their results. Construction of the analytical scheme has given no indication that such a position might be appropriate. Thus the content of argument E-11 also does not appear to challenge the range of available positions on this dimension of the analytical scheme.

With each of the six dimensions of the concept of teaching, it is possible to identify one or more of a dimension's three positions in the arguments to which a dimension is applicable. The *Nature of knowledge* dimension is applicable to arguments D-1 and E-1; in the former, the composite perspective is suggested, and in the latter, the information emphasis. The *Nature of learning* dimension is applicable to arguments D-1, E-8, E-9, and G-1, while the *Nature of teaching* dimension is

applicable to arguments D-1, E-2, and E-7. All three positions of both dimensions are identifiable within these several applications. The range and detail of the dimensions seem adequate and no modifications are suggested.

Arguments D-1 and G-2 permit application of the *Communication* dimension, and two of its positions are identifiable. The application to argument D-1 identifies a difficulty in distinguishing between the relevance of this and the *Use of expertise* dimension, particularly with respect to the information emphasis.

The *Authority* dimension finds application only in argument E-3, where the position associated with the information emphasis is recognized.

The *Use of expertise* dimension is relevant to arguments D-1, E-4, E-8, and E-9. All three positions on this dimension are identifiable within these arguments. As noted in the discussion of the *Communication* dimension, the application to argument D-1 indicates a need to distinguish more clearly between these two dimensions, and to ensure that there is a significant difference which justifies two separate dimensions.

One source of confusion is readily identifiable: the word "expertise" appears in the positions of the *Use of expertise* dimension and in the information emphasis position of the *Communication* dimension (refer to Table 2, page 149). There are indeed significant differences between the dimensions, as shown in their derivation in Chapter IV and confirmed in the application of the scheme. The *Communication* dimension calls attention to an important aspect of teaching involving expertise in the processing of information. There are other types of expertise possessed by teachers, and issues other than communication are involved in their use. Two specific suggestions for improving the clarity of these dimensions emerge from applying the scheme. In the revised statement of the analytical scheme, in Appendix B, the *Communication* dimension is stated after the *Use of expertise* dimension, to give visual support to the fact that the former is to some extent a sub-dimension of the latter. Also, the phrase, "expertise in processing information" is changed to "ability to process information." The new wording parallels the wording of the insight-emphasis position on the *Communication* dimension. It has the same meaning,

in essence, but it indicates more clearly that the particular concern of this dimension is the processing of information by teacher and pupils, not the general use of expertise by the teacher. This is the only modification suggested or required by the results of application of the analytical scheme to these arguments about the teaching of science.

Results of analysis across  
the four selections

3. *Does analysis of an argument according to dimensions of the analytical scheme permit one to determine whether issues are addressed clearly, distinctly, and comprehensively in the argument?*

This question can be answered affirmatively, with the support of instances in which issues are not addressed clearly, distinctly, or comprehensively. There are several cases in which issues are not addressed distinctly. In argument B-4, scientific objectivity and the status of scientific conclusions with respect to truth are treated simultaneously, as a single issue. In argument D-1, the words "teaching" and "learning" are given restricted meanings for a brief time, without addressing the more basic question of different emphases in the interpretation of both words. In Selection E, analysis indicates a possibility that the position about the nature of science could appear to be derived from the position about the concept of teaching.

There are also instances in which issues are not addressed comprehensively. Perhaps the clearest case occurs in argument D-1, in which the author develops three "approaches" to teaching which initially seemed to be similar to the three perspectives on the concept of teaching. In developing his argument the author is less than comprehensive. He focuses attention on contrasting two approaches but neither is compared to the third.

There are several cases in which one concludes from the analysis that issues are not addressed clearly. Argument G-1 illustrates a failure to address issues either clearly or comprehensively. In a single sentence (lines 25 to 30), the author touches upon issues associated with three dimensions of the nature of science without clearly identifying them as issues or providing details of his position on those issues.

4. *Does analysis of an argument according to dimensions of the analytical scheme facilitate identification of the authority upon which the argument rests?*

This question can be answered affirmatively in the light of criteria set down in the illustration of the format of the analysis, earlier in the chapter. In each of the four selections, analysis focuses on a particular and significant element of argument. In Selection B, analysis addresses the Backing of argument B-2, and, ultimately, of argument B-1 as well. In Selection D, analysis provides an assessment of the Data of the argument. Analysis of Selection E provides many perspectives on the Data of argument E-12, while in Selection G, analysis provides an assessment of the Data of arguments G-1 and G-2. In each instance, results of analysis of an important element of an argument contribute to a conclusion about the authority upon which the argument rests.

5. *Do significant issues arise in the selected passages which cannot be analyzed in terms of dimensions of the analytical scheme? Are additional dimensions required or suggested?*

The four selections do not present issues about science or teaching which cannot be analyzed in terms of dimensions already included in the analytical scheme. Accordingly, no dimensions are added to the scheme at this point. This decision is not meant to suggest that the scheme is or has been shown to be complete. However, this initial assessment of the applicability of the scheme does not demand or suggest additional dimensions.

#### Results of analysis relevant to argument-structure

The five questions answered above serve to organize the information obtained about the content of the four selections which have been analyzed. It is also appropriate to examine the information obtained about the structure of arguments, through use of the "argument-pattern" concept.

Selection B is characterized by complete arguments which are elaborated rather extensively. Argument B-1 begins with Data and Backing; the Backing is developed during the chapter, as the Warrant is

established which permits the Claim presented at the end. The relationship of arguments B-3 and B-4 to B-2 probably accounts for the observed sequence of argument-elements. Argument B-2 begins with Backing and Data. Then the Claim is presented, before the Warrant which permits it had been established. The Warrant is established by presenting the Data and Conclusions of arguments B-3 and B-4.

Selection D is dominated by presentation of the Data of the argument, for which no Backing is identifiable. Warrant and Qualifier precede the Data, and the three elements together permit one to recognize an implicit Claim. The Warrant being used is repeated at the end of the argument, which closes with conditions of Rebuttal.

In Selection E, many arguments are presented, and some are both brief and incomplete. When one interprets the first eleven arguments as Data of the argument for the final Claim, it is necessary to infer both Warrant and Backing from the expression of the Data.

Finally, the two arguments in Selection G are characterized by the same sequence of elements. Data and Backing precede each Warrant being established. Only after the Warrant is stated is the supporting Conclusion presented.

There are no instances of explicit references to argument structure in the four selections; the authors argue without commenting on the ways they argue. The variations among these four selections, in terms of presence, sequence, and elaboration of elements, indicate significant diversity among the authors' styles for structuring an argument. The scheme permits one to detect various failures to make provision for acceptance on rational authority. Provision would be made by presenting and elaborating all necessary elements in a sequence which leads up to the Claim (of a Warrant-using argument) or the Warrant (of a Warrant-establishing argument).

As a final note, one use of the scheme had not been anticipated, one in which there is direct interaction between the structure of an argument and dimensions of the scheme itself. Selection G provides two instances in which the authors' manner of expanding the meaning of an element of the argument seems to imply a position on a dimension of the concept of teaching. Only limited application of a dimension is possible in these instances.

Comments on the subsidiary  
analysis in Appendix A

By initial inspection, the four selections in Appendix A were set aside for subsidiary analysis because they did not provide as strong and comprehensive a test for the scheme as the selections analyzed and discussed above. Reference to Table 5 shows that there are not as many opportunities to apply the scheme in Selections A, C, F, and H.

Application of the analytical scheme reveals that several of the arguments make quite limited stipulations, without reference to other significant aspects of science or teaching. Inadequacies in the Data about science or teaching and shortcomings at the level of Backing can only result in unacceptable Claims or Warrants for the teaching of science.

Nothing has been found in the subsidiary analysis which adds to or deviates from the findings of the main analysis in this chapter. The joint application of the *Communication* and *Use of expertise* dimensions does not arise in the subsidiary analysis; modifications to those dimensions are based solely on the analysis of Selection D. In short, analysis of Selections A, C, F, and H corroborates the main findings reported above from analysis of Selections B, D, E, and G.

Summary

In this chapter, four passages have been selected from textbooks on the teaching of science, and the content and structure of arguments in those passages have been analyzed by applying the analytical scheme, in conjunction with Toulmin's argument-pattern. Results of this main analysis, and of the subsidiary analysis of an additional four passages presented in Appendix A, have been reviewed and interpreted.

The overall purpose has been to apply the analytical scheme and interpret the resulting information for purposes of enhancing the applicability of the scheme. One significant modification of the scheme has been made as a result. The modified analytical scheme is presented in Appendix B.

