AN ANALYSIS OF CHILDREN'S IDEAS OF

HEAT PHENOMENA

by

Gaalen L. Erickson

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Department of Education

The University of British Columbia
2075 Wesbrook Place
Vancouver, Canada
V6T 1W5

Date April 28, 1975

ABSTRACT

This study was directed towards the resolution of three, interdependent problems: 1) the identification of 'typical' beliefs about heat phenomena held by children; 2) the development of a method for examining the organization of these beliefs; and 3) the application of the results to a classroom situation.

Underlying these problems was the fundamental assumption that knowledge of children's intellectual commitments is an important precursor to the systematic development of instructional strategies. Some recent studies have suggested that a discrepancy between students' existing commitments and those portrayed by the curricular materials may be the source of significant "learning difficulties" encountered in the science classroom.

The methods of study used were in part descriptive and in part empirical. In the first part, interview data were collected and analyzed while the second part involved the construction of a type of instrument for identifying conceptual profiles of indivdual children and groups of children. The Conceptual Profile Instrument (C.P.I.) consisted of statements about heat obtained from the interview data, representing 'typical' children's ideas, along with statements representing the kinetic and caloric theories of heat. Children were required to respond to each statement on a set of bipolar scales representing belief and familiarity dimensions.

The results of the interview data were summarized in terms of a number of ideas about heat called a "Children's Perspective." It was

concluded that most children possess some genuine beliefs about heat and temperature. These beliefs were hypothesized to be based at least in part upon common-sense intuitions developed from everyday experience. For example, the temperature of an object was thought to be related to the amount of heat possessed by that object and so many children concluded that the temperature of an object depended, in part, upon its size. "Heat", and frequently "cold", were generally conceived to be a type of subtle substance (often referred to as fumes or rays) capable of penetrating most objects. Heat was thus considered to be an active external agent accounting for the expansion-contraction and melting-freezing behaviour exhibited by many substances.

Analysis of the results obtained from administering the C.P.I. to twelve classes of grade 5, 7 and 9 students provided evidence for three clearly distinguishable belief patterns about heat phenomena. The belief patterns corresponded to the 'built-in' kinetic, caloric and children's perspectives. These patterns were termed "Model Conceptual Profiles" in the study. These Profiles were interpreted in terms of different levels of understanding of heat phenomena. One Model Conceptual Profile appeared to represent a more abstract view of heat as manifested by higher ratings of the kinetic and caloric statements. Another was interpreted to represent a more concrete, common-sense viewpoint, while the third was thought to represent a type of transitional level.

Two ways of applying the results of the study to a classroom situation were discussed: an interpretive use of the profiles and an applicative use. A set of potential teaching maneuvers, cross-referenced to a particular Model Conceptual Profile were proposed.

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CHAPTER ONE

THE PROBLEM

1.00 Introduction

The purpose of the study is to find answers to three broad questions concerning instruction in science:

1) How can children's beliefs and intuitions about natural phenomena be identified?

2) How can these beliefs be represented in a meaningful way?

3) How can these representations be used to advantage by the teacher in classroom practice?

Since the third question concerning educational applicability placed certain constraints upon the methods used to answer the first two questions, all of the questions ought to be treated as interdependent rather than separate research questions.

As an introduction to the dissertation the first chapter contains an outline of the nature of the problem and its educational significance. A brief discussion of the methods used and the limitations of the study are also included in this chapter. The second chapter contains a discussion to embed the study in a broader educational and methodological context. Previous work relating to the problem is examined and the resulting synthesis of methods designed for the study is described.

The first question above, concerning the identification of children's beliefs, is addressed in Chapter Three. It provides a description of the specific methods used to gather interview data and an illustration of the analytical scheme used to process these data. A discussion of the results is also included in this chapter.

Chapter Four contains a description of a classroom instrument (based in part upon the interview data) that was designed to answer the second question -- the development of a method for obtaining a representation of children's beliefs. This chapter includes a discussion of the statistical techniques used to analyze the data obtained from administering the instrument to a sample of school children. The results of the analysis are presented in Chapter Five.

The last question posed above is addressed in Chapter Six. An application of the study to an educational setting is discussed and the chapter concludes with a sample illustration of how the classroom instrument might be utilized by a teacher. The final chapter consists of the major conclusions of the study and a list of recommendations for further research in the area.

1.10 The General Problem

There is widespread agreement, spanning the entire spectrum of educational orthodoxies, that knowledge of what the learner brings to the learning situation is an important component in planning any educational program. The behaviorists have long endorsed the notion of assessing 'entry behaviors', but only with the rediscovery of Piaget did support for this position extend to the left wing of school reform -- the open education movement. Perhaps the most emphatic statement of this position is made by Ausubel (1968) who introduced his book, Educational Psychology: A Cognitive View, with the following statement:

> If I had to reduce all the educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.

Given this rare instance of agreement across wide sections of the educational community it is indeed surprising how little research has been directed towards the problem of ascertaining what the learner already knows. Those few curricula that have attempted to incorporate this point of view into their program (for example, "The Science Curriculum Improvement Study" and "Science 5/13") have generally been content to simply point out the match between their materials and Piaget's somewhat elusive stages of development. While this may represent a reasonable beginning, much more work is needed on the identification of the beliefs and commitments of children at various age levels and then integrating this knowledge into the curricular process.

The general problem of the study is to <u>identify the substance and structure of children's ideas about heat and temperature and to explore the usefulness of this knowledge for application in a classroom setting</u>. It is being hypothesized that children do possess a somewhat systematic set of beliefs and intuitions which can be represented in such a way as to have potential educational application.

1.11 <u>The Specific Problems</u>

The general problem described above can be conveniently subdivided into three specific problems which are addressed in the dissertation. These specific problems:

a) To identify the substantive beliefs about heat and temperature held by children aged eleven to fifteen.

b) To map out a set of possible structural relationships between these beliefs.

c) To suggest and illustrate ways in which knowledge obtained from a) and b) could be used by a teacher in a classroom setting.

These specific problems correspond to three somewhat distinct phases in the study. Hence the major purpose of Phase One is directed towards identifying the salient beliefs expressed by children about heat phenomena, while Phase Two describes one method for representing the structural relationships of these beliefs. Phase Three is devoted to exploring the educational value of the first two phases. Each of these phases will be elaborated upon in the following section on methods.

1.20 Methods of Study

Phase One consisted of a series of relatively open-ended interviews with children ranging in age from six to thirteen years. This phase culminated in the video-taping of ten in-depth interviews with twelve year olds. The analysis of these interviews provided considerable evidence concerning the substantive ideas about heat and temperature held by children of this age. Although some attempt was made to develop an appropriate category system that would readily yield some indication of structural relationships, it became evident that patterns of this sort could best be detected with a semantic-differential type of instrument. Adoption of this instrument also made it possible to obtain data readily from large groups of children.

The subsequent development, administration, and analysis of results of such an instrument constituted Phase Two of the study. This instrument consisted of twenty-nine statements about heat; with each statement requiring the child to make six different judgments along a seven-point scale using the following scales: agree-disagree, clear-confusing, easy-difficult, true-false, familiar-unfamiliar, and like my ideas-unlike my ideas. These statements were created so as to sample three different points of view -- the present scientific theory, the Kinetic Viewpoint; its predecessor, the Caloric Viewpoint; and a Children's Viewpoint that evolved from the interview data. In order to make some of the statements more concrete and meaningful for the younger children, several demonstrations, directly related to the statements, were performed for each class. The subsequent analysis of these data provided the major source of evidence regarding the structural relations existing among the ideas held by the children and the extent to which these structures resemble the three built-in Viewpoints.

In contrast to the previous two phases, the last phase, dealing with specific problem c), was speculative in nature. Using the results from the interview and questionnaire data as guidelines, several potential classroom applications were identified and discussed.

1.30 Educational Significance of the Study

Heat was selected as the area of investigation for the following reasons: 1) it is a topic generally found throughout the entire school science curriculum ranging from primitive investigations in thermometry in the primary grades to rather sophisticated experiments of heat transfer in high school; 2) most children have an opportunity, commencing with the acquisition of language, to formulate an intuitive set of beliefs about the nature of hotness and coldness; 3) it is an area that is conspiciously absent from the studies of children's conceptions carried out by Piaget and others. The results of an investigation into children's ideas about heat and temperature can be applied to problems of educational practice in two broad ways. The first, and more concrete application, is the creation of instructional packages based upon knowledge obtained from the study. Such a package might be as formal as the development of a diagnostic instrument complete with a set of units on heat aimed at the different levels of understanding identified in the study.

A second way in which the study can make a significant contribution to educational practice is by providing the teacher with a well-documented and rich description of the many ideas that children use to try and account for situations involving heat phenomena. In contrast to the more formal application discussed above, the teacher would be using this knowledge in a more informal, or interpretive manner to make intelligible the children's existing set of beliefs about heat. By acting upon this background knowledge, the teacher can respond to given situations in such a way as to maintain the basic integrity of the child's attempts to account for or explain the phenomena observed.

As with most claims about the educational significance of a study there are several presuppositions associated with the above two considerations. Obviously, in the first instance it is assumed that there will be some homogeneity among the ideas held by children at particular age levels. If this assumption is tenable then curricular materials could be developed that would utilize the knowledge obtained about children's ideas as the primary basis for instruction.

The interpretive use of knowledge, as discussed above, also contains some hidden premises. In order to act upon this type of tacit knowledge it is being assumed that the teacher has a fairly well-defined instructional problem to solve, or, in other words, a clear vision of the educational goal being sought. In the present instance the broad, overarching goal would be something akin to "the cultivation of the inquiring mind" whereby the teacher would be seeking to nurture those situations which he judged to be supportive of this goal.

1.40 Limitations of the Study

Because each of the three phases of the study dealt with somewhat unique problems the limitations of each phase will be discussed separately. The criteria used to assess the reliability and validity of the results of Phase One depart somewhat from standard practices in educational research. The usual concerns are: 1) the low reliability of an unstructured interview; 2) the small size and possible bias in the sample; 3) the validity of the inferential statements about children's ideas of heat and temperature. But here the major consideration for the Phase One procedures was one of identifying genuine beliefs, or, as Piaget calls them -- "liberated convictions".[1] For this task the unstructured interview was judged to be a more sensitive and productive method than a more standardized procedure. However, as these data on children's ideas were used to develop the instrument for Phase Two, the real value of this method can only be determined to the extent that the data that it produces hold up under further empirical scrutiny. An opportunity for this extended scrutiny was afforded in Phase two where the children's ideas were incorporated into the classroom instrument that was developed. The subsequent analysis of these data provided some evidence about the existence of the hypothesized structure of children's ideas.

In general there are two major concerns in the measurement of a construct, such as the hypothesized "viewpoints of heat" held by children. The first is the reliability of the instrument and the second is the validity of the procedures used. One estimate of reliability for an instrument is the test-retest procedure. In the present study the instrument was administered in a classroom setting but under conditions in which it was not feasible to return on another day to retest the same children. There are fortunately, other ways of assessing reliability. The internal consistency of a questionnaire is often interpreted as a measure of reliability. In the present analysis two separate estimates of response consistency are calculated: the patterns of response to the six scales used in the instrument and the clustering of the statements representative of a particular heat viewpoint. The statistical analysis of the data, which is discussed fully in Chapter Four, indicated that both of these estimates are reasonably high, thus providing some degree of confidence in the questionnaire. In addition, an item analysis of the instrument reported in Appendix D, was performed and the results generally substantiated this claim.

In turning to the issue of validity, Kerlinger (1973) provides an outline of the three major types: content validity, construct validity, and criterion-related validity. Each of these will be discussed as it related to this study.

Content validity attempts to assess "the representativeness or sampling adequacy of the content of a measuring instrument." (Kerlinger, 1973, p. 458) Since the instrument was constructed to contain representative items from three different viewpoints of heat the question of content validity arises. How representative and accurate was the sampling of items from each of these domains? An attempt was made to assess the accuracy of the items sampled from two of the viewpoints (the Caloric Theory and the Kinetic Theory) by checking them with three judges who were knowledgeable in these areas. The items from the Children's Viewpoint were selected on the basis of how frequently they occurred in the interview data and their relevance to the demonstrations performed during the administration of the instrument. The adequacy with which each of these domains was sampled cannot be ascertained without further empirical studies.

While construct validity is perhaps the most important form of validity, as Kerlinger suggests, it is also the most difficult to assess. It is concerned with questions such as: What does a score on this instrument mean in some theoretical sense? What factors or constructs might account for the observed results? and so on. In Kerlinger's words the interest is focused "more on the property being measured than on the test itself." (Kerlinger, 1973, p. 461) The theoretical inspiration for the present study is to be found in the writings of Piaget and several recent papers by Witz and Easley. While the techniques used in Phase Two differ from their approaches, the 'property' under surveillance -- the structural characteristics of children's thought -- is common ground. The empirical results of this study might well be interpreted as evidence in favor of the type of cognitive organization that is so characteristic of their theoretical perspective. This perspective will be discussed in Chapter Two.

The question of criterion-related or predictive validity is not addressed in this study as the only external variable being considered -- the grade of the subject -- is of no real interest as an object of prediction. While it is expected that there will be a shift towards the more sophisticated Kinetic Viewpoint as the subjects increase in age, it is impossible, at present, to determine whether it would be a genuine developmental trend (in the Piagetian tradition) or simply an environmental effect due to increased exposure to the adult view.

To digress briefly to discuss a related point, the author believes, as indicated earlier, that too little educational research ever finds its way into actual classroom practice. One way to draw more attention to this issue might be to specify a validity index which indicated the degree to which a particular study fulfilled some criterion of educational applicability or significance. This index, which might be called pedagogical validity, would be an important member of the general class of results considered under criterion-related validity.

This leads to a discussion of the limitations for the Third Phase of the study -- the proposed applications for classroom use. Because the major purpose of this research was directed toward solving the problems emanating from the first two phases, most of the foregoing comments are speculative in nature.

The decision to proceed with Phase Two, the development and analysis of the instrument data, was made largely because it was believed that both the instrument and the type of data collected would prove to be of more immediate value to the classroom teacher than would an elaborate method for analyzing interview data. The first limitation, then, centers around the strength of the procedures developed in Phase Two. First, the instrument would have to be developed using a much larger and more representative sample of children. And second, the instrument would have to be simplified both in terms of its length and the methods for computing the results for a child or a class of children.

A second limitation is to be found in terms of the development and effective use of the curricular packages to accompany the instrument. It will require considerable effort to develop materials and activities that can be cross-referenced to performance on the instrument. The task of orienting teachers to its effective use is an even more important issue that will have to be addressed. There are at present very few teachers trained in the mode of individualized or even small group instruction based upon a set of well defined diagnostic procedures.

A final hurdle in the path of implementing the results is that the techniques suggested above presuppose a somewhat different rationale for a science program than is now being practiced in the schools. As this issue will be raised again in Chapter Two, suffice it to say at this point that teachers will have to be convinced that the reorientation of goals can be justified and is attainable in a classroom setting.

Perhaps the easiest way to obtain an overall perspective of the study and its constituent procedures is by examining the flowchart which follows.

FLOWCHART OF THE STUDY

Operation	Phase of Study	Characteristics	Function
1. Pilot Interviews	1	1. 9 unstructured interviews with children aged 6 to 13	1. To provide information of children's ideas and establish a set of interview procedures for step 2
2. Final Interviews	1	2. 10 semi-structured interviews with children aged 12	2. To gather data on the substantive aspects of children's beliefs about heat
3. Conceptual Inventory	1	3. Summary of Ideas expressed by individual children	3. To provide input for Children's Viewpoint in the construction of classroom instrument
4. Development of Classroom Instrument	2	4. Creation of 29 statements representing three Heat Viewpoints (Kinetic, Caloric and Children	4. To establish evience of cognitive organization in children's ideas about heat
5. Administer Classroom Instrument	2	5. Given to 276 subjects in grades 5, 7, and 9	5. To gather data for structural analysis of children's ideas
6. Analysis of Instrument Data	2	6. Factor analysis of scales and statements. Guertin's Profile Analysis	6. To check reliability and validity of the instrument. To generate model profiles for grouping of children
7. Educational Applications	3	7. Examination of model profiles for 'point of view' of heat illustrated	7. To develop profiles for diagnostic and instructional procedures

NOTES FOR CHAPTER ONE

1. An eloquent justification of a non-standardized interview technique (Piaget refers to it as a "clinical method") is given in the first chapter of Piaget's (1969) The Child's Conception of the World. In this chapter he outlines and characterizes five potential types of responses made by the child in an interview situation: answers at random, romancing, suggested conviction, spontaneous conviction and liberated conviction. The responses of interest to the analyst are those in the last two categories.

CHAPTER TWO

CONTEXT OF THE STUDY

In an extensive, critical review of educational research encompassing the past twenty years, Averch et al. (1972) concluded that only limited improvement of present educational practices can be expected through expanding the current base of educational research. Rather, more effort ought to be directed towards investigating current educational reforms. This study, in focusing upon instructional difficulties emanating from recent curricular reforms in science education, represents such an effort. To gain an overall perspective of the study this chapter will examine issues related to the educational, psychological and philosophical aspects of the problem.

2.00 Educational Context of the Problem

2.01 Relationship to Curriculum Problems in Science Education

The past fifteen years have witnessed an unprecedented growth of new science curricula. Emerging from these numerous projects have been two trends: an increased emphasis upon the processes of science instead of the products, and secondly, a tendency to utilize student inquiry as the predominant method of instruction.

Proponents of the new programs have extolled the virtues of focusing upon the methods used in obtaining scientific knowledge rather than committing to memory a body of facts which will soon be forgotten or obsolete. The implementation of this "process" philosophy has varied significantly among the different programs. On one extreme, authors of Science: A Process Approach have identified and defined thirteen processes, ranging from simple like 'observation' and 'classification' to more complex ones like 'defining operationally' and 'experimenting'. Authors of other projects like the Elementary Science Study and Nuffield Junior Science have been content to use a much more informal approach whereby the child is engaged in wide-ranging investigations of natural phenomena with the expectation that he will develop these 'process skills' in the course of his inquiry.

This so-called "process approach" has had such an impact upon science education that it has prompted the authors of one textbook on elementary science instruction to comment:

> Of the many goals proposed and adopted for teaching elementary school science, those goals associated with process-oriented science seem to be most relevant for the next twenty years. In particular the goal of the cultivation of the inquiring mind, is stressed because it represents a whole philosophical style of thinking about what science is, how it should be taught, and what curricular structure (or lack of structure) is appropriate. (Kuslan and Stone, 1972, p. 179)

As indicated by the above quotation the adoption of an overarching goal such as "the cultivation of the inquiring mind" also suggests a certain style of teaching. The style, adopted by most of the new curricula, has been labelled the "inquiry approach." The implicit assumption is that if we are attempting to teach students the skills of scientific inquiry, then, like other skills that we teach, an opportunity must be afforded the students to practice those skills. This trend of student inquiry, or 'sciencing' as it has been called by some, has been further buoyed up by a rediscovery of Piaget's work on the intellectual development of the child. The cornerstone of Piaget's position --

that the active child, through interaction with his environment, is constantly engaged in the business of restructuring his own thought processes -- is a very attractive theoretical foundation for curricula adopting an inquiry-based mode of instruction.

However, in emphasizing student inquiry within a process-oriented program, curriculum developers have tacitly assumed that the subtle regularities of nature, apparent to the scientist, can be 'discovered' by an inquiring child. While the child may indeed be like a scientist in some important respects, there is an ever increasing body of psychological literature, to be discussed in Section 2.10, which concludes that children see the world from very different perspectives than that of adults in general, and scientists in particular. Thus perhaps the real utility of the 'child as a scientist' metaphor is not that it suggests one can simplify or reduce the complex body of scientific knowledge and methods into pedagogically digestible programs, as has been done to date. Rather, it is to view both child and scientist as engaged in the same basic activity of attempting to perceive some sense of order in their world -- only at different levels of abstraction. Bohm (1965) has effectively argued this point in an appendix to his book on special relativity. His thesis is that the process of perception does not differ significantly between the child and the adult. Rather, the sophisticated conceptual construction, "embodying, in effect, a hypothesis that accounts for the invariant features that have been found in [past] experiences" (Bohm, 1965, p. 217), of the adult scientist is a natural extension of the child's perceptual process, only at a higher level of abstraction.

The implications of such a position for the development of science curricula seem clear. Instead of attempting to package the abstract perceptions of the world, based upon many years of accumulated experience, curriculum development ought to proceed from the simple and more concrete phenomena associated with the child's world toward the more powerful and sophisticated conceptions of the adult world. This type of reorganization entails the evolution of curricula in an upward direction from the child's own ideas and ways of thinking, instead of the present downward direction from established, adult frameworks of methods and knowledge. Such an approach, however, is not without problems. Among the most prominent would be the need for teachers to become more adept at identifying and diagnosing the child's perspective of the subject matter being studied.

2.02 Relationship to Teaching-Learning Problems in Science Education

Anticipating a possible reorientation in curricular emphasis, such as that discussed above, researchers at the University of Illinois have conducted a number of exploratory studies into some of the basic teaching-learning problems that might accompany such an approach. For example, Hanson (1970) found that beginning teachers tended to reject any alternative theories (that is, different from the prevailing scientific theory being 'taught' by the teacher) held by the children. These teachers either ignored any alternative theory put forward by the students or else attempted to persuade them to change their minds. Ashenfelter (1970) and Craig (1971) also worked on the problem of teachers' insensitivity to the intellectual commitments of their students. In the latter study by Craig, an attempt was made to "create for a group of beginning science teachers an environment in which these teachers could become more sensitive to and more familiar with high school student ideas." (Craig, 1971, p. 1) The results of these studies, which indicated that beginning teachers are insensitive to (and in some cases intolerant of) student perceptions of scientific phenomena, point out the need for a revision of our present teacher-training programs. As it now stands the students are being encouraged to inquire into some phenomenon, and in so doing they formulate something akin to Bohm's "inner construction". But any attempts to formalize or make these inner thoughts explicit are met with resistance by the teacher. Hence the students either experience frustration as they attempt to accommodate to the unfamiliar ideas set forth by the teacher, or passively acquiesce to a viewpoint they do not really understand or accept. Neither of these outcomes is compatible with the stated goals of the new science curricula.

Earlier, Hawkins (1965), in a much publicized article entitled "Messing About in Science", also recognized the attendant teaching-learning problems inherent in an inquiry-based approach. He suggested that educators must learn to recognize and cultivate that very powerful style of learning which is responsible for "most of what children have already learned, the roots of their moral, intellectual and esthetic development." (Hawkins, 1965, p. 7) But, as is illustrated by the Illinois studies, this learning style (which Hawkins calls "messing about") and the ideas it produces, are most often alien to teachers who are steeped in the adult traditions of scientific knowledge. Sensing this gap between the teacher and child, Hawkins calls upon curriculum designers to assist the teacher by designing materials and activities with a rich variety of alternative pathways for the child to choose. In so doing he assumed that the child, with assistance from the teacher, will be free to pursue those avenues of inquiry which are most appropriate to his present interests and intellectual capabilities. Hawkins has thus mapped out a somewhat informal strategy for meeting the divergent experiential backgrounds that exist between teacher and child, and also to a lesser extent between different children.

The assumption from which this study stems is that a preliminary step of gathering data about the substance and structure of children's beliefs would greatly facilitate any approach to the above problem; whether it be the development of the type of materials envisaged by Hawkins or some other more formal approach.

2.03 Review of Studies Related to the Problem

Written accounts of the ideas held by children date back at least as far as the late 18th Century with the careful observations made by Pestalozzi on his own child. But the first set of large scale studies of children's intellectual commitments was reported in G. Stanley Hall's The Content of Children's Minds on Entering School (1883). Ever since, there have been numerous investigations probing into the world of the child, the purposes of which have ranged from identifying the expressed interests of children to charting children's behavior with the use of sophisticated category systems. This latter type of study, which involves classifying some type of verbal response, usually generated by an interview situation, has been very prevalent in the area of science education. The early, pioneering studies examined the development of causal reasoning in the child.[1] But soon investigations of this nature spread to other areas of interest to the science educator. Thus there were a number of studies probing into the child's conception of natural phenomena (e.g., Oakes, 1947; King, 1960; and Inbody, 1964) and several directed at more specific skills such as the child's ability to formulate hypotheses (Atkin, 1958) or to construct models to account for observed physical phenomena (Anderson, 1965; Pella and Ziegler, 1967).

While all of the above studies have contributed to our knowledge of the mechanics of child thought, they still have had little appreciable effect upon educational practice. Several conjectures might be forwarded to account for this lack of influence. One is that many of the above mentioned studies are fragmentary in nature -- each one surveying a number of topics ranging from children's ideas about the origin of geological features, to electricity and magnetism, to their understanding of living objects. For example, Oakes (1947) employed 17 experiments and 15 questions to examine children's explanations of 19 different areas of natural phenomena; while King (1960) had 70 questions ranging over 5 broad topic areas.

A second reason for the lack of educational effect might be attributed to a failure on the part of the authors to address serious educational issues within the bounds of their study proper, thus leaving the implementation of their results to others.[2]

The author of the present study has attempted to meet the first shortcoming (in terms of educational applicability) of most previous studies by focusing upon children's conceptions of heat. By limiting the area of investigation to a single topic it was felt that two outcomes could be accomplished: 1) to generate at least some tentative hypotheses about children's ideas of heat; and 2) to provide an example of a possible method for charting other areas of interest to educators.

The second shortcoming, listed above, was approached by proceeding beyond the stage of simply identifying and categorizing children's views. As described in Chapter One, the method employed in Phase One to summarize the substantive aspects of children's beliefs about heat consisted of a type of categorization procedure. However, this level of analysis, which is the point of termination for most of the above-mentioned studies,[3] was judged to be insufficient in depth and scope for meeting any serious educational problems. Hence the decision was made to try to examine the data for some evidence of a type of organization or structure that might be of value to both the curriculum writer and the classroom teacher.

2.10 Psychological Context of the Study

2.11 Relationship to Structural Analysis

Since the current language of education is replete with various usages of the word 'structure' (for example, frequent references are made to: the "structure of knowledge", the "structure of the curriculum", a "structured lesson plan", and so on), at this point it is advisable to specify what is intended by the phrase, 'the structure of children's beliefs'. A standard dictionary definition of structure is: "that which is constructed; a combination of related parts."[4] The focus in the present study is upon the manner in which the parts (that is, the children's ideas) are organized into some meaningful whole.

The systematic study of the organization of a set of ideas held by a child is a much more demanding task than simply enumerating or categorizing the ideas according to their substance, as discussed earlier. It is generally not feasible to simply ask children (nor adults for that matter) to describe directly the organization of their ideas, or the possible relationships between these ideas, with regards to some physical phenomena. Hence the problem becomes one of attempting to develop a suitable method for formally representing those ideas by means of some theoretical framework. Generally this formalization procedure is a result of theorizing which functions in such a way as to try to reconstruct the 'mental space' of the subject in terms of a set of theoretical constructs.

2.12 Relationship to Piaget's Structures of Intelligence

Undoubtedly the most prominent theoretician concerned with a structural analysis of children's thought is Piaget. Because his writings have strongly influenced the conception, and to a lesser extent the methods of the present study a brief account of his theoretical position (as it influences his structural analysis) would seem warranted.

Although Piaget professes to be a genetic epistemologist -- that is, one who seeks to explain knowledge "on the basis of its history, its sociogenesis, and especially the psychological origins of the notions and operations upon which it is based" (Piaget, 1971a, p. 1) -- he is best known for his comprehensive studies of children's intellectual development. In his desire to describe the way in which the thought processes of the child gradually evolve, through a series of closer approximations to the perceived reality of the adult world, he has attempted to wed psychological investigation with a type of logical formalization. The result of this union is the structural analysis which has become prevalent in Piaget's writings. As a first approximation one might describe this type of analysis as an attempt to represent mental processes in terms of theoretical entities which can properly be called cognitive structures. Piaget claims the distinguishing features of these psychological structures, in addition to other theoretical structures posited in fields like mathematics, linguistics and anthropology, are based upon a system of transformations and the laws governing these transformations. (Piaget, 1971b) Hence in Piaget's description mental growth is derived from a number of successive transformations producing the developmental stages. The elemental constituents in this process, as well as the determining factor for sorting out the level of intellectual development, are the operational structures. For example, the kind of operational structures that appear at the 'stage of concrete operations' are those pertaining to: class inclusion and classification, seriation and ordering, and correspondence. According to Piaget these structures do not just unfold in a genetically predetermined sense; they must be constructed by the child through interacting with concrete, physical objects and then, at later stages of development, mentally acting upon and transforming the reality perceived by the child. Or, in Piaget's words:

> From the most elementary sensorimotor actions (such as pushing and pulling) to the most sophisticated intellectual operations, which are interiorized actions, carried out mentally (e.g., joining together, putting in order, putting into one-to-one correspondence), knowledge is constantly linked with actions or operations, that is, with *transformations*. (Piaget, 1970, p. 704) (Italics his)

2.13 Relationship to Witz and Easley's Deep Structures

Witz and Easley (1971) have recently pointed out the limitations of relying solely upon operational structures as the theoretical basis for explaining specific patterns of behavior. They argue that operational structures, in themselves, are insufficient for interpreting why children react in characteristic ways towards certain physical systems. Their solution is to propose a new type of cognitive structure which they entitled "physical deep structure". While Piaget recognized the influence of what he called physical knowledge or experience, he did not accord it the full structural status as have Witz and Easley. To place this issue in proper perspective it must be remembered that Piaget is interested in describing normative trends and mechanisms while Witz and Easley admit that they are more concerned with making sense out of the actions of a particular child interacting with a particular set of materials. To quote Witz and Easley:

> When the child is interacting with a particular physical system, or when he contemplates one, a [physical deep structure] comes into play, gives rise to what appears in introspection as intuitive

> feelings of weight, momentum, inertia, etc., and strongly influences his externally observable behavior. (Witz and Easley, 1971, p. 2)

To identify a physical deep structure, then, the analyst must carefully observe a child interacting with a physical system (for example, a pendulum) and construct inferences about the nature of the physical deep structures from the child's actions and discussion with the interviewer. Ideally, the interviewer ought to be capable of formulating these hypotheses and checking them out during the interview instead of relying upon a post hoc reconstruction from transcript data.