TABLE 5

ARGUMENTS RELEVANT TO EACH DIMENSION  
OF THE ANALYTICAL SCHEME  
(Selections A, C, F, and H)

<i>Demarcation of science</i>	A-2		
<i>How empirical content increases</i>			
<i>Objectivity of science</i>			F-2
<i>Relationship of science to truth</i>		C-1	F-1
<i>Progress of science</i>	A-1	C-2	F-1
<i>Nature of knowledge</i>			
<i>Nature of learning</i>			
<i>Nature of teaching</i>		C-1, C-2	
<i>Communication</i>		C-1, C-2	H-1
<i>Authority</i>			H-1
<i>Use of expertise</i>			

## CHAPTER VI

### CONCLUSION OF THE STUDY

#### Introduction

In this study, the investigator has derived and demonstrated the applicability of an analytical scheme relevant to a significant but previously unstudied aspect of science teacher education programs--the provision made for the development of views of science and teaching. This final chapter begins with a review of the study's major components; formulation of the research problem, analysis of relevant literature, development of theoretical perspectives on science and teaching, and derivation and application of an analytical scheme. In the second section of the chapter, specific conclusions are drawn about the direct applicability of the analytical scheme to planning and evaluation of several aspects of science teacher education programs. The chapter closes with identification of areas for further research based upon the analytical scheme which is made available by the study.

#### A Review of the Study

##### The problem

In the opening chapter of the study, it is argued that views of science and teaching held by teachers have consequences for both pupils and teachers. Views of science and teaching can influence a teacher's selection and interpretation of objectives, his planning and presentation of teaching behaviors to pupils, and the criteria he uses to interpret pupils' behaviors and his own influence on them. Views of the nature of science and the concept of teaching can be expected to influence the range of possible pupil outcomes of science instruction and the teacher's ability to monitor his professional actions.

The investigator argues that science teacher education programs are an appropriate forum for the development of views of science and teaching by prospective and experienced science teachers. However, little is known about the potential or actual influence of science teacher education programs on teachers' ways of thinking or subsequent teaching behaviors. It is the purpose of the study to take a significant first step in the analysis of this complex question. The study addresses the problem of developing a way to examine the potential conceptual interaction between claims made about why and how science should be taught and views already held by those to whom the claims are presented. Both the kinds of claims made (conclusions of arguments) and the ways they are made (structure of arguments) are of interest and importance.

#### Context of the problem

Recognition of the research problem is influenced by new perspectives on teacher education. The problem is formulated on the premise that how teachers teach is a matter not only of techniques but of ways of thinking. The manner in which the problem is studied is influenced by new perspectives on research in science education. The research style has the specific purpose of making theoretical perspectives relevant to matters of educational practice.

These new perspectives on teacher education and research are examined in Chapter II of the study. Rationales for science instruction and science teacher education in this century are reviewed in broad terms, to lend credibility to the interpretation that science instruction has been intended to achieve more than simple transmission of scientific knowledge to pupils. As argued earlier, however, teacher education has seemed to assume that further development of subject-matter expertise and study of instructional techniques are the necessary and sufficient elements of preparation for teaching.

Three new perspectives are examined as productive challenges to long-standing assumptions about the nature of teacher education. Their common theme is that teachers and teacher candidates have ways of thinking which influence their teaching behaviors and which require development appropriate to the various duties and responsibilities of a teacher.

From psychological considerations, Sarason, Davidson, and Blatt have constructed and tested analytically the position that teachers require specific preparation relevant to observation and interpretation of pupil behavior and selection of subsequent teacher actions. From an analysis of teacher education experiences, Belanger and Cogan have argued that teachers and teacher candidates hold and use views about how teachers behave in classrooms, so that teacher education must be directed toward developing more effective "models of teaching." Scheffler has argued that the responsibilities of a teacher cannot be addressed fully and adequately without an informed philosophical perspective on the subject one teaches.

Familiar styles of science education research are reviewed in broad terms to provide evidence for the conclusion that none is well-suited to the research problem identified in terms of the new perspectives on teacher education. An alternative to styles based on observation or achievement is described and examples are discussed. The alternative is the development of theoretical perspectives relevant to issues in science education, with explicit derivation of an analytical scheme which permits one to study science education phenomena in terms of the selected theoretical perspectives. The alternative is similar in some respects to existing types of observation studies, but quite different in its emphasis on bringing new perspectives to bear on the analysis of educational events.

#### Development of theoretical perspectives

Views of science and teaching are taken, a priori, as elements of thought which have significant potential for influencing outcomes of science instruction, both for pupils and for teachers. The theoretical perspectives developed in the study are concerned with the nature of science and the concept of teaching.

Theoretical perspectives on science are the subject of Chapter III. The analytical device of a "categorical framework," developed by Körner, is used as the basis for an examination of systematic accounts of science put forth by Carnap, Popper, and Kuhn. Körner argues convincingly that individuals' explanatory standards and metaphysical beliefs are closely related to their ways of classifying objects of experience. Körner's argument lends further support to the position that ways of thinking about science and teaching may be expected to influence teachers' interpretations of their teaching.

Körner's device proves useful for its intended purpose. Each of the three accounts of science is summarized with a statement of the implied categorical framework, which renders more intelligible various "metaphysical" issues associated with the particular position. The comparative analysis of the accounts of science suggests five significant issues on which the accounts differ. The issues are adopted as five dimensions of the analytical scheme, on the interpretation that the issues represent ways of expressing significant features of views of science. The views of Carnap, Popper, and Kuhn are stated concisely on each dimension, as positions to which less formally stated views of science may be compared.

As one might expect from the obvious differences between "science" as an area of disciplined intellectual inquiry and "teaching" as an activity which may enable others to participate in inquiry, the development of theoretical perspectives on teaching proceeds in a different manner in Chapter IV. Philosophical analysis of purposes and activities of teaching has been conducted from numerous vantage points. From issues raised in five different analyses selected as offering distinct and significant contributions, six more dimensions of the analytical scheme are derived.

For the dimensions relevant to the concept of teaching, alternative positions are obtained not by contrasting the different

authors' views but by developing a common feature of their arguments. Each analysis suggests that there are two typical divergences from a comprehensive perspective on teaching, one overemphasizing information (termed the "information emphasis") and another overemphasizing individual judgment (termed the "insight emphasis"). The two emphases and the "composite perspective" (as it was named) are used to develop statements of three alternative positions to which views of teaching relevant to a particular dimension may be compared.

#### Application of the analytical scheme

The manner in which theoretical perspectives on science and teaching are developed yields an analytical scheme of eleven dimensions, with three alternative positions stated on each dimension. It is the task of Chapter V to demonstrate application of the analytical scheme in the context of making an initial assessment of the scheme's applicability.

Dimensions of the analytical scheme are appropriate for examining the content of views of science and teaching, but they do not touch directly on the manner in which views are held or expressed. To permit application of the scheme to take account of the structure of arguments as well as their content, the analytical device of an "argument-pattern" for rational arguments is used, as developed by Toulmin. Supplemented by the argument-pattern, the analytical scheme is used to examine passages selected from textbooks which discuss rationales and methods of science teaching. Four passages are analyzed in Chapter V and judgments about the scheme's applicability are made on the basis of the results. Passages from the remaining four of eight textbooks initially selected as sources of data are analyzed in Appendix A, to which readers may refer for purposes of further assessment of the scheme's applicability.

#### Conclusions Related to the Applicability of the Analytical Scheme

The application of the analytical scheme to excerpts from science methods textbooks permits the statement of a number of conclusions about the applicability of the scheme. The answers to the questions which guided the assessment of the scheme's applicability provide the most straightforward conclusions.

Each of the eleven dimensions of the analytical scheme is found to be relevant to at least one of the arguments analyzed in Chapter V. From the evidence available each dimension appears to have sufficient range and detail to be useful in the analysis of arguments about why and how science should be taught. Application of the scheme indicates that the scheme's clarity is improved by one modification which is shown in the revised version of the scheme in Appendix B.

Analysis of arguments according to dimensions of the analytical scheme does permit one to make inferences about the extent to which issues are addressed clearly, distinctly, and comprehensively in an argument. The content of the analyzed passages does not demand or suggest additional dimensions for the scheme, and the dimensions developed initially appear to have the comprehensive coverage appropriate to such a scheme.

Application of the analytical scheme also facilitates identification of the authority upon which an argument appears to rest. Toulmin's argument-pattern is shown to be a valuable supplement to the scheme, particularly for analysis of provision made for an argument to be accepted on rational authority. Variations in the structure of arguments can be detected in the course of application of the analytical scheme.