Thus, on first view one might conceive of physical deep structure as a sub-species of cognitive structure acting as a type of general data base to be manipulated and transformed by the operational structures.[5] In this sense both constructs are necessary if one is attempting to explain any complex, cognitive action.

The educational implications of mapping out the content-oriented, physical deep structures would appear to be more significant than simply considering operational structures. Previous attempts to modify or accelerate operational development have met either with little or only short-term success. Piaget, when discussing the issue of acceleration of operational structures, is quick to point out that there are two non-accessible, biological factors which regulate the development of structures -- maturation and equilibration -- and so any instructional program will be limited by these two factors. (Piaget, 1964). On the other hand physical deep structures, as Witz and Easley point out, are theoretical constructs that attempt to account for children's characteristic ways of dealing with physical systems and would therefore seem to be more responsive to the type of experience provided in the classroom. In other words, because they have a strong content component, exposure to content-oriented experiences would increase the likelihood of bringing about a change in these structures. It would seem that if 'typical' physical deep structure patterns could be identified and mapped out for specific groups of children, then at least two distinct educational gains would accrue.

The first educational application could be directed towards the production of curricular packages for use by the classroom teacher. Such a package might contain a diagnostic instrument, for identifying the pattern of physical deep structures of a particular group of children, along with a number of potential teaching strategies matched to that pattern. Of course, the pedagogical basis for such a matching procedure would depend upon the overarching goals for science instruction in the schools. For example, if the aim was to find the most efficient route for initiating the child into a more adult way of perceiving the world, then the strategies would take on a very different appearance from other aims such as fostering intellectual curiosity or developing an appreciation of our environment. More will be said of these possible teaching strategies in Chapter Six.

A second beneficial effect would result from making available to teachers the knowledge obtained about the organization of children's physical intuitions or deep structures. By possessing such knowledge it is hoped that the teachers' perceptions of the instructional task will be altered in such a way that the basic integrity of the child's beliefs and primitive methods of inquiry will be respected. While this second effect is much more tenuous in nature, Broudy et al. (1964) have argued that this type of interpretive use of knowledge may be as powerful as the more conventional applicative usage.

2.14 The Concept of Structure Used in the Present Study

The task for the present study, as outlined in Chapter One, is to identify the substance and structure of children's ideas about heat. Although Witz and Easley's theoretical conception of physical deep structures would appear to be a useful construct for examining the organization of children's beliefs about heat phenomena,there are several drawbacks in considering their approach for this study. The first is an inadequate articulation of a set of procedures to assist others in the identification of physical deep structures. As with Piaget, they have selected only those passages from several different transcripts appropriate to illustrate the point of theoretical contact being discussed at the time. A second reason is that their approach also presupposes some knowledge of children's understanding of heat, so as to orient both the interviewer and the analyst -- a condition which could not be satisfied due to the lack of work in the area of children's beliefs about heat. But, perhaps the most compelling reason for not using their approach is to be found in one of the stated aims of this study: the application of the results of this study to actual classroom situations. In this regard a concise and standardized instrument, based upon the interview data, would appear to be much more useful than a somewhat abstract discussion outlining the potential organization of beliefs manifested by a child, or a small group of children.

Hence a search was initiated for an alternative to the Piagetian type of analysis for investigating the structural characteristics of children's ideas about heat phenomena. It was hoped that a model could be found that would retain the content orientation of the physical deep structures, and yet meet the two objections raised above.

A promising approach for revealing some aspects of the potential organization of children's beliefs is that of multidimensional analysis. There are two inter-dependent issues that must be addressed before an analysis of this nature can be carried out. Decisions must be made with regards to the methods to be employed for the collection of the data and the type of statistical model that is to be used to analyze the data.

The task in the present study, then, was one of first, translating the substantive beliefs, gathered in Phase One from the interview data, into a format that allows other children to respond to those beliefs and second, choosing some suitable analytical model.

The first attempt at approaching the above issues was inspired by a report written by Miller <u>et al</u>. (1967) entitled, <u>Elementary School Teachers' Viewpoints of Classroom Teaching and Learning</u>. In this report they outlined a technique, called Latent Partition Analysis, which relied upon data obtained by sorting a large number of cards (generally around 150) into piles which were similar in some respect. Each card contained a description of some classroom-relevant behavior in which a teacher might engage. Those cards which the subject perceived to be associated with the same type of behavior were placed into the same pile -- which was subsequently called a "manifest category." By comparing these categories over a number of subjects for their commonalities a number of latent categories emerge. Hence the claim that this procedure is tapping in some manner, a latent cognitive structure that is responsible for organizing the subjects' perceptions in the manner observed.

Although the technique is capable of producing the kind of structural analysis that is desired, the somewhat sophisticated sorting procedures proved to be too difficult for the seven different children who tried to sort statements about heat and temperature. Furthermore, it would be extremely difficult to administer this type of sorting task to a whole class at a time -- a desirable feature both for sampling large numbers of children and for adapting the questionnaire for eventual classroom use.

Taylor's (1966) study, entitled The Mapping of Concepts, provided some useful alternatives to the sorting techniques described above for the gathering of data suitable for the analysis of structural relationships. All of the methods of collecting judgmental data that he discusses -- ratio judgment, paired-comparison, category sort, and semantic differential -- are suitable for use with a multidimensional analysis model. After a review of the literature concerning these techniques, it was decided that the method that would best meet the requirements of the study (that is, it would be simple enough for an eleven-year old to comprehend and could be presented to a large group of children) was that of the semantic differential, or some simple variation of this technique (Osgood et al., 1957). Subsequent pilot runs with small groups of children and finally with an entire class of grade five children indicated that a modified semantic-differential instrument did indeed meet these requirements.

The data generated by the use of this instrument could be analyzed using several different statistical models. The model selected was the factor-analytic model because it was judged to better satisfy the particular needs of this study, outlined in the preceeding two chapters. Both the measuring instrument and the factor-analytic model are described in detail in Chapter Four.

In summary, the procedures that are used in the study to ascertain the 'structure of children's beliefs' about heat entail the measurement of the perceived psychological associations between a number of statements drawn from three different Perspectives of heat. This measure was obtained by asking a class of children to judge a set of statements about heat using six criteria (the scales on the instrument) as their basis for judgment. Using an appropriate factor-analytic technique, it was possible to assess the number of relevant dimensions being used by the subjects in making the judgments. As the instrument was constructed with statements using three differing heat Perspectives, it was hypothesized that one ought to be able to identify these as somewhat separate dimensions. The study showed that it was possible to identify the extent to which a child, or a group of children, subscribed to a particular point of view regarding heat phenomena (that is, how heavily weighted their judgments were on a given dimension). The collection of the data and the techniques used to determine the structure of the children's judgments are discussed in Chapter Four.

NOTES FOR CHAPTER TWO

1. Some examples of these early studies on causal reasoning in the child are: Piaget (1930), Issacs (1930), Keen (1934) and Huang's (1943) comprehensive review article.

2. A notable exception to this trend was the work of Gerald Craig who went on to develop a very successful program based upon his studies of children's interests and their relationship to the prevailing scientific ideas of the day.

3. Piaget is obviously to be excepted from this claim as he has always been interested in carrying his analysis much beyond the categorization stage.

4. Funk and Wagnalls Standard Dictionary (1962).

5. Although this point is not addressed by Witz and Easley in their paper, Easley (1969) has argued in an earlier paper that Piaget's conception of the operational structures (that underlie the development of logical thinking in the child) can best be interpreted as functioning in a generative capacity for the child. That is, the child utilizes these structures, such as Piaget's famous INRC group, to create a number of potential hypotheses when faced with a problem situation, as opposed to using them to test the validity of the proposition. The physical deep structures could then be conceptualized as the content-oriented product of these deliberations by the child when interacting with some physical system. For example, most children believe that the weight of the pendulum bob is a determining variable in how long it takes to complete one swing. However, as the child works with the system he identifies other variables, such as length of string, shape of bob, and amplitude of the swing. Once these variables become known then the operational structures enable him to generate other potential hypotheses (in theory, all of the possible elements of the various combinations of variables) regarding the mechanism of the pendulum. As these new hypotheses are examined empirically they may displace the child's existing notions thus creating a new, or altered physical deep structure.

CHAPTER THREE

METHOD OF COLLECTING AND ANALYZING THE INTERVIEW DATA

3.00 The Preliminary Work

The preliminary approach to Phase One of the study involved working with several small groups of 11 and 12 year-old children who visited The University of British Columbia Campus.[1] Exploratory experiments and discussions concerned with heat and temperature were conducted with these groups. Following these sessions additional informal, individual interviews were conducted with elementary school children ranging in age from 6 to 13 years. The author's work with these children served as a type of pilot study providing clues concerning the types of experiments and demonstrations that are of interest to children. They also provided some indication of typical patterns of response to certain questions and to the materials themselves. Out of these sessions, which spanned a period of two months, emerged the tasks that were finally chosen for the formal interviews. These tasks, which will be described in detail in Section 3.22, consisted of five different sets of experiments or demonstrations relating to some aspect of heat phenomena.

3.10 A Description of the Formal Interviews

3.11 The Subjects

While the ages of the children used in the pilot interviews varied from 6 to 13, a decision was made to use only 12 year-old children for the final interviews. This decision was based on several considerations: (1) most of the younger children interviewed in the pilot sessions appeared to either have given little thought to the subject of heat or else had some difficulty in expressing their ideas; (2) children older than 12 have often been introduced to adult theories of heat in a school setting, thus, interfering with the intent of the study -- to examine children's ideas of heat; (3) finally, 12 is about the age at which a child is beginning to reason in a more abstract, theoretical manner and it was hoped that some of these more theoretical commitments could be identified in the interview.

The ten children interviewed (five boys and five girls) were selected from two elementary schools in the City of Vancouver. There was a considerable amount of diversity among the subjects in their socio-economic background and levels of achievement in school. This was determined from informal conversations with the children prior to and after the interview, and by assurances from the teachers that the children represented a wide range of abilities. The latter judgment by the teachers appeared to be substantiated by the varying responses to the interview situation. Some of the children attempted to provide a full, rich description of their ideas while others were content to respond to many of the questions posed by the investigator with very brief, often non-commital answers.

3.12 The Tasks

This section will outline the five tasks used to engage the subjects in discussions of their ideas about heat phenomena. In addition, the section will include a brief description of the physical apparatus used and an abbreviated discussion of the general types of questions accompanying each task. The criteria used for task selection were: the inherent interest or appeal of the task to the child and the degree of diversity in heat phenomena illustrated in the tasks.

The apparatus for the first task consisted of a 125 ml. Erlenmeyer flask containing water coloured by red food colouring. A one-hole stopper containing a 30 cm. capillary tube was inserted into the flask until a column of 'red liquid' rose up part way into the tube.[2] Each child was shown this apparatus and was asked to examine it. If no promising questions emerged from this initial encounter, the investigator asked the child if he could think of some way to lower the level of liquid in the tube. Eventually all of the subjects ended up immersing the flask in beakers of cold and hot water, although a number of other idiosyncratic methods were also used to try to affect the liquid level. Questions such as: Why did the liquid change as it did? Would other liquids react in a similar fashion? What happens to the hot/cold water when this jar is immersed in it? were posed at appropriate moments while the child was handling the materials.

The second task consisted of placing eight different objects, all cube shaped, in an aluminium tray on a hot plate and observing the result. The objects consisted of: two metal cubes (copper and aluminium), wood, sugar, wax, butter, ice, and a mothball. Before placing the tray on the hot plate, the child examined each of the cubes, usually attempting to identify or name each cube. If the question did not arise spontaneously, the investigator asked the child what would happen when the tray was placed on the hot plate. Other questions raised by either the children or the investigator related to the nature of the melting process, and why some substances melt more quickly and easier than others. When time permitted a related experiment of comparing the melting rate of ice cubes in water and in air was performed. This melting race, staged between an ice cube in air at 70° F. and one in about 200 ml. of water at 50° F. was of interest to most of the children. The obvious question as to why it melted faster in the water drew a large variety of responses.

A third task consisted of mixing water at different initial temperatures in a specially constructed plexiglass container of dimensions 8 inches by 4 inches by 4 inches. A removable barrier in the middle allowed water at different temperatures to be poured in each side without mixing. The barrier could then be removed to mix the water if desired. The investigator first posed questions concerning the transfer of heat through the barrier before it was removed. Then the child was asked to predict the final temperature when the water at two different temperatures was mixed by removing the barrier.

This apparatus was also used to investigate an interesting discovery made by the investigator during the pilot sessions. After observing a similar pattern of responses made by children aged 6 to 10 it became apparent that one criterion used by some children for judging the temperature of water was the 'amount of water present'. Thus the apparatus was used to alter the amounts of water at the same temperature to further explore the nature and prevalence of this belief.

A fourth task involved heating different sized metal and glass rods with a candle flame to see which one would heat up the quickest. Three pins, embedded in wax, were placed along the rods to trace the progress of the contest. The questions that accompanied this experiment were: Why does the opposite end (to that being heated by the candle) of the rod get hot? Why do some rods get hot faster than others? One question frequently asked by the children about the experiment was: How is heat able to move along the rod? While the investigator pursued this type of question, using the child's own language where possible, he was careful not to initiate questions of this nature which might suggest heat to be a type of material substance.

The final task proved to be the most difficult for the children to comprehend. The basic apparatus was designed to illustrate the expansion of a solid when heated. It consisted of a 12-inch horizontal metal rod anchored at one end of a wooden frame (by drilling a small hole in the rod and inserting it into a small nail protruding up from the frame). The other end of the rod rested upon a long, straight pin attached to a cardboard dial 4 inches in diameter. When the rod was heated by two candles the linear expansion of the rod caused the pin to turn. The motion of the pin was translated to the large dial, which contained numbers that could be read by using a reference point attached to the frame. A diagram of this apparatus is provided in Appendix B. While the children were very fascinated by the motion of the dial only two children were able to provide a somewhat reasonable explanation of what was occurring. Most of them simply shrugged their shoulders and said something like: "Well I guess the heat is doing it somehow, but I don't know how."