Two broader generalizations may be drawn from the evidence available in Chapter V. In the twenty-nine applications of a dimension to an argument in the main analysis (see Table 4, page 193), there is not one clear identification of a position expressed by Popper, Carnap, or Kuhn with respect to science or of the positions interpreted as elements of a comprehensive perspective on teaching. (This result is corroborated by the subsidiary analysis.) This "non-result" suggests the hypothesis that textbooks concerned with methods of teaching science have not incorporated significantly or successfully the achievements of philosophy of science or philosophical analysis of teaching. The hypothesis, which merits investigation, conforms to expectations one might derive from the traditional assumptions which appear to have been made about requirements of teacher education programs.

A second generalization concerns the structure of arguments. The evidence in Chapter V suggests the hypothesis that the structure of

an argument is not taken into account explicitly by the authors of science methods textbooks. Each of the four styles examined in the main analysis has shortcomings when assessed on criteria derived from the argument-pattern construct developed by Toulmin. The variability of authors' styles suggests that the structures of arguments are more idiosyncratic than intentional or systematic. The absence of explicit references to the structure of arguments is an absence of direct attempts by authors to attend to the manner in which their claims are perceived by readers. (On this point, evidence in the subsidiary analysis is consistent with the evidence in Chapter V.)

This study has focused on the question of the provision made by science teacher education programs for the development of views of science and teaching. The study illustrates how the analytical scheme may be used to assess the provision made by science methods textbooks. Science teacher educators could use the analytical scheme in other ways as well. The scheme could be used as an analytic device for making experiences consistent and comprehensive in a program of science teacher education. From the scheme one might develop questions relevant to the identification of individuals' views of science and teaching. The scheme may help determine appropriate directions for development of views of science and teaching. Finally, it may even be appropriate to teach the substance of the analytical scheme to prospective science teachers.

#### Topics for Further Research

The analytical scheme developed and applied in this study has passed an initial test of its value for examining the potential conceptual interaction between claims about the teaching of science and the views of science and teaching which a prospective science teacher might hold. The most direct research extension of the study would be to various aspects of science teacher education programs other than textbooks--for example, verbal interaction in various preparatory courses. The theoretical perspectives developed in the study should also provide a conceptual basis for research concerned with views of science and teaching actually held by teachers, views implied by their teaching behaviors, and processes by which views or teaching behaviors actually

do change. Each of these extensions beyond the analysis of written claims in textbooks on the teaching of science merits brief discussion.

The provision for development  
made by verbal interaction

As already mentioned, it would be appropriate to assess the analytical scheme's applicability to other elements of science teacher education programs. Additional considerations may arise in the analysis of the medium of verbal interaction. The most obvious formal setting which involves verbal interaction is the class meeting of a preservice or inservice course for science teachers. A meeting held for the analysis of teaching practice may be of special importance because it deals with events in which the teacher or teacher candidate is an influential participant. Although supervision of beginning and experienced teachers has been analyzed in many ways, it has not been studied for the development of elements of a teacher's "model of teaching," such as views of the nature of science and views of the concept of teaching. It would be valuable to determine the usefulness of the analytical scheme for that purpose.

Analysis of individuals' views  
and teaching behaviors

Intentionally, the study has been limited to the provision made for the development of views of science and teaching. Views actually held by prospective and experienced science teachers and views implied by their teaching behaviors are obvious and significant areas for extension of the work begun in this study.

As noted in Chapter I, there is a small body of research in which teachers' views of science and teaching have been investigated. The analytical scheme appears to represent a sound basis for an alternative approach to the study of teachers' views. To what extent views of science and teaching actually held by individuals can be identified with the aid of the scheme developed in this study is an interesting and important empirical question.

Another research topic to which the study may contribute is analysis of science teachers' behaviors for their implied views of science

and teaching. The analytical scheme developed here is an addition to the group of instruments described in Chapter II as products of research conducted in the same manner as the present study. The perspectives on science and teaching expressed in the analytical scheme should be useful in the observation and interpretation of science instruction.

Comparison of teachers' professed views of science and teaching with the views implied or suggested by their teaching behaviors is yet another topic of potential interest. The comparison of words and actions also suggests itself as a technique which could be assessed for its contribution to the development of views of science and teaching by science teachers.

Confidence in techniques for identifying views held by teachers or implied by teaching behaviors would permit one to initiate longitudinal studies for the purpose of detecting changes in professed views and changes in teaching behaviors. Both the content of changes and the processes by which changes occur would be of interest, with direct implications for the preparation and supervision of science teachers.

These topics for further research are suggested not with a view to the eventual control of teachers' views or behaviors, but with a view to informing those who are in positions to make provision for science teachers to develop more complex and effective models of teaching. It is expected that such development would have significant implications for outcomes actually achieved by students of science and for the professional maturity achieved by teachers of science.

#### Summary

This study develops and assesses the applicability of an analytical scheme for examining the provision made by science teacher education programs for the development of teachers' views of the nature of science and the activity of teaching. The scheme may be applied to the design and to the interpretation or evaluation of arguments making claims about rationales and methods of science instruction. Both the content and the structure of arguments may be analyzed. Several significant topics for further research arise from the theoretical perspectives developed in the study.

The study develops implications of viewing a teacher as an autonomous professional rather than a technician. The corresponding task of teacher education is the identification and development of an individual's model of teaching, by processes which are systematic but not routine. The study demonstrates the application of an alternative form of science education research to issues and practices of science teacher education.

APPENDICES

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Appendix A. SUBSIDIARY ANALYSIS OF PASSAGES FROM FOUR  
TEXTBOOKS ON THE TEACHING OF SCIENCE . . . . . A2

    Selection A  
    Selection C  
    Selection F  
    Selection H

Appendix B. REVISED ANALYTICAL SCHEME . . . . . A24

APPENDIX A

SUBSIDIARY ANALYSIS OF PASSAGES FROM FOUR  
TEXTBOOKS ON THE TEACHING OF SCIENCE

A2

222

Selection A

Toward More Effective Science Instruction in Secondary Education, by Andersen and Koutnik, begins with a chapter titled, "A Definition of Science Relevant to Science Teaching."<sup>1</sup> Selection A is taken from a section of the chapter headed "Scientific Objectives for Learners."<sup>2</sup> The first of two main arguments develops a position related to how science should be taught. The second argument develops a position on the topic of recognizing a "scientific" subject area. One dimension of the analytical scheme is relevant to each argument.

## TEXT

## INITIAL ANALYSIS

Scientific Objectives  
for Learners

We have given attention to the "different way of looking" at common things that has probably accounted for some of the most significant breakthroughs in science. Then we considered and rejected patterned scientific method, which left applying, understanding, and valuing (attitude) the "basic skills" of scientists and inquirers. (Recall that the "basic skills" we refer to include such operations as interpreting, observing, hypothesizing, designing and executing investigations, and defining problems, though not necessarily in a reliable order of occurrence.) What we have is a combination of creative and critical thinking (that is, the divergent view and inquiry skills).

The first paragraph (lines 1-23) contains the Data used in the first argument. The authors repeat, in some detail, the Claims of two previous arguments. In their analysis, science has progressed by looking at common things in new ways (lines 1-6) and by creative, divergent thinking (lines 19-22). Scientists' methods include "basic skills" of inquiry or critical thinking, not one patterned method (lines 6-23) The *Progress of science* dimension is likely to be relevant to this position on the nature of science.

---

<sup>1</sup> Hans O. Andersen and Paul G. Koutnik, Toward More Effective Science Instruction in Secondary Education (New York: The Macmillan Company, 1972), pp. 1-9.

<sup>2</sup> Ibid., pp. 6-8.

It should follow that if  
 25 science instruction is to pro-  
 vide learners with a realistic  
 view of science, it should pro-  
 vide opportunities and active  
 support for comprehension and  
 30 application of basic skills to  
 the acquisition of increased  
 understanding. Furthermore, it  
 must encourage divergence and  
 the development of predisposi-  
 35 tions to view issues from vari-  
 ous perspectives, including  
 those of other individuals or  
 groups. In such instruction the  
 learner's primary objective is  
 40 increased understanding. (As  
 such, no stigma need be attached  
 to being "wrong" or accepting  
 someone's opinion other than  
 one's own if increased under-  
 45 standing results.)

We hypothesize that the suc-  
 cess and reward experiences  
 associated with application of  
 basic skills and divergent ob-  
 50 servation in an environment  
 relatively free of threats to  
 the self are likely to aid  
 learners to be sensitive to and  
 objective about information,  
 55 ideas, ideologies, and institu-  
 tions in society. . . .  
 . . . . .