3.13 The Format of the Interview

As standard procedure for the interviews, the investigator would meet each child at his or her school and drive the child to The University of British Columbia for the interview. This system allowed the investigator to chat informally with the child for 10 to 20 minutes before actually initiating the interview. An opportunity was thus provided to assure the children that it was not a 'testing type' of situation, but one that they would enjoy. It was also possible to gather some simple biographical data during these discussions. The child was told that the investigator was trying to develop a new science course for their grade level, and so he was interested in their ideas regarding the experiments about heat and temperature. The time required to complete the entire interview session ranged from 40 to 70 minutes, with most of the children taking about 60 minutes.

The room used for the interviews was equipped with one-way mirrors and microphones. A one-inch Sony videotape recorder and camera were placed behind the mirror, however, each child was informed of its presence and was asked for permission to record the interview. A diagram of the actual physical layout is given in Appendix B.

The model adopted for conducting the interviews resembled that of Piaget's "clinical method". (Piaget, 1969) Effective use of this technique requires the interviewer to:

> ...unite two often incompatible qualities; he must know how to observe, that is to say, to let the child talk freely, without ever checking or side-tracking his utterance, and at the same time he must constantly be alert for something definitive, at every moment he must have some working hypothesis, some theory, true or false, which he is seeking to check. (Piaget, 1969, p. 9)

In keeping with this technique no formal interview schedule of questions was used. Rather, the investigator attempted first to get the child involved in some aspect of the task. Having established some avenue of inquiry or interest, open-ended questions were posed, using the child's own language where appropriate. The "working hypotheses" that guided some of the questioning during the interviews were largely based upon the results from the pilot sessions. For example, the notion that heat was a 'sort of invisible substance, something like air' pervaded many of the pilot interviews. Although the investigator was alert to this potential view of heat, to the point of getting the children to try and clarify and expand upon their ideas, he also attempted to 'check out' other beliefs which appeared to be discrepant with this substance notion of heat. A careful scrutiny of the transcripts from the interviews indicated that while a number of opportunities for checking out some of these beliefs were missed, some evidence of genuine beliefs, or "liberated and spontaneous convictions" as Piaget calls them, could be found. These beliefs are the subject of discussion in the following section.

3.20 Analysis of the Interview Data

There are a number of different methods for analyzing qualitative data such as these generated by the interviews described above.[3] They range from the very "free-wheeling" type of analysis employed by Piaget and his co-workers to the more standardized methods such as those found in books by Barker (1963) or Raush and Willems (1969).

In Piaget's method, the interview data are invariably analyzed in terms of a progression of developmental stages, but systematic presentation of the interviews is not attempted. This may be directly attributed to his overall theoretical perspective, outlined briefly in Chapter Two. However, Piaget's informal method of reporting and substantiating his research claims has long been a subject of controversy. Many other investigators have tried to 'objectify' his procedures either by developing standardized instruments (for example, Goldschmid and Bentler, 1968; Tuddenham, 1922; and Green, Ford and Flamer, 1971) or attempting to be more explicit in the manner of analysis and subsequent reporting of the interview data. (Knifong, 1971)

In contrast to Piaget's techniques of selecting and classifying only a few relevant passages from an interview, another frequent mode of analysis is to divide the entire transcript into segments according to some well defined criterion. This criterion may be as arbitrary as the passage of a given amount of time (Flanders, 1970) or, it may be based upon the definition of some meaningful unit of behavior (for example, Smith _et al_. (1962) _A Study of the Logic of Teaching_).

The basis for the method used in the present study is given by Witz (1970) in a paper entitled "Analysis of Frameworks in Young Children." Witz outlined a method to "...describe and document mental structures which a child has, and which are specific to the child, without adopting a preconceived system of behavior categories." (Witz, 1970, p. 1) The Frameworks, which are the end products of his analysis, are constructed by first identifying a set of ideas expressed by the child that seem connected and are somewhat stable -- that is, extend over a period of time. Once initially identified, the analyst can modify the framework, as necessary, while examining the remainder of the transcript. An attempt is made at all times to use the child's own language where possible in describing the framework.

Instead of constructing frameworks, which are conceived to be representative of the underlying mental structures possessed by the child, the present analysis is confined simply to isolating those beliefs or convictions which appeared to be used by the child in a situation involving heat and temperature phenomena. The unit of analysis used for examining the interview data, which is called an "Idea", thus represents a level of analysis which is more task specific and consequently lacks the direct theoretical import of a framework.

3.21 Definition of an Idea

An Idea is defined as: an attempt by the child to explain or in some way account for a problem situation that was identified in the course of the interview. While the investigator most often initiated the problem situation with one or more questions related to some aspect of the task being considered, it was also possible for the subject to initiate the problem situation while interacting with the experimental materials.

3.22 Identification of Ideas

The procedure used to identify Ideas in the transcript began with an attempt by the analyst to recognize a potential problem situation. Considerable care was exercised to determine whether this was indeed a genuine problem situation for the child or whether it was artificially imposed upon the child by the interviewer. That is, the analyst tried distinguish between those responses where the child did not understand the nature of the question(s) being asked and so answered at random simply to satisfy the investigator, and those responses which were an accurate reflection of the child's thoughts about the situation. Using the child's own language where possible, the analyst then attempted to formulate the Idea used by the child to account for the problem situation. In many instances these initial formulations were altered later in the transcript when the child either embellished the basic Idea in some way or perhaps even changed it completely. The following brief excerpt from a transcript should serve to illustrate the type of analysis described above.

A Sample Analysis for Identifying Ideas

Analyst's Remarks

Analyst's summary of an Idea is in BOLD PRINT

Formulation of the liquid expansion problem by Interviewer.

Subject seems familiar with the expansion of objects when heated, however, he obviously hasn't thought too much about the mechanism of expansion and so tries a familiar process -- condensation. While this might qualify as an Idea, he doesn't pursue the notion of condensation further and so it is not included.

While I pushed S to go a little further with his explanation, it is obvious that I did not in any way suggest the notion of cells or particles to S. Hence the cell notion seems to be genuine. It is uncertain at this point whether the cells are related in any way to his initial condensation hypothesis or not.

Excerpts from the Interview Transcript

(Explanatory comments in brackets)
I = interviewer S = subject)

I: Why do you suppose that liquid goes up when we put it in hot water and down when we put it in (S interrupts)

S: It expands. (3 second pause) It might condense or something and the condensation might lift it up some, the water that's in the tube. And probably the water when it's in the tube might start bubbling or something.

I: Now let's try it step by step. (I picks up apparatus and motions as if to put it in the hot water beaker) As soon as we put it in the hot water what do you think might happen inside, say? If you could see what's happening inside what do you think might have taken place?

S: The cells might be expanding.

I: Now by expanding what do you think is happening?

S: It's getting larger.

I: What is getting larger?

S: The water. (S points to the colored liquid in the expansion container)

I: Okay, the water. And then what?

It is noteworthy that S quickly returned to his cell idea even though he had an opportunity to divert the discussion away. From his uncertainty "Well I guess..." one might infer that he had not thought of this idea before. On the molar level he knew substances expanded, and on the molecular level he was familiar with the notion of cells. But it may well be the first time that he had connected the two together.

Hence the Idea might be expressed:
THE WATER GOES UP IN THE TUBE BECAUSE THE WATER GETS LARGER WHEN IT IS HEATED DUE TO THE EXPANDING OF THE CELLS IN THE WATER. WHEN THE WATER COOLS THE CELLS CONTRACT AND THE WATER GOES BACK DOWN AGAIN.

S: It goes up when it is heated, just by the heat of my hand. (S is holding the apparatus in his hand) Look at that! It doesn't take very long.

I: That's very interesting. Are you sure you're not forcing it out with your hand?

S: No. (5 second pause) Well I guess the cells would expand.

I: Okay, right, we were going to...the cells would expand and then what?

S: The water has to be forced out somewhere and this (S points to the tube) is the only exit for it.

I: And when it cools down?

S: It contracts and goes back to the bottom like a thermometer.

I: You think that's how a thermometer works huh?

S: Yes. Well like some thermometers are made of colored water aren't they?

I: Could be. I'm not sure. I don't break thermometers that often so,...Now what do you think makes it expand?

S: Well the heat.

I: And where is the heat coming from?

S: The hot water.

I: The heat comes from the hot water. And how does it get from the hot water?

Another Idea is being suggested here which is developed more fully later in the transcript. WHEN A COOLER OBJECT (the expansion flask) IS PLACED IN CONTACT WITH A HOTTER OBJECT, (the hot water) THE TWO OBJECTS EVENTUALLY REACH THE SAME HOTNESS (temperature).

S: Through the glass. (S laughs)

I: And then where does it go?

S: The heat penetrates the water in here. (S points to the expansion container) If you left it in there (the hot water beaker) long enough, in the boiling hot water, it would get just as hot inside here. (the expansion container)

3.23 Construction of Conceptual Inventories

By looking at the entire set of Ideas held by a child one can get a much better global perspective of the child's understanding of heat and temperature phenomena. In an endeavor to simplify this overall summarization procedure it was decided to organize the Ideas into a number of content-oriented categories to form a Conceptual Inventory. These categories were based upon those topics most often found in science textbooks and elementary science programs dealing with heat and temperature.

The following set of categories was adopted for constructing a Conceptual Inventory for each child interviewed:

A. NATURE OF HEAT

- 1.0 Composition of Heat
- 2.0 Movement of Heat
- 3.0 Effects of Heat
- 4.0 Source of Heat
- 5.0 Matter and Heat

B. NATURE OF TEMPERATURE

- 6.0 Description of Temperature
- 7.0 Change of Temperature
- 8.0 Temperature and Heat

3.24 An Example of a Conceptual Inventory

The following example of a Conceptual Inventory should serve to better illustrate the nature of the Conceptual Inventory and illustrate the wide range of Ideas identified in a single interview. This Conceptual

Inventory of Ron's Ideas corresponds with a full transcript of his interview in Appendix A. Ron was 12 years 9 months and was in grade six. Like most of the other children he could not remember if he had ever studied 'heat' in school.

A Conceptual Inventory for Ron

(Numbers in Brackets refer to transcript page in Appendix A)

A. NATURE OF HEAT

1.0 Composition of Heat

1.1 Heat is like a wave that rises up from the road. It looks like fumes. (p. 147)

1.2 Hot substances contain fumes, and when they cool down these fumes escape gradually into the air (p. 152)

1.3 There are two types of heat -- hot heat and cold heat. (p. 155)

1.31 The cold heat is more powerful and moves faster than the hot heat. (p. 156)

1.32 Cold heat might look different from hot heat, but I don't know what it would look like. (p. 156)

2.0 Movement of Heat

2.1 The movement of heat occurs by passing through objects in a stepwise manner. (p. 146)

2.2 Heat passes from a hot object to a colder one when they are touching. (p. 146)

2.3 The whole metal rod heats up because the heat keeps moving from one part of the rod to the next until the whole rod is hot. (p. 167)

2.4 Heat travels faster in a smaller rod because it doesn't have as much rod to get the heat to. (p. 167)

2.41 Heat travels through all substances. (p. 167)

3.0 Effects of Heat

3.1 The liquid in the tube goes up because water rises when it gets hot. (p. 149)

3.11 When you heat something it gets bubbles in it, and the bubbles take up space. So that's why the water in the tube rises. (p.171)

3.2 Some things like ice and suger cubes melt because they contain air bubbles. (p. 161)

3.3 The dial (on the linear expansion apparatus) moves because the rod is melting and stretching. When it cools off it shrinks. (p. 170)

4.0 Sources of Heat

4.1 Heat comes from any object that is hot. (p. 146)

5.0 Heat and Matter

5.1 Everything contains air bubbles. Some of the bubbles might contain hot air and some cold air. (p. 156)

B. NATURE OF TEMPERATURE

6.0 Description of Temperature

6.1 The temperature of an object is based on the amount of heat (fumes) it contains. (p. 151)

6.2 A small ice cube has the same temperature as a large ice cube. (p. 163)

7.0 Change of Temperature

7.1 When a cold object meets a hot object the cold object get warmer and the hot object gets colder. After awhile they reach the same same temperature. (p. 147)

7.2 An object cools when it gives off some of its heat as fumes. (p. 152)

8.0 Temperature and Heat

(Ron doesn't really make a distinction between heat and temperature and appears to equate the two on several occasions as is suggested in 6.1)

3.25 A Children's Perspective of Heat

The final step of the analysis of the interview data involved an attempt to extract the commonalities from all ten Conceptual Inventories and construct a composite picture of the children's Ideas. This composite structure was called a Children's Perspective of heat.

The guidelines employed to develop the Perspective consisted of examining all ten Inventories for Ideas which occurred more than once; preference was given to those which appeared in three or more different Inventories. The Children's Perspective, then, consists of a series of Ideas judged to be representative of those children who were interviewed in the study.

An attempt of this nature -- to distill the essence of ten interviews into a limited set of statements -- is subject to severe limitations and open to criticism with regard to the rather large inferential leap that must be made. However, as it was intended to subject this Perspective to an empirical check in Phase Two of the study, this procedure does not differ significantly from the theorizing process in other fields of inquiry.

Ron's interview was selected to illustrate the Conceptual Inventory because his Ideas were reasonably typical of all of the children. Thus his Inventory will also be used to illustrate briefly the type of statements used to construct the Children's Perspective of heat.

In examining the Ideas expressed in Ron's Inventory one can readily detect a tendency to perceive heat as a type of material substance that has properties that we generally attribute to matter. For example, he frequently discusses heat in terms of "fumes" that are capable of "transferring into or out of an object". In fact at one point, to account for the heating and cooling of an object, he talked about 'hot heat' and 'cold heat' -- clearly a substantial, two-component view of heat embodying a type of positive and negative quality. In addition to this notion, most of the other children attributed to heat an additive-subtractive property where the temperature of the object could be changed either by adding or subtracting heat from the object. In one particular task, which consisted of heating different types of cubes over a hot plate, more than half of the children accounted for the observation that the metals heated up before the wood or sugar by stating that "the metals could attract the heat better than the other object." While this latter explanation is virtually identical with a view of heat prevalent in the late 18th and early 19th Centuries (the caloric theory of heat), it was felt that there were many other Ideas expressed by the children which could not be accommodated to the caloric theory proper. The decisionwas made to construct a unique Children's Perspective; albeit one which was similar in some respects to this earlier material conception of heat.[4]

Several of the statements used to develop the Children's Perspective are discussed below as they relate to Ron's Ccnceptual Inventory. The remaining statements are outlined in Chapter Four. Since the statements are directly related to some of the experiments performed during the interview they consist of two parts: the observational part describing what happened in the experiment and an explanatory part, in

BOLD PRINT, which is the Idea to account for the observation.

(1) The whole rod gets hot because:
THE HEAT BUILDS UP IN ONE PART UNTIL IT CAN'T HOLD ANYMORE AND THEN IT MOVES ALONG THE ROD.

This Idea, which is found in a rudimentary form in Section 2.3 of Ron's Conceptual Inventory, illustrates the material aspect of heat as it portrays heat accumulating in one spot and then, like a fluid, overflows to another part of the metal rod.

(2) The temperature of the water decreases when an ice cube was added because:
SOME OF THE COLD LEFT THE ICE CUBE AND WENT INTO THE WATER.

It was interesting that many of the children interviewed mentioned the existence of cold as an opposite to heat. Note that it is also endowed with a material property as it is transferred from the ice cube to the water. The basis for this Idea is in Section 1.3 of Ron's Conceptual Inventory.

(3) The red liquid went up the tube because:
THE HEAT MAKES THE RED LIQUID LIGHTER AND SO IT RISES.

This statement does not focus upon the material property of heat but rather the intuitive notion that heat makes things rise. While some of the children were content to leave the explanation at this point, many others like Ron attempted to search for some intermediate, causal agent. In Ron's case he qualifies the statement he makes about hot water rising (Idea 3.1) with Idea 3.11, which suggests that it is the bubbles, added during heating, that take up space and so force the liquid up the tube.

NOTES FOR CHAPTER THREE

1. These children were participating in a program in which one or two classes of elementary school children are brought out to the University of British Columbia campus for a week to work with prospective teachers in the Faculty of Education.

2. Diagrams of any non-obvious pieces of equipment used in the tasks are given in Appendix B.

3. Barton and Lazarsfeld (1955) have written a comprehensive article entitled "Some Functions of Qualitative Analysis in Social Research" which is devoted to an examination of the different types of analysis in studies involving qualitative data.

4. It may be possible to fashion an argument similar to that used by Elkind in his introduction to Piaget's (1968) Six Psychological Studies. He suggests that Piaget often seeks parallels between the thought of children and earlier systems of thought, not to demonstrate recapitulation, rather, to illustrate the "...partial constancy of cognitive structuring across long time periods." (Piaget, 1968, p. vii) The major difference is that the children's intuitive conceptions have not yet been formalized into a comprehensive, abstract system such as Aristotle's Natural Philosophy or the caloric theory. And so one sees glimpses of the somewhat sophisticated caloric theory, but the children obviously have not attempted to formalize their thinking in any way.

CHAPTER FOUR

METHOD OF OBTAINING CONCEPTUAL PROFILES

4.00 Introduction

In Chapter Two it is stated that the type of structural analysis adopted for the present study was based upon a multidimensional analysis model. Using judgmental data produced by a semantic-differential type of instrument, the model was employed to generate structures referred to as "Conceptual Profiles" of heat. The construction of these Conceptual Profiles, which constituted Phase Two of the study, posed three major problems: (1) the choice of an appropriate model to guide the analysis; (2) the development of an instrument that would meet the constraints imposed by the model on one hand, and the realities of the classroom setting on the other; and (3) the adoption of a set of analytical techniques that would yield the desired Conceptual Profiles. This chapter is devoted to a description of the methods used to resolve these three basic problems.

4.10 A Model for Structural Analysis

The problem of structural analysis in the present context is to try and reconstruct in a systematic way a structure or organization of children's beliefs about heat, referred to in this study as a Conceptual Profile. A number of different models seemed appropriate for this reconstruction process. Two models were elaborated in Chapter Two -- the descriptive analyses offered by Piaget and Witz and Easley in contrast to the class of models involving a multidimensional analysis. In view of the declared aims of the study, however, it was argued in Chapter Two that a multidimensional analysis model held more potential in terms of achieving those aims.

While there are a number of analytical methods which could be included under the general class of multidimensional analysis, the specific model used for generating the desired structures in the present study is a factor-analytic model.[1] Viewed in simple terms, it is an analytical procedure for reducing the M-dimensional space defined by the M original variables to a space defined by a minimum number of independent dimensions necessary for representing the essential relationship between the original variables. This reduced space can be thought of as a structure in which the relationship between the original variables and the dimensions which define the structure is expressed mathematically. If the original variables are psychological in nature, such as concepts or persons, then the dimensions of the reduced space can be interpreted as important psychological dimensions of the variables.

Basically a factor-analytic model functions "...either to test hypotheses about the existence of constructs, or if no credible hypotheses are at issue, to search for constructs in a group of interesting variables." (Nunnally, 1967, p. 289) In using the factor-analytic model for the analysis of the data in Phase Two, both of these functions were realized to some extent. One aspect of the analysis entailed a test for the existence of the hypothetical construct, 'the Children's Perspective of heat', described in Chapter Three. While at the same time a search was made to determine whether other constructs, derived from different Perspectives of heat, could be differentiated by the subjects.

In the study a type of semantic-differential instrument, called a Conceptual Profile Instrument (hereafter called a C.P.I.), was developed to assess the children's conceptions of heat phenomena. The factor-analytic model was first used to reduce the six-dimensional space of the rating scales used in the C.P.I. to a structure defined by two independent dimensions or sets of scales. One set of scales was termed "belief-scales" and the other set, "familiarity-scales".

Responding to one scale at a time, the subjects were required to rate the different statements about heat in terms of the strength of their beliefs about the statements and in terms of the degree to which they were familiar with the ideas contained in the statements. By factor-analyzing the responses to these statements it is possible to reduce the complexity of the dimensions used to define the responses. The dimensions defining this reduced space can properly be called "Viewpoints of Heat" held by the subjects and they constitute one method of structuring the set of statements contained in the C.P.I. The viewpoint analysis thus provides for a test of whether the Children's Perspective could in fact be differentiated from the two other Perspectives, the Kinetic Perspective and the Caloric Perspective, and whether or not the latter two Perspectives could be singled out.

The basic relationship being assessed by the structural analysis of viewpoints is the degree of psychological association between the various statements as perceived by the subjects. This method of structural analysis differs from the descriptive analyses of structure offered by Piaget and Witz and Easley in at least two important ways:

(1) the rules for creating the analytical categories and the assignment of behaviors to those categories are explicit in the factor-analytic model but are mainly intuitive in the latter; (2) the former model does not allow for any serious generation or alteration of existing theoretical constructs because it is restricted to manipulating the input data. While the latter type of model has the potential to develop a richer and more adaptable theoretical framework due to its dependence upon the ingenuity and insight of the theoretician. In contrasting these two analytic approaches it would appear as though they might well be complementary -- the more divergent theorizing approach being responsible for generating tenable hypotheses which could then be checked out against reality by using a large number of subjects in a factor-analytic study. Phases One and Two of the study correspond roughly to these complementary approaches.

With the structural analysis of the data culminating in discrete clusters of concepts, or Viewpoints, some evidence has been accumulated to suggest that the subjects were indeed able to differentiate and discriminate between the conceptual statements representing the different Perspectives of heat. However, it is not possible to say whether or not there are groups of subjects who hold to these Viewpoints differentially. To resolve this problem, which is very important for the educational application of the analysis, the model was applied to a matrix of subjects versus concept ratings. (That is, a matrix of individual profiles.) The profile space was reduced by the factor-analytic model, using a transposed profile matrix, to a three-dimensional structure. These dimensions were defined by sets of profiles of similar shape. To determine whether these dimensions could be further refined on the basis of level and dispersion, those profiles most representative of each dimension were factor-analyzed. The clusters of profiles obtained in this last analysis were used to construct Model Conceptual Profiles -- each Model Profile being an idealization of a 'type of person' who responded to the C.P.I. in a similar fashion. These Model Conceptual Profiles, then, are the sought after reconstruction of children's beliefs about heat.

4.20 Development of the Conceptual Profile Instrument

4.21 Operationalizing the Attribute

Before designing an instrument to measure the attribute of interest in this study -- children's conceptions of heat phenomena -- several preliminary problems had to be resolved. The most important problem was operationally defining the attribute to be measured. Unlike the measurement of many physical attributes (such as length, weight, force, etc.) which usually can be defined in such a way that they can be measured directly, only indicants of psychological attributes can be assessed. Consequently these attributes are much more dependent upon theory. In measuring psychological attributes, theory functions first, to guide the difficult task of operationally defining the attribute (that is, obtaining some measurable indicant of it) and second, to provide an interpretation of the measurements made on the indicants.

Much of the input for guiding the identification of measurable indicants of children's conceptions of heat phenomena and the interpretation of the measurements came from the interview data. The set of Ideas which constituted the Children's Perspective formed much of the theoretical basis for developing the C.P.I. Statements representing this Perspective, along with those from two other alternative Perspectives, made up a pool of items from which the C.P.I. was developed.

4.22 Method of Assessing Psychological Relationship

A second problem, that had to be considered prior to the construction of the C.P.I., was the choice among available techniques for obtaining an estimate of psychological relationship. Most of the common techniques available for measuring psychological attributes require the subjects to make some type of judgment about a selected set of stimuli. For example, the comparison procedures, such as paired comparison or successive intervals, require the subject to rank all of the stimulus-pairs according to their similarity. Unfortunately all of the comparison methods require a large number of judgments to be made even for a modest number of stimuli. In this study the absolute minimum number of items considered for the C.P.I. was fifteen (five items per Perspective). Using the method of paired comparisons, for example, would have required a total of 105 ($n(n-1)/2$) judgments. Obviously this method would be inappropriate for general classroom use.

Another technique for gathering data on the relationship of psychological attributes requires the subjects to do a comparative sorting of all the stimuli. In the most common of these techniques, the Q-sort, the subjects must sort all of the stimuli into a number of ordered categories. The investigator has the freedom to determine the number of categories and the membership of each category. By using a fixed distribution this forces all of the subjects to have the same mean rating and same standard deviation of ratings, whereas in a 'free-sort' the subject is allowed to determine both of these parameters with the subsequent loss in standardization of the subject's ratings which is characteristic of the Q-sort. These sorting techniques, then, have the advantage of being able to accommodate a large number of stimuli without requiring an inordinate number of judgments. But whether a sorting task could be translated into a procedure suitable for the target age (11 to 15 years) and could be easily administered in a classroom setting could not be predetermined.

A number of trial sessions were initiated in order to determine the feasibility of using some type of sorting procedure. Each of these sessions consisted of small groups (from two to four children) who were given up to 35 statements about heat to sort into piles that were alike in some way. (That is, a free-sort method was used.) These statements were drawn from the three Perspectives of heat as discussed in Section 4.24. The children were gradually introduced to the task through two training sessions. First, a deck of playing cards was used to illustrate the number of different ways in which the cards could be sorted into piles. Then a set of statements about sickness and health, designed to approximate the form of the heat statements, were introduced. The children and the investigator discussed different ways in which these cards could be sorted. Finally the statements about heat were introduced.

While the children were able to sort the playing cards into numerous piles, they experienced more difficulty with the statements about 'health and sickness'. Their first sorting of the 'health and sickness' statements was generally into piles of right and wrong, or, agree and disagree. However, when the investigator pointed out other ways of sorting these statements (for example, "piles of kid's ideas and adult ideas") they readily agreed that this was also a good way to separate the cards. When they began to sort the statements about heat it was soon apparent that the preferred method was again to use two piles. In the words of the children "the cards in that pile are ideas that I sort of like or agree with, but the cards in this pile are ideas that I don't like much." Most of the children thus appeared to employ a type of preference criterion in making the sort with the heat statements.

Although a preference criterion would be quite acceptable for an assessment of psychological relationship, more than two categories would be desirable to gain sufficient discrimination among the statements. An attempt was made in a subsequent trial session to create at least four categories by instructing the children to divide each of the two piles one more time. Again they seemed to understand the task but had great difficulty in discriminating between those ideas they "liked a lot" and those they "only liked a little". Given the amount of preliminary instructions necessary and the amount of individual attention required it was decided that a sorting procedure would not be a suitable procedure for use in collecting data in a classroom setting.

Another method that has been used to generate data for multidimensional analysis is that of the semantic differential, as described by Osgood et al. (1957). The subject is required to respond to a stimulus in terms of a number of scales anchored by bi-polar adjectives. In selecting the set of adjectives the investigator is, in effect, providing the subject with a set of criteria to be used in making his judgment about the stimuli. Contrary to the previous techniques of comparative judgment, the semantic differential requires the subject to make a number of independent judgments along predetermined scales, usually consisting of seven steps each.

In order to establish the degree of relationship among the stimuli, or the statements (which contain ideas about heat from the three Perspectives), the factor-analytic model is applied to an inter-statement correlation matrix. The resultant dimensions of the reduced 'viewpoint space' can be interpreted as a measure of psychological relatedness of the heat statements for the given sample of subjects.

4.23 Alterations in the Standard Semantic Differential Format

Most of the previous studies using the semantic differential have adhered to the standard format as set out by Osgood et al. (1957) in The Measurement of Meaning. This is particularly true of those studies directed toward an elucidation of the semantic space of children. (For example, see DiVesta, 1966; Long et al., 1968; and Williams, 1972) But in the development of the present instrument two basic alterations were made in the standard format. The semantic differential is described by Osgood et al. as "...essentially a combination of controlled association and scaling procedures " (Osgood et al., 1957,

p. 20). As they are seeking a type of association response their instructions to the subject suggest that they should "...work at a fairly high speed...[as] it is your first impressions, the immediate 'feelings' about the items, that we want." (p. 84). In contrast to this procedure the investigator was seeking a slower, more thoughtful response, or judgment, of the statements.[2] This difference in response orientation was due to an assumption by the investigator that the instrument would be tapping some form of genuine cognitive structure and not simply sentiments held toward the statements.

The second alteration is a deviation in the form of presentation of the stimuli. Generally the stimuli consist of one or two words which permits the subject to read it quickly and respond immediately. It was decided that the stimuli for the C.P.I. ought to be similar to the Ideas identified in the interviews, and so the length would certainly exceed two or three words. The inherent problems involved in a situation where there are a number of words in the stimuli have been discussed in the literature under the topic of concept-scale interactions. Simply stated, it is difficult to know if the subject is responding to the whole statement or parts of it. (Bashook and Foster, 1973.) Or it is possible that a subject is using some of the scales in judging one part of the statement and other scales in judging another part. For the purposes of interpretation the investigator must be alert to this type of interaction effect when a complex stimulus is being judged.

In an effort to assess the impact of these deviations and also to try to establish a number of appropriate scales, two somewhat informal trial sessions were held with two and three children respectively. Before constructing the final version of the C.P.I. a further trial run was made in a grade five classroom under actual test conditions. On the basis of the first informal session it was apparent that the statements were too abstract and that they would have to be accompanied by some concrete demonstration of the heat phenomena being referred to in the statement. The second session included several of the demonstrations used in the interview tasks and proved to be much more successful. These demonstrations are described in detail in Section 4.33.

Feedback from the children provided the investigator with useful information regarding their perceptions of the type of judgments they were being requested to make and resulted in several changes being made on the adjectival scales. As a result of the classroom trial session the investigator discovered a prime example of a 'concept-scale' interaction. A number of children responded to one of the statements by indicating that they felt it was 'very true' and yet on another scale further down the page they indicated that it was 'very much unlike their ideas'. After questioning several children about this apparent anomaly it became clear that they were responding to the observational part of the statement with the 'true-false' scale (of course it was true because this part of the statement was simply a summary of a demonstration they had just observed) and to the explanatory part of the statement with the 'like my ideas-unlike my ideas' scale. This confusion was resolved by placing the observational part of the statement in small print at the top of the page and putting the more important explanatory part in bold print and enclosing it in a box. The final version of the C.P.I. is presented in Appendix C.