Science Can be Many Things  
 in School

Science, defined as a combi-  
 nation of applied inquiry skills  
 60 and predisposition to view  
 available things from unusual  
 perspectives, is more of a  
 generalizable collection of  
 behaviors, understandings, and  
 65 attitudes than a group of  
 academic disciplines with  
 "scientific" names ending in  
 -ology or -ics. As such we  
 offer the proposition that any  
 70 subject matter area in which  
 inquiry and divergent observa-  
 tion have operated together to

The second paragraph (lines 24-  
 45) completes the first argument.  
 The Claim is made (lines 27-38)  
 that science instruction should  
 encourage understanding and use  
 of both basic skills and diver-  
 gent observation. The statements  
 that science instruction should  
 provide a realistic view of  
 science (lines 24-27), for pur-  
 poses of increased understanding  
 (lines 38-45) seem to serve as  
 Backing for an implied Warrant  
 that science instruction should  
 be patterned on characteristics  
 of science.

The final portion (lines 46-56)  
 of discussion relevant to the  
 first argument seems to suggest a  
 Warrant which could be estab-  
 lished if certain learner out-  
 comes are achieved as a result of  
 teaching science according to the  
 Claim already presented (lines  
 22-38). References to success,  
 reward, and freedom from threats  
 seem too general for comparison  
 to dimensions of the analytical  
 scheme.

The second argument (lines 58-  
 76) begins by indicating that  
 viewing science as a combination  
 of inquiry skills and creative  
 thought is regarded as a defini-  
 tion of science (lines 58-62).  
 The balance of the first sentence  
 (lines 62-68) appears to provide  
 both Data and Conclusion. As  
 Data, the authors indicate that  
 science is often viewed as a  
 group of academic disciplines.  
 As Conclusion, they indicate a  
 view that science is "more of a  
 generalizable collection of

75 have produced the generally  
 recognized major increments in  
 development of the area may be a  
 scientific one. Without too  
 much trouble one could, accept-  
 ing this, produce an argument  
 80 for nearly the whole curriculum  
 of the school being science and  
 inquiry oriented, where the same  
 student skills are objectives of  
 the many disciplines and the  
 total program of a school is  
 85 coordinated to develop creative  
 and critical thinkers.

Your initial teaching assign-  
 ment may not be in such a center  
 of inquiry, but this need not  
 90 release you from the obligation  
 to represent your area of sci-  
 ence in a way consistent with  
 science itself. Other parts of  
 this book will deal with  
 95 theories and technologies of  
 science instruction. It is  
 enough here to advocate learn-  
 ing objectives in the creative  
 and critical thinking domains  
 100 of science as we have attempted  
 to define it.

behaviors, understandings, and  
 attitudes." These serve to  
 establish the Warrant that any  
 subject area may be scientific  
 if it develops by inquiry and  
 divergent observation (lines 68-  
 76). So interpreted, the Backing  
 of the argument is the definition  
 of science (lines 58-62). The  
*Demarcation of science* dimension  
 seems relevant to this argument.

The remainder of Selection A  
 (lines 76-101) extends the  
 results of the first two argu-  
 ments to the school curriculum  
 and to the teacher's role. These  
 are subsidiary arguments which do  
 not appear to raise new issues.

#### Detailed analysis

In both arguments, it is possible to identify or infer directly  
 the basic argument-elements. The first argument is a Warrant-using  
 argument; the second is a Warrant-establishing argument. The patterns  
 of these arguments are displayed in Figures 9 and 10. The Data of  
 argument A-1 and the Backing of argument A-2 are identical.

The *Progress of science* dimension provides perspectives for  
 examining the authors' statement, in argument A-1, that science seems to  
 develop as a result of divergent or creative thinking and critical  
 thinking. While the authors' position does not conflict with the  
 dimension's three positions, it does not coincide with any either.  
 That is, Carnap, Popper, and Kuhn have different interpretations of what  
 is involved in the progress of science, while the authors of Selection  
 A seem to regard recognition of progress as unproblematic. Analysis

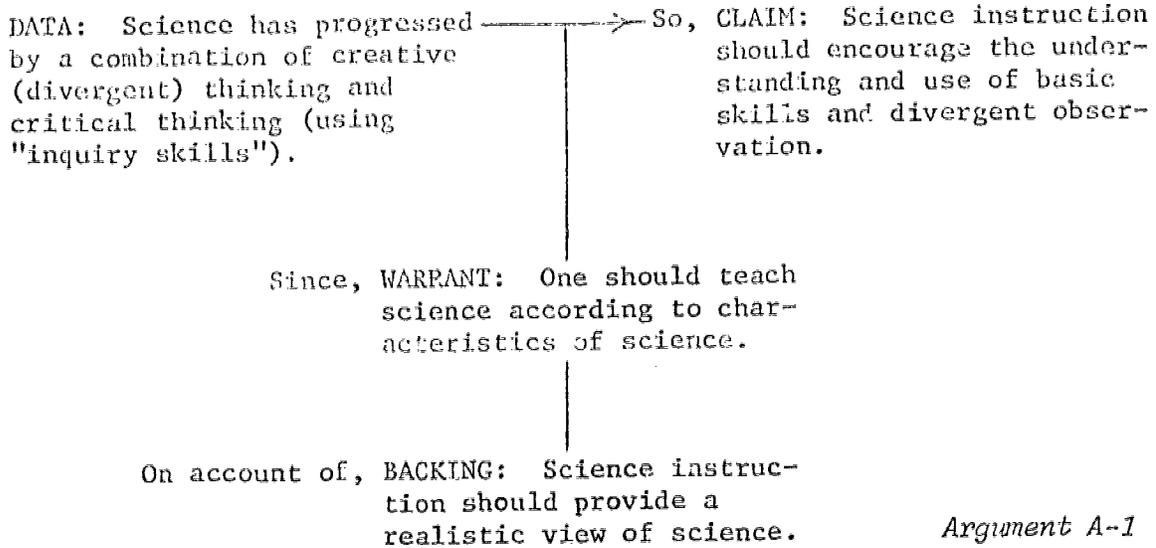


Fig. 9.--The pattern of the first main argument of Selection A, with Warrant made explicit.

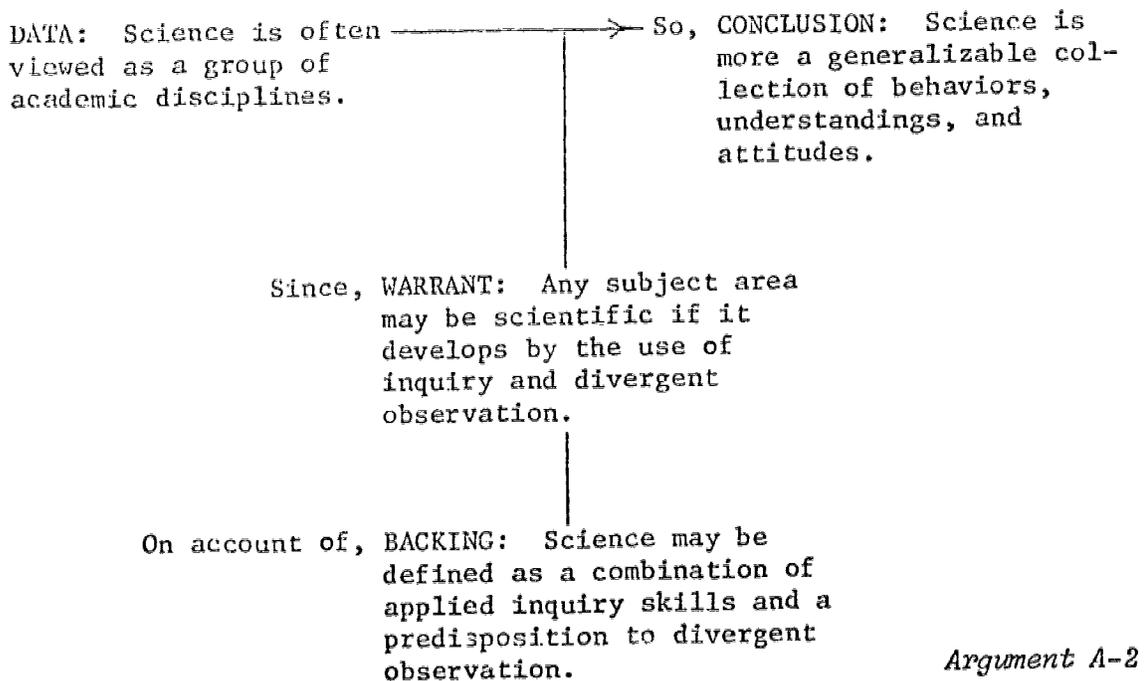


Fig. 10.--The pattern of the second main argument of Selection A.

in terms of the *Progress of science* dimension helps to establish just what is and is not implied by the authors' analysis of science.

How the authors' definition of science stands up as a criterion for the demarcation of science is an interesting question. The authors appear to have followed an approach similar to Kuhn's in the sense that they have looked at how science has progressed. Their result is different from Kuhn's position, but the more significant difference is what they make of their result. Having formulated a criterion of demarcation, Carnap, Popper, and Kuhn do not attempt to use it to extend what is recognized as science. While the authors' definition of science appears relevant to the question of demarcation, their use of the definition in argument A-2 differs from the customary use of a criterion of demarcation. It appears that they have identified several significant characteristics of science, but not a definitive set of characteristics.

#### Commentary on the analysis

In Selection A, two dimensions of the nature of science may be applied to the authors' interpretation that science involves a combination of creative and critical thinking. In argument A-1, their view serves as Data and is related to the question of the progress of science. In argument A-2, the view is used as Backing in establishing a Warrant which seems comparable to a criterion for the demarcation of science.

Reference to different positions on the dimensions of *Progress of science* and *Demarcation of science* suggests that the authors' interpretation of science is a limited and oversimplified one. While the arguments appear to be complete, they do not meet the standards of assessment suggested by two dimensions of the analytical scheme. No modification of the scheme is suggested by analysis of this selection.

Selection C

The passage selected from Collette's Science Teaching in the Secondary School concludes a chapter titled "The Nature of Science,"<sup>1</sup> in which the author discusses the nature of science as a body of knowledge, as a way of investigating, and as a way of thinking. The passage<sup>2</sup> provides an example of an argument which moves from actual characteristics of science to desirable characteristics of science teaching.

Selection C has more to say about characteristics of science than about characteristics of teaching. The discussion focuses on the fact that science changes and on the existence of various processes and methods of inquiry. The language used to express conclusions about how science should be taught appears to imply a position about the nature of teaching.

TEXT

The Implications of the Nature  
of Science for Science Teaching

What are the implications of the nature of science for science teaching in this day and age? Science is  
5 necessarily a dynamic, changing enterprise and thus should be presented as such in our modern science teaching. Not only will this  
10 emphasis on the dynamic nature of science give a "truer" picture of science but hopefully it will help young people to expect changes, to  
15 have positive attitudes towards change, and to prepare them for the future. Traditional or conventional type science courses, which  
20 present science as an immutable body of disparate facts, become outdated quickly and therefore do not provide the experiences needed for  
25 understanding and coping with change. Neither do these courses present a good picture

INITIAL ANALYSIS

The first argument (lines 1-28) uses Data that science is dynamic and changing (lines 4-6). This point is followed immediately by the Claim that science teaching should present science as dynamic and changing (lines 6-9). Subsequent remarks indicate the nature of the Warrant available in support of the Claim. Emphasizing the dynamic nature is more accurate (lines 9-12), and it is hoped that it will prepare pupils to cope with change (lines 13-17). The author does not rely on a Warrant which has been established previously. He does report with confidence that teaching science as unchanging has been tried and found wanting. This related argument seems to be based on a Warrant that it is logically impossible for a "conventional" course to achieve the results he desires, (lines 23-26). The contrast between "changing" (line 6) and "immutable" (line 21) may raise issues on the *Relationship of science*

<sup>1</sup>A.T. Collette, Science Teaching in the Secondary School (Boston: Allyn and Bacon, 1973), pp. 1-24.

<sup>2</sup>Ibid., pp. 22-23.

of the scientific enterprise.  
 Science is an ongoing, self-  
 30 corrective inquiry process.  
 It is a means for studying  
 the environment. Science  
 teaching, therefore, should  
 reflect the processes and  
 35 methods of modern science.  
 It should be emphasized in  
 our teaching that there is  
 no single method and no  
 formalized set of procedures  
 40 which lead to discovery.  
 Although there are general  
 procedures such as question-  
 ing, observing, hypothesiz-  
 ing, collecting, and inter-  
 45 preting data, theorizing, etc.,  
 which are common to all  
 sciences, the specific  
 processes and procedures  
 used vary from one science  
 50 to another. Whatever the  
 science taught, the general  
 and specific science processes  
 and methods of inquiry should  
 be emphasized. Hopefully,  
 55 through this emphasis the  
 student will not only come to  
 better understand the nature  
 of science but will acquire  
 certain intellectual skills  
 60 which make it possible for  
 him to organize his thinking,  
 recognize and use relevant  
 information, and in general,  
 perform as an intelligent and  
 65 rational human being.

[An omitted argument concludes  
 that science teaching should be  
 based on conceptual schemes, to  
 show the order and structure of  
 scientific knowledge.]

In summary, a high school  
 science course should  
 emphasize the methods of  
 modern science and its  
 70 conceptual framework. In  
 order to understand science,  
 the student must not only  
 have the knowledge of the  
 concepts, theories,  
 75 principles, and laws of the

to truth dimension.

The second argument (lines 29-  
 65) uses Data about the processes  
 and methods of scientific inquiry  
 (lines 29-32, 37-40, and 41-50).  
 The Claim appears to be stated  
 twice, first in terms of "re-  
 flecting" scientific processes  
 (lines 33-35) and then in terms  
 of "emphasizing" them (lines 36-  
 40 and 50-54). Again the Warrant  
 is expressed as a hope (line 54).

The two Warrants have certain  
 common features. The word "hope"  
 is associated with both, and both  
 mention understanding science  
 accurately and acquiring skills  
 useful in information-processing.  
 It may be inferred that the Back-  
 ing of both arguments includes  
 the opinion that representing  
 characteristics of science accu-  
 rately will contribute to the  
 objectives which the Warrants  
 share.

The second argument's focus on  
 procedures or processes of  
 inquiry seems relevant to the  
*Progress of science* dimension.

The final paragraph begins by  
 summarizing the Claims of  
 three arguments, one of which has  
 been omitted from the text of the  
 selection. Lines 70-83 seem to  
 provide an overall rationale for  
 the arguments. In view of the  
 lack of support for the Warrants  
 used, these statements may be  
 interpreted as Backing for the

discipline, he must appreciate how his knowledge is obtained and how it fits into a structural framework. A science course should convey the revisionary nature and uncertainties of scientific knowledge.

Warrants. The last sentence (lines 80-83) seems to rephrase the Data used in the first argument.

Detailed analysis

Several features of the arguments in Selection C merit comment. In both arguments, the Claim is presented immediately after the Data, before the Warrant is provided. Also, each Warrant is expressed as a hope, suggesting that the author may not be able to provide arguments in which the Warrants have been established. In these circumstances, Backing is particularly important; the two arguments have a common Backing which is presented at the end of the selected passage.

*Argument C-1*

D: Science is changing and dynamic. Conventionally, it has been taught as immutable.

C: Science teaching should present science as dynamic and changing.

Since, WARRANT: Emphasizing the dynamic nature of science is more accurate and (hopefully) more likely to prepare students to cope with change.

*Argument C-2*

D: Science is an on-going self-corrective inquiry process. Some procedures are common to all sciences; some are unique to each.

C: Science teaching should emphasize general and specific processes and methods of inquiry.

Since, WARRANT: Emphasizing processes and methods of science will (hopefully) produce better understanding of science and develop desirable skills.

On account of, BACKING: Presenting characteristics of science completely and accurately should enable students to understand science and use its information-processing methods.

Fig. 11.--Argument-patterns from Selection C

The position expressed by interpreting science as dynamic, changing, and revisionary (rather than immutable) seems more relevant to the *Relationship of science to truth* dimension than to any other. Both Popper and Kuhn consider the characteristic of change in science, but they place this characteristic in relation to others. The author of Selection C seems concerned with the recognition of revision and change as a feature of science, and he does not analyze the characteristic further.

Recognizing that scientific inquiry may involve a number of "procedures and processes" is, again, different from analyzing the characteristic in relation to other characteristics of science. This characteristic could relate to two dimensions of the analytical scheme, *How empirical content increases* or *Progress of science*, although the latter seems more likely. That it is not possible to be more specific and to relate the characteristic noted by the author to the three positions in the scheme seems to result from the fact that the author puts a characteristic forward without analysis or illustration.

Selection C seems to express implicitly a position related to the *Communication and Nature of teaching* dimensions. "Present" (lines 7, 20, 27) and "emphasize" (lines 10, 36, 54, 55, 68) are the two words most frequently used in association with the phrase "science teaching should" or its equivalent. "Give" (line 11), "help" (line 13), "provides" (line 23), "reflect" (line 34), and "convey" (line 81) are also used with the same phrase. On the two dimensions noted above, these words seem more likely to connote positions associated with the information emphasis. The author may not have intended to express this or any position about the nature of teaching, but the repetitive use of a few related words does suggest positions which may be placed on dimensions of the analytical scheme.