According to the feedback from these sessions it seemed that the children were enjoying both the demonstrations and the challenges provided by the C.P.I. Further, they appeared to experience no appreciable difficulty in making the required judgments in order to complete each of the items on the C.P.I.

4.24 Construction of the Conceptual Profile Instrument

An underlying assumption of Phase Two of the study was that the Ideas identified from the interview data are also characteristic of the thinking of other children. These Ideas, then, outlined earlier as a Children's Perspective, formed the primary basis of item construction for the C.P.I. The remainder of the items were constructed from two other alternate Perspectives of heat -- the current kinetic theory of heat and its predecessor, the caloric theory of heat. Parallel items from these three Perspectives provided the children with an opportunity to discriminate among the statements; they also enabled the investigator to determine the extent to which the older children may have embraced the more sophisticated kinetic theory.

Statements representing the Children's Perspective were taken, where possible, directly from the most prevalent and typical Ideas identified in the interview transcripts. Since the procedure was fully outlined in Chapter Three it will not be repeated here. Once a number of potential statements from the Children's Perspective were adapted to correspond with the demonstrations being used to accompany the C.P.I., parallel statements from each of the other two Perspectives were constructed.

Two criteria were used in the construction of all the statements: (1) the language and phrasing of the statements must be such that a typical grade five student could comprehend it; (2) the statement must maintain the basic integrity of the Perspective from which it was derived. An opportunity to determine the degree to which the statements satisfied the first criterion was provided by the numerous trial sessions during which the investigator was constantly seeking feedback on the children's ability to understand the statements. A check on the second criterion was made by submitting the statements to three people who were knowledgeable about the kinetic and caloric theories of heat.[3] Changes suggested by these judges were incorporated into the final version of the C.P.I.

4.30 Administration of the Conceptual Profile Instrument

4.31 Description of the Subjects

The final version of the C.P.I. was administered in 12 classrooms situated in three different schools in the city of Vancouver. These schools were selected by the research staff of the Vancouver School Board and were described as 'typical' schools in the Vancouver system. A total of 322 students participated: 100 from grade five, 125 from grade seven and 87 from grade nine. However, those students who either did not complete the C.P.I. or else marked it in an obvious pattern (for example, using one column down a page for several pages, or marking each page with an identical pattern) were eliminated from the analysis. The final sample consisted of 276 students: 76 from grade five, 117 from grade seven and 83 from grade nine.

4.32 Description of Administration Procedures

The investigator was present and responsible for introducing the C.P.I. and performing the demonstrations for all twelve sessions. Typically the procedures consisted of a short introduction by the investigator indicating that he was from the University of British Columbia and that he was interested in their ideas about heat and temperature. They were told that the C.P.I. was not a test but was more like a game where they would be asked to indicate how they felt about some ideas -- obtained from talking to other students of their age about heat. The rules for the game were explained by first reading together the first two pages of the booklet and then carefully working through two sample items. During this short training program individual students were asked to indicate how they responded on the various scales and why they did so. Using this approach the investigator felt that most of the students were able to understand: (1) the two-part form of the statement -- the observational part in small print and the explanatory part in bold print -- and (2) the meaning of the scales. Once the investigator was satisfied that all of the students were ready to proceed he introduced the first demonstration.

4.33 Description of the Demonstrations and Statements

The first demonstration and accompanying set of items centered around the heating of two aluminium rods of different thickness. A single candle was placed under each rod and, in effect, a race was initiated to see which rod would get hot enough to melt some attached wax in which was embedded a large drawing pin. While awaiting the outcome of the experiment, the students were asked which one they thought would get hot first so as to get them involved in the experiment. When the pin dropped from the large rod first many children were visibly surprised. The investigator returned their attention to the booklet on their desk and said something like: "Now, here are some different ideas that try to explain what we have just observed. Remember it is the idea in bold print in the box that is important not the smaller print which simply tells us what we observed. I'll read the idea out to you and then you can mark the blanks to indicate how you feel about that idea. I am interested in the ways that you think about the idea in the box, not what your friend or even your teacher thinks."

The first set of three items were then presented individually to the class. All three statements began with the same small-print introduction, each statement being on a separate page. Figure 4-1 is a reproduction of one page from the C.P.I.

The large rod heated up faster than the small rod because:

(1) THE LARGE ROD ATTRACTS MORE HEAT PARTICLES THAN THE SMALL ROD.

(2) THE LARGE ROD HAS MORE METAL PARTICLES TO MOVE AROUND.

(3) THE LARGE ROD HAS MORE AIR SPACES INSIDE FOR THE HEAT TO TRAVEL THROUGH.

The second set of items also refer to the above demonstrations. They were introduced by the investigator in the following way: "We observed that the pin fell off at the opposite end of the rod from

The large rod heated up faster than the small rod because

THE LARGE ROD ATTRACTS MORE HEAT PARTICLES THAN THE SMALL ROD

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

Figure 4-1. A Reproduction of One Page from the C.P.I.

where it was being heated. The next ideas we are going to look at attempt to explain why the whole rod gets hot when we only heated it at one end with the candle." The next three statements were:

The whole rod gets hot because:

(4) THE HEAT BUILDS UP IN ONE PART UNTIL IT CAN'T HOLD ANYMORE AND THEN THE HEAT MOVES ALONG THE ROD.

(5) THE FASTER MOVING METAL PARTICLES BUMP INTO EACH OTHER ALL THE WAY THROUGH THE ROD.

(6) THE HEAT PARTICLES FROM THE FLAME ARE ATTRACTED TO ALL PARTS OF THE ROD.

A second demonstration was begun at this point. Six cubes of different materials -- copper, steel,aluminium, wood, sugar, and wax -- were heated in a tray by two candles while the class observed. Most of students immediately indicated that the wax would melt but opinions were divided over the other objects. As soon as the wax melted the investigator drew the attention of the class to the statements concerned with why the wax melted.

The wax melted because:

(7) IT WAS A SOFT SUBSTANCE.

(8) THE HEAT PARTICLES WENT INSIDE AND FORCED THE WAX PARTICLES APART.

(9) THE WAX PARTICLES WERE MOVING ABOUT SO FAST THAT THEY COULD NOT HOLD ON TO EACH OTHER SO WELL.

Once the class had finished with these items the investigator placed the five remaining cubes, which were still being heated by the candles, on a block of wax and allowed the class to see how far each of the cubes sank into the wax. From this they readily inferred that the wood and suger cubes did not get very hot at all while the metal cubes got very hot. The class went on to do the next set of items.

The metal cubes were hotter than the wood or sugar because:

(10) THE METAL CUBES DREW IN MORE HEAT PARTICLES THAN THE OTHER CUBES.

(11) IT WAS MORE DIFFICULT FOR THE AIR TO GET INSIDE THE HARD METAL CUBES TO COOL THEM.

(12) THE METAL PARTICLES ARE EASIER TO MOVE.

At this point a single item that was related to the demonstration was introduced to the class. This was an extra item from the Children's Perspective that was quite prevalent among the ideas expressed by the less sophisticated children in the interviews.

The metal cubes did not melt because:

(13) THEY WERE NOT HEATED LONG ENOUGH.

The next four items were introduced to the class without the benefit of a demonstration. This was done because the investigator assumed that all of the children had experienced the effect of lowering the temperature of some water, or a soft drink, by adding an ice cube. The student's strong positive reaction to the investigator's query about this assumption indicated that they experienced no difficulty understanding the observational part of the statement.

The temperature of the water decreased when an ice cube was added because:

(14) THE ICE CUBE ATTRACTED SOME OF THE HEAT PARTICLES AWAY FROM THE WATER.

(15) SOME OF THE COLD LEFT THE ICE CUBE AND WENT INTO THE WATER.

16) THE WATER PARTICLES LOSE SOME OF THEIR SPEED BY BUMPING INTO THE ICE PARTICLES.

Once again a popular Children's Idea, which was related to the above statements was included.

A large ice cube takes longer to melt than a small ice cube because:

(17) THE LARGE ICE CUBE HAS A COLDER TEMPERATURE THAN THE SMALL ICE CUBE.

The last demonstration consisted of taking the liquid expansion apparatus used in the interview task (described in Appendix B) and immersing it in hot water. The next three statements were concerned with explaining the observed results.

The red liquid in the tube went up because:

(18) THE HEAT MAKES THE RED LIQUID LIGHTER AND SO IT RISES.

(19) THE LIQUID'S PARTICLES MOVED MORE QUICKLY AND SO TOOK UP MORE SPACE.

(20) THE HEAT PARTICLES TAKE UP SPACE INSIDE THE LIQUID AND FORCE THE LIQUID OUT THE TUBE.

When these items were completed the investigator indicated that there were nine more ideas about heat and temperature and that he would like them to complete these items on their own. He further indicated that while the first two items were of the same type as the previous ones (that is, they had an observational part and an explanatory part) the remaining seven items were just general ideas about heat and temperature and so did not have any small print at the top of the page.

The remaining statements are:

Objects rubbed together get hot because:

(21) THE PARTICLES INSIDE THE OBJECTS MOVE FASTER.

(22) THE HEAT PARTICLES INSIDE THE OBJECT ARE FORCED OUT.

The next seven statements, then, did not have any small print preceding the idea in the box.

(23) HEAT IS THE MOTION OF AN OBJECT'S PARTICLES.

(24) TEMPERATURE IS A MEASURE OF THE MIXTURE OF HEAT AND COLD INSIDE AN OBJECT.

(25) HEAT IS A SUBSTANCE SOMETHING LIKE AIR OR STEAM.

(26) ALL OBJECTS CONTAIN A MIXTURE OF HEAT AND COLD.

(27) TEMPERATURE IS A MEASURE OF THE NUMBER OF HEAT PARTICLES IN AN OBJECT.

(28) HEAT IS MADE UP OF TINY PARTICLES THAT CAN MOVE.

(29) TEMPERATURE IS A MEASURE OF THE SPEED OF PARTICLES IN AN OBJECT.

4.40 Analysis of the Instrument Data

The analytical methods employed to transform and compress the raw data from the C.P.I. proceeded through two separate stages. First, the number of independent dimensions or scale-clusters used by the subjects were determined through a component analysis. Once the scale dimensionality was identified, then the second stage consisted of generating statement-clusters by performing a component analysis on a persons by statements matrix for the averaged scores on a particular scale dimension. These statement-clusters, or Viewpoints, were then used as the primary input data for the profile analysis discussed in Section 4.50. Since these two stages are standard analytic procedures and furthermore have been outlined in some detail by McKie and Foster (1972), only the substantive aspects of these procedures, as they relate to the present study, will be reported.

4.41 Analysis of the Scale Dimensionality

In developing the scales for the C.P.I. the investigator attempted to 'build in' two separate criteria or dimensions for judgment. Since the attribute to be assessed by the C.P.I. was "children's conceptions of heat phenomena" one criterion for judgment clearly ought to be some type of "belief dimension". After trying out a number of potential scales during the trial sessions it appeared that a second set of scales, tentatively labelled a "familiarity dimension", would be useful for interpreting the subject's perceptions of the various heat concepts being presented in the items.

A common practice when using a semantic differential is to include a fairly large number of scales (in most studies the number of scales range from 15 to 30) so as to better sample all possible bases of judgment which an individual might naturally use. The most prominent scale-clusters (dimensions of judgment) used by the subjects are determined by some appropriate analytical method. It is the investigator's opinion that the use of a large number of scales not only induces boredom in the subjects, hence increasing carelessness and unreliability in their responses, but, also is unnecessary when the desired dimensions for judgment are known in advance. Since the investigator was able to determine whether appropriate scales were chosen to represent the desired dimension through component analysis, it was decided to try and minimize the monotony of the task by choosing a minimal number of scales for each desired dimension. Thus six scales were used in the present study with the expectation that two independent scale-dimensions would emerge from the subject's responses.

Although Fishbein and Raven (1967) have used a number of scales to assess a belief dimension, several of their scales (for example, probable-improbable, likely-unlikely, and possible-impossible) did not seem to be meaningful to the subjects in the trial sessions. Only one of their scales, the true-false scale, was retained for use. The other two scales used were the agree-disagree scale and the like my ideas-unlike my ideas scale.

Potential scales which were explored in the trial sessions to establish a second dimension were suggested by Nunnally's (1967) "understandability" dimension and Taylor's (1966) "difficulty" dimension. The scales which were eventually used in the C.P.I. were: clear-confusing, easy-difficult, and familiar-unfamiliar. This last set of scales was termed a "familiarity dimension" while the other three scales (true-false, agree-disagree, and like my ideas-unlike my ideas) were labelled as a "belief dimension."

To ascertain the degree of correspondence between the built-in dimensions and the actual responses of the subjects, the data cube was first collapsed over persons to produce a statements by scales matrix. The columns of this matrix were then intercorrelated and the resultant scales by scales correlation matrix subjected to a component analysis, followed by varimax rotation.[4] The eigenvalues of the component matrix, along with the loadings of the rotated components appear in Table 4-1.

As is evident from Table 4-1 the first two components are by far the most dominant accounting for 96% of the total variance. Thus only

TABLE 4-1

Rotated Principal Component-Loadings for

Inter-Scale Correlation Matrix

Variables (Scales)	Components I	II
Agree- - Disagree	.9758	-.1836
Clear - Confusing	.1578	-.9639
Easy - Difficult	.2184	-.9683
True -False	.9700	-.1807
Familiar - Unfamiliar	.5493	-.7758
Like my ideas - Unlike my ideas	.8332	-.5160
Variance	4.457	1.305
Per cent	74.29	21.76

two components were rotated to yield the scale dimensions used by the subjects in making their responses.[5] An examination of the scales that load highly on the first component reveals the "belief dimension" that was built into the scales. Likewise, the second component gives evidence for the "familiarity dimension". These results were used to obtain a belief-score on a statement for a particular subject by averaging their scores on scales 1, 4 and 6. A familiarity-score was obtained by averaging scores over scales 2, 3 and 5.

4.42 Analysis of Statement Dimensionality

Having obtained a composite belief-score and familiarity-score, the second stage of the analysis was to examine the data for evidence of meaningful clusters of statements. These clusters can be likened to a particular viewpoint of heat. In effect, this procedure consists of a type of empirical check upon the three Perspectives that were built into the items. The question being addressed by this stage is: Did the children perceive any basic differences between the statements? In other words,did some statements cluster together in the 'Viewpoint Space' in such a manner as to suggest a consistent way of looking at and thinking about heat phenomena? A second question naturally follows: What is the potential diagnostic value of these clusters of Viewpoints once they are identified?