#### Commentary on the analysis

Analysis of Selection C reveals two arguments in which a characteristic of science is identified but not elaborated or related to other features of science. Reference to relevant dimensions of the analytical scheme highlights the fact that characteristics are stated but not discussed. The author presents each characteristic as one which has not

been recognized in "conventional" science teaching (lines 18 to 28 and 36 to 40) and moves directly to a Claim that the characteristic should be reflected in science teaching. The Warrants are tentative, and their Backing is a position concerning outcomes of particular methods of science teaching.

The structure of the arguments is complete, but the Warrants and Backing are not adequate to support the Claims made by the author. The uninformative results of reference to dimensions of the analytical scheme calls attention to the limited nature of the Data provided in each argument. No modification to the scheme is suggested.

Selection F

Teaching Science by Inquiry in the Secondary School, by Sund and Trowbridge, begins with a chapter titled "What is Science?"<sup>1</sup> Included in the broad range of topics are the nature of theory development in science and the importance of objectivity in scientific research. The selected passage includes the final paragraphs of a section titled "The Goals of Science," and the entirety of the following section, titled "Research."<sup>2</sup>

The discussions of the two topics in this selection proceed in similar fashion. In both instances, a fairly complete argument establishing the authors' position is followed by several unsupported claims on subsidiary issues. As the initial analysis indicates, dimensions of the analytical scheme are applicable only to the two primary arguments.

## TEXT

## INITIAL ANALYSIS

## THE GOALS OF SCIENCE

## Theories and Scientific Principles

(Three paragraphs omitted)

Theories are based on facts which are derived from observation and experimentation. As our experimentation progresses and reveals new information, theories often have to be modified. Scientists search for theories and principles which are true and unchanging, but the history of science has shown that there is no certainty in science but only probability. Because theories evolve and are modified as our knowledge of nature increases, the goals [sic] of science in formulating broad, encompassing ideas of knowledge--theories--

The discussion of science in lines 1-37 focuses on the unending nature of theory-building. In lines 1-9, four distinct categories are indicated: phenomena, facts, theories, and individuals who experiment and theorize. The Claim that theory development has no end in science (lines 16-19) relies on the Warrant that theories are modified as new information demands (lines 3-7 and 13-15). Data are drawn from the history of science (lines 7-13). The *Progress of science* dimension is relevant to the account of theory modification (lines 3-7), while

<sup>1</sup>Robert B. Sund and Leslie W. Trowbridge, Teaching Science by Inquiry in the Secondary School (Columbus, Ohio: Charles E. Merrill Books, Inc., 1967), pp. 1-24.

never ends. There is always  
20 an assignment for the next  
generation.

With this realization, a  
scientist is humble about what  
he knows and thinks he knows.  
25 At first thought, it seems that  
the futile search for certainty  
would be frustrating, but there  
is joy in the discovery that  
knowledge is unending. There  
30 is always more to do and learn  
and more problems to solve.  
Life itself is a process of  
solving problems, and a scien-  
tist enriches his life and his  
35 self-concept by being involved  
in problems of value to all  
men.

#### RESEARCH

Students often confuse science  
with research--not all science  
40 is research, as was previously  
indicated in this chapter.  
Research may be defined as an  
attempt to collect unbiased  
information about observed  
45 phenomena. Research implies  
active involvement in the  
solving of a problem not  
previously answered by man. A  
student may follow scientific  
50 procedures in solving a problem,  
the answer to which he does not  
know; however, if the answer  
has been determined previously  
by a scientist, the student is  
55 scientific but he is not doing  
research. Since man is often  
biased, the scientific pro-  
cesses have been devised to  
insure that he is objective in  
60 his decision making and in his  
approaches to a problem. It  
would seem to be easy for a  
novice to do research, but the  
untrained mind seldom has  
65 learned the techniques of  
guarding against unbiased de-  
cisions. Training in the pro-

the *Relationship of science to  
truth* dimension seems relevant to  
the choice between certainty and  
probability (lines 7-13).

The second paragraph (lines 22-  
37) contains three Claims about  
the attitudes of scientists  
toward the unending nature of  
theory development. These atti-  
tudes are humility (lines 22-24),  
joy (lines 25-29), and enrichment  
of life and self-concept (lines  
32-37). None of these Claims is  
supported by additional argument-  
elements. Dimensions of the  
analytical scheme are not applic-  
able.

The *Objectivity of science*  
dimension is relevant to the dis-  
cussion in the final paragraph  
(lines 38-72). The discussion  
begins with criteria for recog-  
nizing research, and the defini-  
tion is applied in an example  
which distinguishes between  
"being scientific" and "doing  
research" (lines 48-56).  
"Unbiased" and "not previously  
answered" are the essential  
characteristics of research. The  
definition (lines 42-48) serves  
as Backing for the argument which  
takes man's frequent bias as  
Datum (lines 56-57) and moves to  
the Claim that "scientific  
processes" have been developed to  
insure objectivity (lines 57-61).  
Two incomplete arguments conclude  
the discussion (lines 61-72).  
The authors present Claims about  
the research-readiness of a  
person with an untrained mind  
and about the length and value of  
training to do problem-solving.  
Dimensions of the scheme are not  
applicable.

cesses and techniques of solving problems intelligently  
 70 requires a long period of education but one having value beyond calculation.

#### Detailed analysis

Initial analysis of Selection F indicates that there are two major Warrant-using arguments, concerned with the nature of scientific theory development and with the objectivity of scientific research. Presentation of the patterns of these two arguments is useful preparation for the task of applying relevant dimensions of the analytical scheme to the content of the passage.

The arguments appear relatively straightforward when displayed as in Figures 12 and 13. The Backing of the first argument is not presented explicitly, but the Backing hypothesized in Figure 12 is certainly implicit in the presentation of the argument. Thus it is reasonable to suggest that these arguments could be accepted by a reader on rational authority rather than the personal authority of the author. Such decisions to accept or reject on rational authority depend on the acceptability of the Backing of each argument. Dimensions of the analytical scheme provide criteria for assessing the acceptability.

Two dimensions are relevant to the content of the first argument. The sentence in lines 7 to 13 raises the issue of the *Relationship of science to truth*. It also associates truth with certainty, and suggests that what is not certain is probable. The sentences in lines 3 to 7 and 13 to 19 indicate that scientific theories are modified in the light of new information or knowledge of nature. This topic is considered in the *Progress of science* dimension.

The authors of Selection F suggest that scientists would prefer to develop theories characterized by truth and certainty, but that history shows they must be content to settle for probable theories which evolve over time, as new information is obtained (lines 7 to 15 and 25 to 29). Reference to positions on the *Relationship of science to truth* dimension suggests that Carnap, Popper, and Kuhn have gone well beyond the history of science for their analyses of this question. In different

DATA: The history of science records many instances in which theories regarded as true and certain were modified at a later time.

So, CLAIM: Scientific theories are probable, not certain, and may be said to evolve, so that the development of theory has no end.

Since, WARRANT: When new information is obtained [which conflicts with an accepted theory], it is necessary [and possible] to modify the theory to accommodate the new information.

On account of, BACKING (hypothesized): The status of theories and the nature of their development may be determined from the historical record of science.

*Argument F-1*

Fig. 12.--The argument-pattern of the first major argument of Selection F, with Warrant expanded and Backing hypothesized.

DATUM: "Man is often biased."

So, CLAIM: "Scientific processes have been devised to insure that [man] is objective in his decision making and in his approaches to a problem."

Since, WARRANT: Research must be done objectively, without bias.

On account of, BACKING: "Research may be defined as an attempt to collect unbiased information about observed phenomena."

*Argument F-2*

Fig. 13.--The argument-pattern of the second major argument of Selection F.

ways, Carnap and Popper interpret scientific statements so as to preserve the usefulness of the concept of truth. Kuhn argues that no reference to the concept of truth is necessary. Interestingly, the issues raised by the subsidiary Claims in lines 22 to 37 seem insignificant if one adopts any of the three positions on this dimension of the analytical scheme. Reference to this dimension suggests that a less complex view of the question is being taken by the authors. The efforts to turn disappointment into satisfaction (lines 22 to 37) lend support to a view that the authors discount the possibility of alternative interpretations of, and inquiry into, the relationship of science to truth.

The authors' account of theory modification also appears less complex than those accounts expressed in positions on the *Progress of science* dimension. Statements in Selection F (lines 1 to 7 and 13 to 19) seem to imply that once one accepts that theories change, it is easy to agree about how they change: by modifying theories to accommodate new information obtained without reference to theory. Carnap, Popper, and Kuhn present three different interpretations which take into account considerations other than the need to incorporate new information, and possibilities other than modification and continuous theory evolution. Again, reference to a dimension of the analytical scheme indicates that there are significant issues which are not called to the reader's attention by the authors.