The analysis started with a persons by statements matrix of belief or familiarity-scores produced by the previous stage. On the basis of the large number of children who were either not able to complete the entire C.P.I. or began to pattern their responses after the first twenty items, a decision was made to include only those statements which were related to the demonstrations. As there was a total of 276 subjects who completed this part of the C.P.I. the resultant data matrix consisted of a 276 by 20 (persons by statements) matrix of belief-scores. A similar matrix of familiarity-scores was also analyzed. As before, the columns of the matrix were correlated to yield an inter-statement correlation matrix which was the input data for a component analysis.

Results of the varimax rotated component loadings for the belief-scores are reproduced in Table 4-2. Since the component structure for the statement-clusters was somewhat more complex than that of the scale-clusters, the decision regarding the number of components to rotate was not so straightforward. The six components reported in Table 4-2 are a result of rotating only those components with an eigenvalue greater than one. However, an examination of these components reveal only one clearly defined dimension, the first component. This component contains five statements with high loadings (greater than .40). All five statements belong to the Kinetic Perspective. Statements belonging to the other two Perspectives, the Children's and the Caloric, appear to be split among the other five components. For example, the Children's statements were split between the second and the fifth component. To determine whether this type of 'fission' was due to the number of components rotated, it was decided to rotate fewer components in search of a more interpretable solution.

Three additional computer runs were made rotating 5, 4 and 3 components respectively. The solution given in Table 4-3, with four

TABLE 4-2

Rotated Principal Component-Loadings for

Inter-Statement Correlation Matrix of Belief-Scores

(Six Components Rotated)

Variables (Statements)	Components I	II	III	IV	V	VI
1 (Caloric)*	-.1078	.2013	.6352	.1780	-.0490	.1835
2 (Kinetic)	-.3145	.1480	.6282	-.0266	-.1853	-.0057
3 (Childrens)	-.2900	.0692	.2288	-.0857	-.2966	.5516
4 (Childrens)	.0196	.1829	-.0459	.1887	-.6587	-.2486
5 (Kinetic)	-.6534	-.1686	.3465	-.1433	-.0553	.0521
6 (Caloric)	-.0246	.3422	.0686	.3314	.1166	.6151
7 (Childrens)	.0762	.2356	.1027	-.0511	-.6303	.1170
8 (Caloric)	-.3555	.0819	-.0141	.4393	-.0529	-.0623
9 (Kinetic)	-.6874	.0987	.0814	.1958	-.0895	-.1096
10 (Caloric)	.0523	.0989	.1498	.7507	.0344	.0565
11 (Childrens)	-.1932	.0851	.0808	.0761	-.6105	.1565
12 (Kinetic)	-.4592	.3105	.2223	-.0279	.0372	-.5185
13 (Childrens)	-.2694	.4623	-.5368	-.1389	-.1068	.1317
14 (Caloric)	-.2417	.6581	-.0437	.2693	-.0282	-.0585
15 (Childrens)	-.0814	-.2381	-.3255	.5302	-.4082	.0013
16 (Kinetic)	-.7712	.1102	-.0211	.0863	.0166	.1257
17 (Childrens)	.0625	.6370	.2033	-.0345	-.2809	.1393
18 (Childrens)	.0223	.5438	.1276	.0283	-.2826	.0487
19 (Kinetic)	-.6773	.0141	.0073	.0734	-.0124	.0743
20 (Caloric)	-.1747	.0707	.1418	.3923	-.1916	.2101
Variance	3.719	1.988	1.443	1.302	1.137	1.0155
Per cent	18.60	9.94	7.21	6.51	5.69	5.08

*The heat Perspective from which the statement is taken is in brackets. For a full description of the statement see Section 4.33.

TABLE 4-3

Rotated Principal Component-Loadings for

Inter-Statement Correlation Matrix of Belief-Scores

(Four Components Rotated)

Variables (Statements)		Components I	II	III	IV
1	(Caloric)	-.1033	.1079	.6722	.1362
2	(Kinetic)	-.3304	.1601	.5887	-.0748
3	(Childrens)	-.1829	.2188	.4698	.1116
4	(Childrens)	-.0287	.5732	-.1367	.1785
5	(Kinetic)	-.6251	-.1374	.3441	-.0999
6	(Caloric)	.0591	.1575	.3742	.4342
7	(Childrens)	.0936	.5861	.1652	.0381
8	(Caloric)	-.3739	.0747	-.0191	.4055
9	(Kinetic)	-.7048	.0995	.0686	.1738
10	(Caloric)	.0334	.0147	.1543	.6765
11	(Childrens)	-.1570	.4529	.1553	.1970
12	(Kinetic)	-.5715	.1703	.0339	-.2274
13	(Childrens)	-.2467	.4640	-.3398	-.0463
14	(Caloric)	-.2913	.4949	.0304	.1812
15	(Childrens)	-.0614	.1115	-.3284	.6186
16	(Kinetic)	-.7402	.0485	.0907	.1440
17	(Childrens)	.0507	.6391	.3210	-.0449
18	(Childrens)	.0004	.5763	.2024	.0068
19	(Kinetic)	-.6521	-.0031	.0755	.1230
20	(Caloric)	-.1453	.1488	.2280	.4393
Variance		3.719	1.988	1.443	1.302
Per cent		18.60	9.94	7.21	6.51

components rotated, provided the clearest and simplest structure. Three out of the four components are interpretable (in terms of the original Perspectives) and no statements load highly on more than one component. A further encouraging observation is that the first component (which might be called a Kinetic Viewpoint) remains undisturbed by the fewer rotations thus providing some evidence that the manifest structure is not simply an artifact of the rotation procedures.

The statements loading high on the second component in Table 4-3 can be interpreted as a Children's Viewpoint -- formed by the fusion of the second and fifth components of Table 4-2. This dimension or Viewpoint, contains six Children's statements and one Caloric statement. Component four also has a very clear conceptual structure. It contains four Caloric statements with high loadings and one Children's statement. The only component that remains uninterpreted is number three which has only three statements that load highly on it -- the first three on the C.P.I. One possible explanation for this component is that it is simply an artifact of the C.P.I., based upon the uncertainty experienced by many of the subjects regarding the nature of the judgmental task. Hence it is possible that they may have responded to this first set of three statements in a similar way as they attempted to get a better understanding of what was required by the C.P.I. Another tenable hypothesis is that the children were not able to discriminate between the three statements and so made a similar response to each.

Results from a similar treatment of the familiarity-scores are presented in Table 4-4. Initially the five components with eigenvalues

TABLE 4-4

Rotated Principal Component-Loadings for

Inter-Statement Correlation Matrix of Familiarity-Scores

(Four Components Rotated)

Variables (Statements)		Components I	II	III	IV
1	(Caloric)	-.1891	.1255	-.0030	.7650
2	(Kinetic)	-.2001	.1703	-.1279	.7366
3	(Childrens)	-.3638	.1862	-.2057	.4302
4	(Childrens)	-.1630	.7132	-.0167	.1069
5	(Kinetic)	-.7218	.0652	.0061	.2667
6	(Caloric)	-.3305	.3180	-.1873	.3213
7	(Childrens)	-.1042	.6210	-.0022	.1137
8	(Caloric)	-.5240	.3778	-.0212	.0740
9	(Kinetic)	-.7109	.2484	-.1390	.1240
10	(Caloric)	.0470	.6012	-.1599	.3248
11	(Childrens)	-.2383	.4291	-.2179	.1363
12	(Kinetic)	-.5753	.1270	-.2256	.2035
13	(Childrens)	-.2317	.1899	-.4150	-.1855
14	(Caloric)	-.0973	.1111	-.6882	.2177
15	(Childrens)	-.0988	.6174	-.2394	-.0505
16	(Kinetic)	-.7143	-.0205	-.3583	-.0148
17	(Childrens)	-.1810	.0353	-.7360	.0172
18	(Childrens)	-.1305	.1642	-.6106	.1503
19	(Kinetic)	-.5596	.0742	-.3556	.2266
20	(Caloric)	-.1470	.3228	-.3138	.2698
Variance		5.702	1.534	1.307	1.022
Per cent		28.51	7.67	6.53	5.12

greater than one were rotated, but again some component-splitting was suspected. It was decided that the solution obtained by rotating four factors was the most interpretable. However, the inherent structure of the components is not as clear as that obtained for the belief-scores. Once again the first component is a very clear Kinetic Viewpoint with a very similar structure to the belief data -- the only exception is the higher loading on a Caloric statement (item number 8). This result might be explained by the resemblance of the statement to the emphasis on particle motion in the Kinetic Perspective. Unfortunately, the structure of the other components are not quite as clear. Instead of obtaining a clear separation of the Children's and the Caloric Viewpoints, as was the case with the belief-scores, components two and three predominantly contain high loading Children's statements with one Caloric statement in each. Since two of the Caloric statements, items 6 and 20, failed to load highly on any of the rotated components, it would seem that no distinct Caloric Viewpoint was perceived by the subjects. As before, the first three statements are clustered together in a single component. The familiarity-scores, then, produced a clear Kinetic Viewpoint and two somewhat ambiguous Children's Viewpoints.

To return to the questions posed earlier it can now be stated with some confidence that the children were able to discriminate between the various statements representing the three different Perspectives. In terms of the student's beliefs about the statements, three relatively clear Viewpoints were identified which correspond rather closely to the 'built-in' Perspectives. While these Viewpoints are not as clearly defined for the familiarity-scores, there is a definite split between a Kinetic Viewpoint of heat and what appears to be a substance notion of heat.

The second question concerning the potential usefulness of these Viewpoints is somewhat more difficult to address. One potential approach suggested by McKie and Foster (1972) involves the creation of profiles of individuals based upon the person's set of factor scores. Such a profile contains much more information than the type of composite score that is the product of many science achievement tests or attitude scales. Furthermore, a profile can be used in a diagnostic capacity by matching an individual's profile with an appropriate set of teaching strategies. This type of matching procedure rests on the assumption made by the investigator that the C.P.I. is tapping some aspect of cognitive structure (perhaps a type of physical deep structure) and hence the literature on structural change and development could serve to guide the development of teaching strategies.

However, before an individual's Conceptual Profile can be of diagnostic value to the teacher, it must be accompanied by a set of Model Conceptual Profiles that will permit the teacher to identify an individual's Conceptual Profile as a member of a given class or family of Model Conceptual Profiles. Once an individual's Conceptual Profile is so categorized it is then possible to match it with a particular type of teaching strategy designed for that class of Profiles.

4.50 The Analysis of Model Conceptual Profiles

By a Model Conceptual Profile is meant a hypothetical profile of scores that is typical of a group of subjects who have responded in a similar way on the C.P.I. To obtain a cluster of profiles one must factor analyze over subjects (generally referred to as Q-analysis) instead of the usual factoring of responses as found in Section 4.41 and 4.42 (which is called R-analysis).

Guertin and Bailey (1970) have mapped out a set of procedures, accompanied by a computer program, that will analyze a large set of profiles into discrete clusters of similar profiles. Once a tight cluster is obtained then the Model Conceptual Profile, which Guertin calls a "modal pattern", can be obtained simply by calculating the average profile for all of the members of this cluster. As such it is not a group statistic, but a statistic based upon the average score obtained by a group of subjects whose profiles are very similar.

To disgress from Guertin's program briefly,much of the controversy over profile analysis has centered around the issue of profile similarity. For example, see Cronbach and Gleser (1953), Nunnally (1962) and Guertin (1970). It is recognized by most that a simple product-moment correlation between profiles only differentiates between the shape of the profiles and does not account for differences in level and dispersion. To illustrate this point, consider the following example used by Guertin (1970). If the raw scores on four items for persons A and B were:

ITEMS

	1	2	3	4	Mean	Dispersion
A	10	20	10	20	10	15
B	100	200	100	200	100	150

The product-moment, r, for this array of scores is 1.00 which indicates a perfect correlation -- a result due to the standardization procedures involved in calculating the correlation coefficient. It is obvious, then, that the product-moment coefficient considers only the relative shapes of the profiles and ignores differences in the level (mean scores) and the dispersion of scores. Thus, the use of an inter-point distance measure in Euclidean space has become the accepted procedure for analyzing for differences in level and dispersion of profile data.

While there is still some disagreement regarding the best distance measure to use, the author accepts Guertin's position that the best measure of this distance (d) is obtained by first squaring the inter-profile distances to remove any negative terms and then taking the square root of this expression. Thus d can be expressed as:

$$d_{jk} = \sqrt{\sum_{i=1}^{n} (x_{ji} - x_{ki})^2}$$

where j and k are profiles of persons being compared and i is the ith item of an instrument consisting of n items.

To return to Guertin's program, then, the first step consisted of performing a Q-analysis on the profiles (persons) by concepts matrix using either the belief or familiarity-scores. As this procedure involved the formation of an inter-profile correlation matrix prior to the factor analysis, the resultant factors, or clusters of profiles, were based upon shape similarity only.

In order to determine whether profiles of the same shape could be further separated on the basis of level and dispersion the next step consisted of computing a similarity matrix (inter-profile distance matrix, or D-matrix) for those profiles that clustered together on the basis of shape alone. Details of the computational procedures used in forming this D-matrix can be found in Guertin (1970). By factoring this matrix it was possible to determine if further sub-clusters of profiles appeared within the same shape family as a result of differences in level or dispersion. Once all of the profile clusters were identified for a given shape family, then a "modal pattern" was computed for each cluster. This was accomplished by calculating a weighted mean score (using only the profiles characterizing that cluster) for each of the statements. The weighting used was the profile factor loading from the analysis of the similarity matrix. These "modal patterns" are the desired Model Conceptual Profiles and can be used in a diagnostic capacity by some matching procedure between individual Conceptual Profiles and one of these Model Conceptual Profiles for the purposes of instruction.

The results obtained for the profile analysis are presented in Chapter Five. Chapter Six includes a discussion of how these Model Conceptual Profiles might be utilized in an instructional setting.

NOTES FOR CHAPTER FOUR

1. Wish (1972) outlines a variety of techniques for generating data that can be subjected to some type of multidimensional analysis.

2. In the literature on the semantic differential the word,"concept", has been used in a generic sense to stand for the stimulus being rated by the subjects. Since these stimuli were most often one or two word nouns, or noun phrases, the term was quite appropriate. In the present instance the stimuli consist of rather lengthy two-part statements. Although the explanatory part of the statement attempts to represent a particular conception of heat, it was decided to deviate from the standard semantic-differential usage and refer to the stimulus as a "statement" about heat. A particular item on the C.P.I., then, consists of a statement to be rated and the six rating scales.

3. Some background information about the caloric and kinetic theories may assist the reader in assessing the validity and effectiveness of the items.

The basic postulate of the caloric theory was that heat existed as some subtle, indestructible fluid that was capable of penetrating all material bodies. The elemental constituents of this fluid, in keeping with the Newtonian conception of the world, were thought to be particles or corpuscules of caloric which occupied the space around the particles of matter. There was an inherent affinity of attraction between particles of caloric and particles of matter -- the degree of attraction depending upon the type of matter. This attraction was expressed as a number and called the specific heat of the substance. It was further hypothesized that the caloric particles were mutually repulsive and so the caloric would naturally move from an area of high density to one of low density. That is, from an object, or part of an object, that was hot to one that was cooler.