A third dimension, *Objectivity of science*, is relevant to the content of argument F-2, which seems intended to explain why certain unspecified "scientific processes" must be followed. The authors identify lack of bias, or objectivity, as an essential criterion of research, which is again interpreted as information collection (lines 42 to 45). Unfortunately, the procedures, processes, or techniques (lines 50, 57 and 58, 65, and 67 and 68) are not specified. Two positions on the *Objectivity of science* dimension establish objectivity without reference to a list of research procedures, while the third questions the possibility of achieving objectivity. The unsupported subsidiary Claims (lines 61 to 72) seem pale in the light of the more fully developed positions on this dimension of the analytical scheme.

## Commentary on the analysis

Perhaps because the Claims are straightforward and uncomplicated, application of three dimensions of the analytical scheme to the arguments in Selection F demonstrates clearly the capacity of the scheme to facilitate assessment of the Backings which the authors provide. The patterns of the two major arguments seem reasonably complete, permitting an assessment that the authors do permit a reader to exercise independence of judgment.

For each of the three relevant dimensions, comparing positions within a dimension to the position indicated by the authors suggests that the issues raised are not being addressed comprehensively. At no point do the authors hint that there are issues to explore or alternatives to consider, at the level of Backing. The dimensions of the analytical scheme provide an indication of the potential range of interpretations at that level. Provision of Backing for an argument does permit a reader some measure of independence, but it in no way insures that a reader will be aware of alternative points of view.

The results of analysis do not suggest any modifications of the analytical scheme.

Selection H

"Methods and Resources of Science Instruction" is the title of one of the four parts of Washton's textbook, Teaching Science Creatively in the Secondary Schools. The chapter titled "Science as a Way of Thinking and Doing,"<sup>1</sup> includes a section which develops a contrast between "developmental" and "authoritative" teaching approaches.<sup>2</sup> Although the argument has some implications for the nature of science, its main point is related to the concept of teaching.

## TEXT

## INITIAL ANALYSIS

Developmental versus  
authoritative approach

As long as the science teacher uses the variety of methods and materials that are usually available through demonstrations, open-ended laboratory experiments and pupil research projects, it is likely that the developmental approach is dominating the instruction. Occasionally, there is a need for a lecture or a narrative or an explanation by the teacher. Explanations by the teacher which last for only a part of the period may occur more frequently. Lectures are classified under the authoritative approach since students are expected to accept the information, including any conclusions that are presented.

If one of the major objectives of teaching science is to develop in pupils the ability to solve problems, think scientifically, and acquire scientific attitudes, then the developmental approach to teaching science

In the first paragraph (lines 1-21) the author introduces a distinction between "developmental" and "authoritative" approaches. The distinction is cast in terms of methods, with demonstrations, open-ended experiments, and pupil research projects seen as significantly different from lecture, narrative, and teacher explanation. Then, in the last sentence (lines 16-21), the authoritative approach is associated with expecting students to accept information so presented. These distinctions are used in the argument which follows. The *Authority* and *Communication* dimensions appear relevant.

In the second paragraph (lines 22-41) the author expresses the core of his argument by saying that if one has certain objectives, one should use certain methods. The first sentence provides both Data (lines 22-27)

<sup>1</sup>Nathan S. Washton, Teaching Science Creatively in the Secondary Schools (Philadelphia: W.B. Saunders Company, 1967), pp. 217-254.

<sup>2</sup>Ibid., pp. 222-223.

should dominate in the various  
 30 instructional methods. The  
 trend is to favor the process  
 of inquiry and problem solving.  
 The developmental procedures  
 enable students to distinguish  
 35 between observations and inter-  
 pretations, to propose and  
 screen hypotheses, to design and  
 perform experiments, to evaluate  
 data critically, to formulate  
 40 conclusions, and/or to suspend  
 judgment.

The developmental approach  
 places the emphasis on deductive  
 and inductive reasoning from  
 45 which students draw the conclu-  
 sions. In the straight lecture  
 or complete narration by the  
 teacher, the students are told  
 what conclusions to accept.  
 50 There are certain basic scien-  
 tific facts and symbols that  
 require acceptance and under  
 many conditions will be  
 presented by the teacher in an  
 55 authoritative manner. However,  
 in general, the overview of the  
 use of methods of teaching  
 science should be for develop-  
 mental purposes, and concepts  
 60 should be taught for meaning  
 and understanding.

For many topics it is essen-  
 tial to plan the sequential  
 order of ideas from simple to  
 65 complex so that what was  
 previously learned may be  
 applied in learning new con-  
 cepts or understandings. For  
 example, students need to  
 70 understand mitosis and meiosis  
 before they can understand the  
 various laws of inheritance.  
 The meaning of haploidy and  
 diploidy are required to under-  
 75 stand genetic parental contri-  
 butions to offspring. A  
 knowledge of the structure of  
 the atom and the molecule is  
 basic to understanding bonding

and Claim (lines 27-30). The  
 next two sentences express two  
 different Warrants. The first  
 is a "trend" (lines 30-32), while  
 the second and more substantial  
 Warrant states a direct relation-  
 ship between methods and objec-  
 tives (lines 33-41). It is  
 assumed that the objectives  
 (lines 24-27) and the abilities  
 (lines 24-41) will be seen to  
 correspond directly. The view  
 of science implied seems too  
 broad to suggest specific  
 dimensions.

In lines 42-49, the author  
 repeats one distinction made in  
 lines 1-21, between students  
 drawing conclusions (developmen-  
 tal) and students being told what  
 conclusions to accept (authorita-  
 tive). Then he introduces a  
 Qualifier (lines 50-55) which  
 states the specific circumstances  
 in which the teacher may authori-  
 tatively tell students what to  
 accept. The Claim, first ex-  
 pressed in lines 27-30, is  
 repeated in lines 55-61. Here  
 the term "developmental" (lines  
 58-59) is applied to purposes  
 rather than methods.

The final paragraph (lines 62-  
 86) is interpreted as a supple-  
 ment to the main argument. In  
 lines 62-68, a sequential devel-  
 opment of ideas is taken as  
 necessary for learning. The  
 three illustrations (lines 68-80)  
 could be interpreted as Data-  
 Conclusion pairings which estab-  
 lish a Warrant. In lines 80-86,  
 the topic of sequence is linked  
 to the developmental approach  
 stressed in the main argument.  
 Here the teacher is referred to  
 as a "guide" for the learner.  
 This term is not sufficiently  
 clear to identify the teacher's  
 role with a position on any

80 in chemical change. The learner is guided by the teacher to make observations, deductions, and inductions as part of the developmental approach in a  
85 planned sequential order of experience.

dimension of the analytical scheme.

#### Detailed analysis

Although there are two arguments in Selection H, initial analysis suggests that one is subsidiary to the other. Only the first argument lends itself to detailed analysis. It is a Warrant-using argument, which can be diagrammed as in Figure 14. The classification of methods as developmental or authoritative and the discussion of the distinction itself seem to serve as Backing for the Warrant used to establish the Claim that one particular approach should be dominant in the methods used to teach science.

The main argument of Selection H is complete. The Backing for the Warrant involves a conceptual distinction rather than an empirical demonstration, and the acceptability of argument H-1 depends largely on the acceptability of the Backing.

As noted in the initial analysis of the first paragraph (lines 1 to 21), two dimensions of the analytical scheme contribute to an assessment of the Backing. The *Communication* dimension is relevant to the actual grouping of methods into two classes; the *Authority* dimension is relevant to the words "authoritative" and "developmental," used to identify the two classes.

Lecture, narrative, and teacher explanation are methods one would associate with the information emphasis, on the *Communication* dimension. Demonstrations, open-ended experiments, and pupil research projects could be associated with either the insight emphasis or the composite perspective. The terms "authoritative" and "developmental" do not clearly connote contrasting positions on the *Authority* dimension, but the author's elaboration of his meaning (lines 42 to 49) indicates that he is concerned with whether students are told what conclusions to accept ("authoritative") or draw their own conclusions ("developmental"). Simply telling students what conclusions to accept connotes the informa-

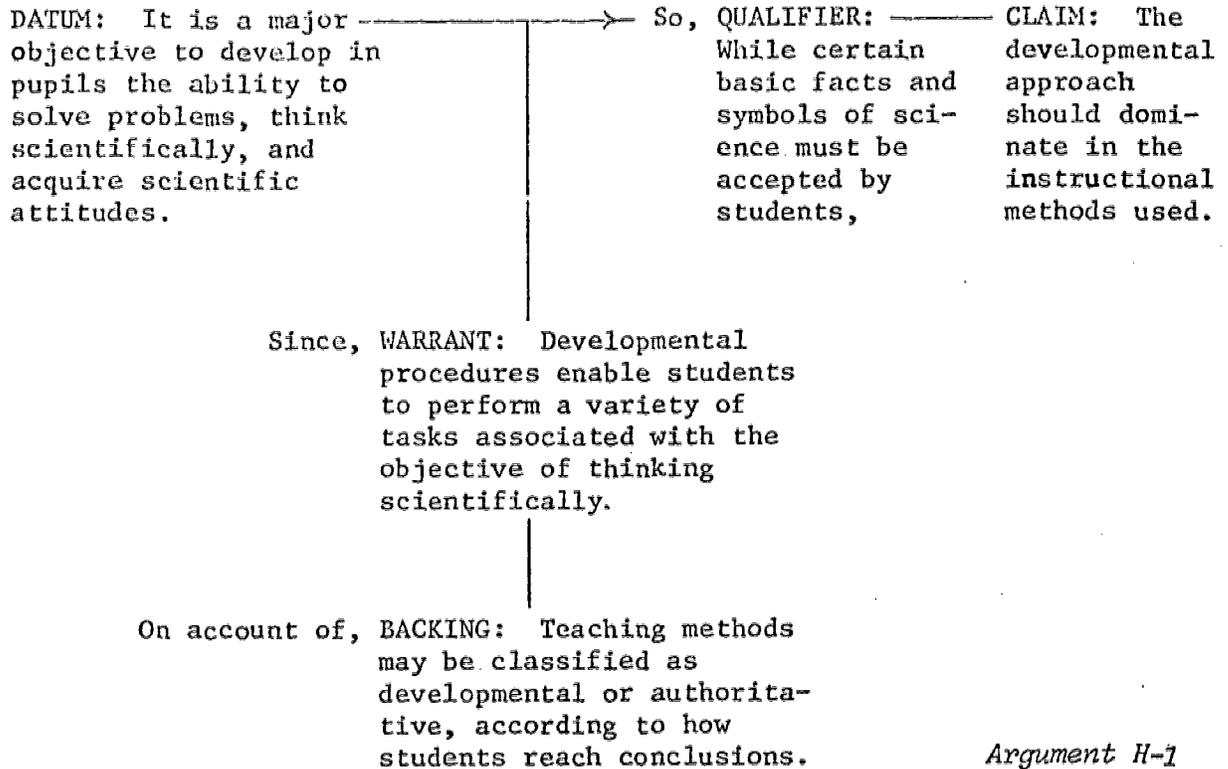


Fig. 14.--Argument-pattern of the main argument of Selection H.

tion emphasis on the *Authority* dimension, since no reference is made to the manner in which students are told. Simply having students draw conclusions suggests the insight emphasis. (Further discussion by the author might permit more definitive placement of his position.) The Qualifier which follows (lines 50 to 55) suggests that there is only one exception to the general rule of having students draw their own conclusions.

The author appears to have compressed two dimensions into one. A reader could interpret the Backing of this argument to mean that whether the teacher talks at considerable length is a necessary and sufficient condition for determining how students perceive the teacher to be using his authority. There may well be a correlation between these two aspects of teaching, as suggested by their association on the information emphasis in the analytical scheme. However, reference to the theoretical perspectives used to construct the scheme confirms that the two issues of "communication" and "authority" are more appropriately regarded as independent variables in teaching.

No one science dimension is clearly relevant to the various abilities associated with objectives for teaching science, in the second paragraph (lines 24 to 27 and 34 to 41) of Selection H. These are general abilities often associated with a scientific approach to solving problems, but they could also be thought of as "critical thinking" skills. On the *Demarcation of science* dimension, only Kuhn's position refers to what scientists do, but his position also refers to characteristics of science which are not "abilities." While the author's references to science have implications for the understanding of science, they are neither detailed nor directly relevant to the argument about methods. Thus further reference to science dimensions of the scheme is not likely to be informative.

#### Commentary on the analysis

Although the structure of the argument in Selection H is complete, the investigator finds that the argument as a whole arrives at its Claim in a disturbing manner. Application of the analytical scheme identifies a significant limitation. Two dimensions are relevant to the classification of teaching methods which serves as Backing for the Warrant. Analysis reveals that two distinct issues have been collapsed into one. In the resulting confusion of terminology, the author leaps to a Claim which lacks an adequate Warrant. No modifications of the scheme are suggested by this analysis.

APPENDIX B

REVISED ANALYTICAL SCHEME

A24

244

DIMENSIONS OF THE ANALYTICAL SCHEME: THE NATURE OF SCIENCE

Carnap

Popper

Kuhn

*Categorization of objects:* What are the highest categories for understanding science?

Objects of reference  
Elementary experiences

Observable events  
(material objects)  
Individuals

Material objects  
Individuals  
Communities of scientists

*Demarcation of science:* How is science distinguished from non-science?

Scientific statements are  
verifiable, since each  
object can be constructed  
from relations among  
elementary experiences

Scientific hypotheses are  
falsifiable, since they  
prohibit at least one  
observable event

Scientists engage in solving  
puzzles identified in terms  
of a shared disciplinary  
matrix which includes  
natural laws and illustra-  
tions of their application  
to phenomena

*How empirical content increases:* By what process does the empirical content of science increase?

By justification, on the  
basis of elementary experi-  
ences, of purely empirical-  
rational statements about  
objects of reference

By intersubjective agreement  
concerning experiences which  
test deductive consequences  
of scientific hypotheses

By acceptance of solutions of  
puzzles in which the current  
disciplinary matrix is  
applied to phenomena

Carnap

*Objectivity of science:* In what way is objectivity achieved in science?

Purely structural definite descriptions eliminate reference to the "material"

Popper

All scientific statements must be intersubjectively testable  
Logical relations among statements are objective, while psychological feelings of conviction about experiences are subjective

Kuhn

Objectivity of either observation language or falsification procedures is not fully compatible with a view of competition between disciplinary matrices

*Relationship of science to truth:*

Scientific statements are those whose truth-value can be decided in principle, by correlating basic relations among elementary experiences

What place has the concept of truth in an account of science?

Although always tentative, better scientific hypotheses approach the truth more closely

Analysis of science does not require reference to the concept of truth

Matrix selection asks which one should guide research, not which one is true

The existence and success of science can be accounted for in terms of evolution from a given state of knowledge

*Progress of science:* What activities of science constitute progress?

"... finding and ordering the true statements about the objects of cognition," by constructing objects of reference and investigating their non-constructional properties and relations

Increasing the truth-content of hypotheses, by achieving greater degrees of falsifiability and corroboration through continuous criticism

Adoption of a new disciplinary matrix by a community of scientists, which sets new criteria for identifying and solving puzzles

DIMENSIONS OF THE ANALYTICAL SCHEME: THE CONCEPT OF TEACHING

<u>Information Emphasis</u>	<u>Insight Emphasis</u>	<u>Composite Perspective</u>
<i>Categorization of objects:</i> What are the highest categories for understanding teaching? Objects of experience Individuals One shared categorial framework	Objects of experience Individuals Personal categorial frameworks	Objects of experience Individuals Communities of inquirers Personal categorial frameworks Disciplinary frameworks

*Nature of knowledge:* What is knowledge?

Public information which increases over time by the accumulation of information

Personally achieved insight or judgment

An inheritance of human achievements, set in various modes of thought which include standards for publicly assessing personal insights

*Nature of learning:* What is the nature of the activity of learning?

Individually accumulating public information and storing it for future use

Creating one's own insights into the nature of personal experience or reality

Acquiring information and coming to possess judgment by which information is used, in accord with public standards

*Nature of teaching:* What is the nature of the activity of teaching?

Transmitting information to preserve what has been accumulated and to make it available to pupils for their personal use

Stimulating pupils to achieve personal insight or to exercise personal judgment

Communicating both information and judgment simultaneously but differently, to introduce pupils to traditions of human understanding while respecting their independence of judgment

Information Emphasis

Insight Emphasis

Composite Perspective

*Authority:* What is the nature of the teacher's authority?

The teacher acknowledges being in authority over his pupils, but he does not distinguish between types of authority

The teacher excludes all forms of authority from his relationship with his pupils

The teacher acknowledges being an authority, and he accepts being in authority for the purpose of enabling many pupils to learn at the same time

*Use of expertise:* How does the teacher use his expertise?

Expertise is imposed by the teacher; structure is considerable or complete

Expertise is made available to pupils by the teacher; structure is minimal or absent

Expertise is used by the teacher to provide enough structure to indicate what is known while providing enough freedom to allow pupils to respond individually

*Communication:* What is the relationship between teacher and pupil, in the processing of information?

Emphasis is given to the teacher's prerogative to share his ability to process information

Emphasis is given to the pupil's prerogative to process information from his personal experience

Balance is maintained for both teacher and pupil prerogatives in their information-processing communication

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