With these three postulates the caloric theory was able to account for most of the experimental observations of the day. Those observations which offered momentary resistance -- such as (1) the weight of an object did not change when caloric was added to it; and (2) during a phase change no change in temperature occurs even though caloric is being added -- were incorporated into the network of the theoretical structure by means of ad hoc additions to the theory. In answer to the first problem it was claimed that the fluid of particles was so subtle that either it possessed no measurable weight or else the balances being used in the experiments were not sufficiently sensitive. The second problem area required a little more imaginative solution. The theorists hypothesized that during a phase change the added caloric particles did not increase the density of caloric around the atoms of matter (as temperature was directly related to the density of the caloric) but, that these caloric particles reacted chemically with the atoms to produce a type of 'latent caloric'. When the phase change was reversed the bound-up 'latent' caloric was again released as 'free' caloric thus accounting for the great amount of heat released during a phase change. While there were some notable dissenters, such as the much publicized Count Rumford, the caloric theory was by far the most favored theory of heat from the mid-18th Century until the mid-19th Century (Fox, 1971).

While most readers will be somewhat familiar with the prevailing kinetic theory of heat,a brief summary of its basic tenets may be helpful. Heat is conceived not to be a separate type of matter, as was the case with the caloric theory, but a property associated with the motion of matter. Heat is thus defined as the total amount of energy possessed by the particles of a body (including all three possible types of motion: translation, rotation and vibration.) Temperature is considered to be a measure of the average kinetic energy of the particles of the object. The temperature of an object is altered by an exchange of energy between a hot and a cold body, as opposed to an exchange of a substance envisaged by the caloric theory.

4. The computer program used to carry out this analysis was obtained from the U.B.C. computing center under the code name of *FAN.

5. Although the usual problem of deciding how many components or factors to rotate was easily resolved in this first stage of the analysis, this was not so in other stages. Because the deliberations surrounding this problem are somewhat similar for all the cases a brief discussion of the issues involved seems warranted.

Factors, or components in the present context, are rotated for one basic reason: "...to obtain a more interpretable pattern of factor loadings and to facilitate estimations of the scores of people on the factors." (Nunnally, 1967, p. 321) With this basic purpose in mind the final decision regarding the number of factors to rotate was primarily based upon the judgment as to whether the components or factors were rendered more interpretable by the rotation procedures. As this judgment is often very difficult, a number of criteria have been developed to provide analysts with some basic guidelines. For example, see Cattell (1966). The most common criterion is that of rotating only those factors with eigenvalues greater than one. In some instances this criterion is inappropriate -- as is the case with the analysis of the profile data in Section 5.10 due to the size of the correlation matrix and the resultant large eigenvalues.

A second popular criterion is the 'slope' criterion. This guideline involved graphing the magnitude of the eigenvalues versus the ordinal value of the eigenvalue. Only those factors which precede the point at which the slope becomes constant should be rotated. One, or sometimes both, of these criteria were used in order to narrow down the range of potential factors. Interpretability of the factor structure was the final criterion for deciding which factors to retain.

CHAPTER FIVE

RESULTS OF THE CONCEPTUAL PROFILE ANALYSIS

The structural analysis of Phase Two of the study culminated with the construction of a number of Model Conceptual Profiles. This chapter contains a discussion and interpretation of the Model Conceptual Profiles resulting from the procedures described in Chapter Four.

5.00 Model Conceptual Profiles for the Belief-Scores

In order to obtain the Model Conceptual Profiles based upon the subjects' beliefs about concepts of heat stated in items on the Conceptual Profile Instrument (C.P.I.), only those statements which were representative of the three Viewpoints (as outlined in Section 4.42) were used for input to the Guertin Profile Analysis Program. Hence statements 1, 2, and 3 in the C.P.I., which comprised a non-interpretable (by the experimentor) principal component, were not included in the analysis.

The basic data matrix for the analysis consisted of a 276 x 17 profiles (persons) by statements matrix of belief-scores. By transposing this matrix and inter-correlating the columns, a 276 x 276 inter-profile correlation matrix was produced. A principal factor analysis of the correlation matrix was produced. A principal factor analysis of the correlation matrix was performed.[1] Table 5-1 lists the sixteen eigenvalues obtained from the analysis.

Since all 16 of the eigenvalues were greater than one, the initial basis for selecting the number of factors to rotate was based upon the "slope criterion." A plot of the magnitude of the eigenvalues versus their ordinal numbers indicated an inflection point at the third

TABLE 5-1

The 16 Eigenvalues from the Principal Factor Analysis of the Inter-Profile Correlation Matrix of Belief-Scores

1.	49.32	9.	12.99
2.	33.61	10.	11.81
3.	27.25	11.	11.58
4.	19.89	12.	10.31
5.	18.48	13.	9.42
6.	16.03	14.	8.32
7.	14.10	15.	8.10
8.	13.74	16.	6.71

eigenvalue and a gradual levelling off of the slope after this eigenvalue. Thus, initially three factors were rotated. Subsequent computer runs, rotating four and six factors were also made on a trial basis. A comparison of the resultant factor structures indicated that the initial solution, with three factors rotated, was the most satisfactory considering the following two criteria: (1) the incidence of undesirable factor splitting whereby a profile loads highly (.50 or greater) on more than one factor; and (2) optimal profile membership in each factor.[2] The three retained factors, referred to by Guertin as Shape Family Factors, define unique families of profiles. Representative members of a Shape Family are profiles having the same shape.

As outlined in Section 4.50 a further factor analysis was performed on a similarity, or D-matrix, obtained from each of the three Shape Family Factors. This step determined if sub-clusters of profiles could be identified in each Shape Family as a result of differences in the level and dispersion. The results of the D-matrix factor analysis indicated that the profiles in each Shape Family did not differ in terms of level and dispersion in any clearly interpretable way. This can be seen in part in Table 5-2 which gives the largest six eigenvalues for each of the three interpretable Shape Families.

TABLE 5-2

The Largest Six Eigenvalues Obtained by Factoring the D-Matrices for Each of the Three Shape Families of Belief-Scores

	Eigenvalues 1	2	3	4	5	6
Shape Family 1	37.60	3.99	2.27	1.93	1.64	1.36
Shape Family 2	27.86	3.30	1.82	1.17	1.15	1.02
Shape Family 3	25.96	4.56	2.17	1.58	1.37	1.22

Application of the "slope criterion" would suggest two possible clusters of profiles in each Shape Family. In each case, however, the second profile associated with the second highest eigenvalue could not be clearly distinguished from the first. For this reason only one set of profiles was retained in each Shape Family. The profiles retained in each Shape Family were subsequently rotated to yield a set of profiles in each Shape Family which were clearly similar in terms of level and dispersion as well as shape. These profiles constituted the Model Conceptual Profiles sought after in the study. The three Model Conceptual Profiles are given in Figures 5-1 through 5-3. These figures are followed by a list of the statements in Table 5-3, classified according to each heat Viewpoint, as they appear in the three Model Conceptual Profiles.

5.10 Model Conceptual Profiles for the Familiarity-Scores

In a similar manner Model Conceptual Profiles were constructed for

Figure 5-1 Model Conceptual Profile 1 (Belief-Scores; N = 58 Subjects)

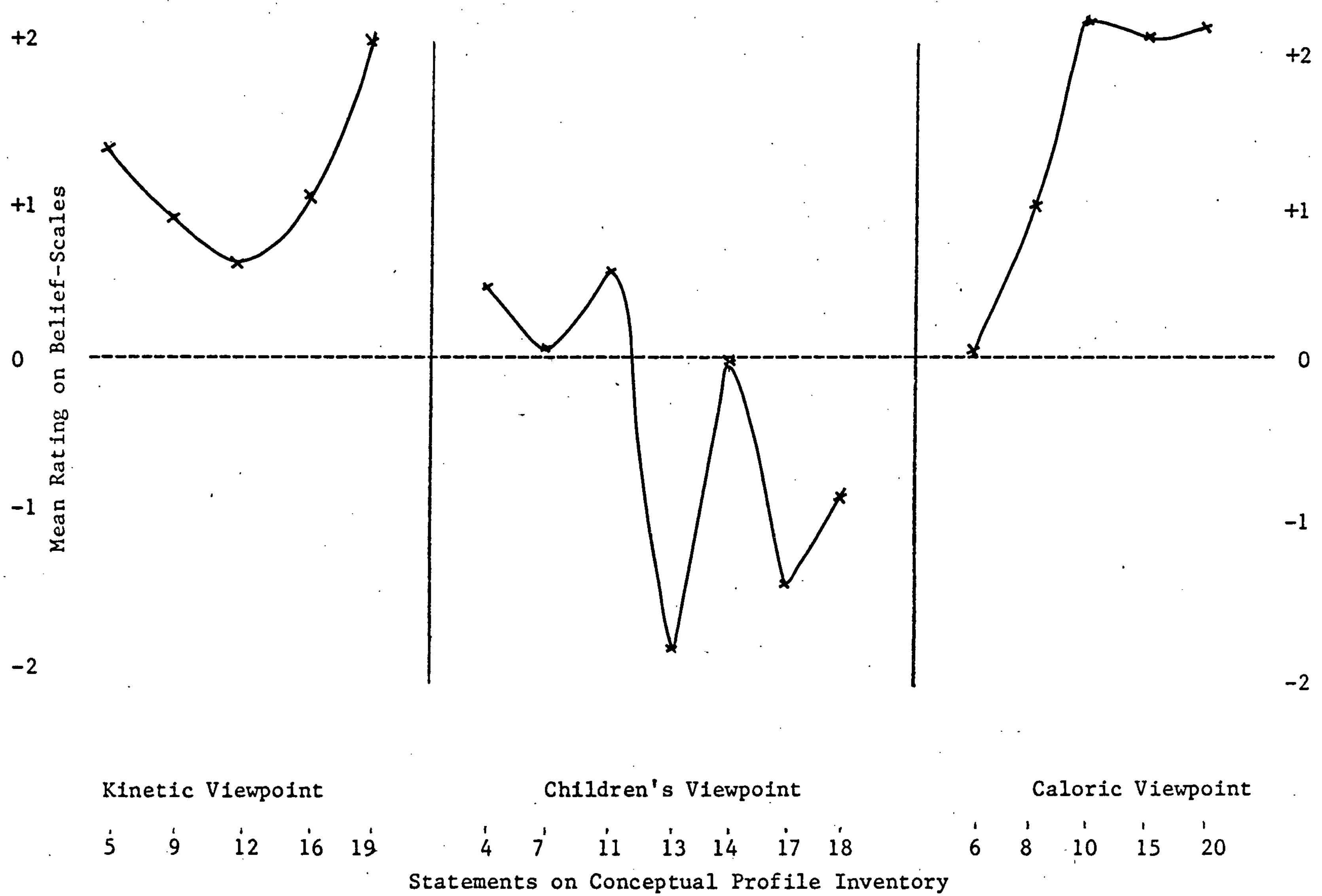


Figure 5-2 Model Conceptual Profile 2 (Belief-Scores; N = 43 Subjects)

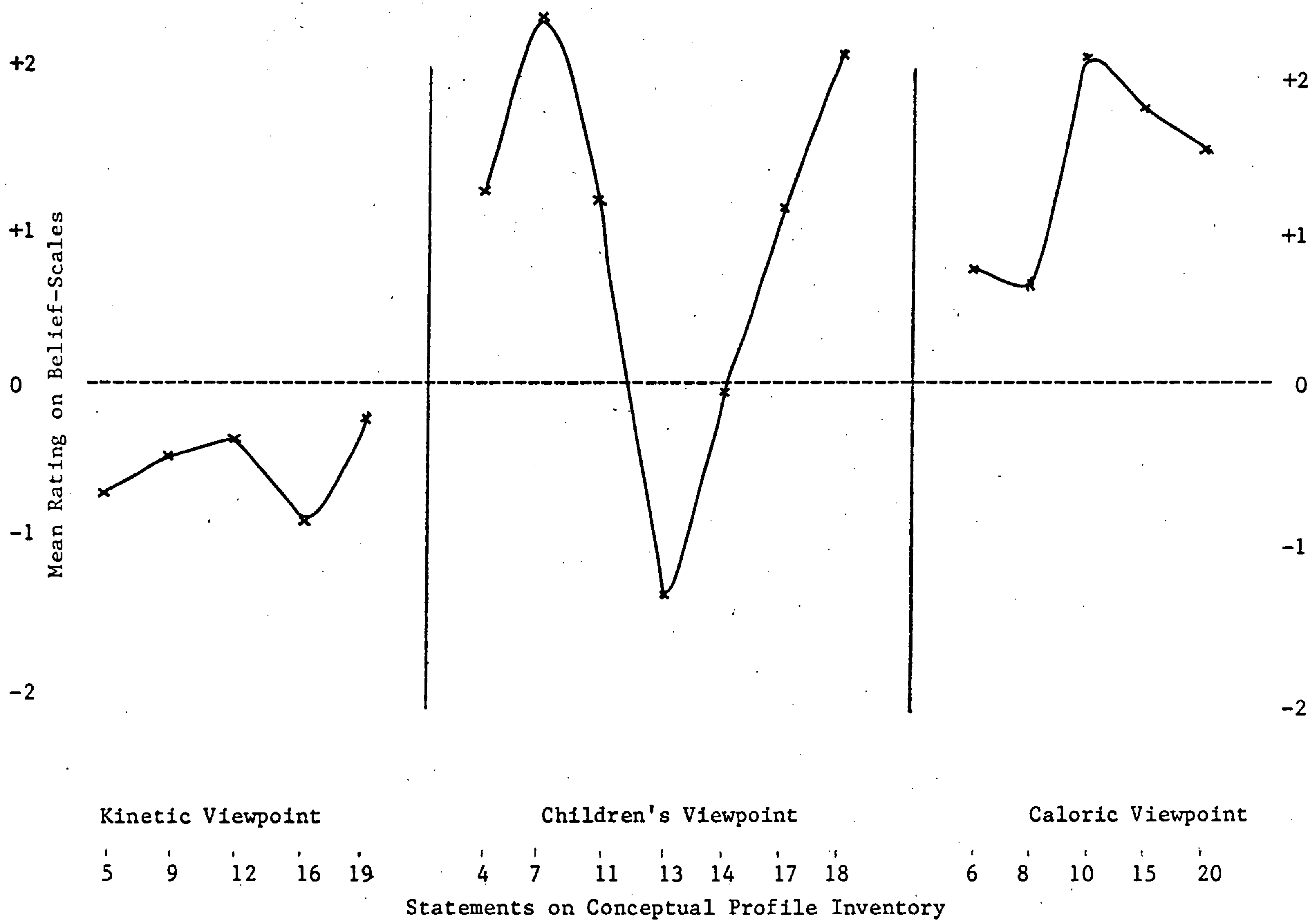
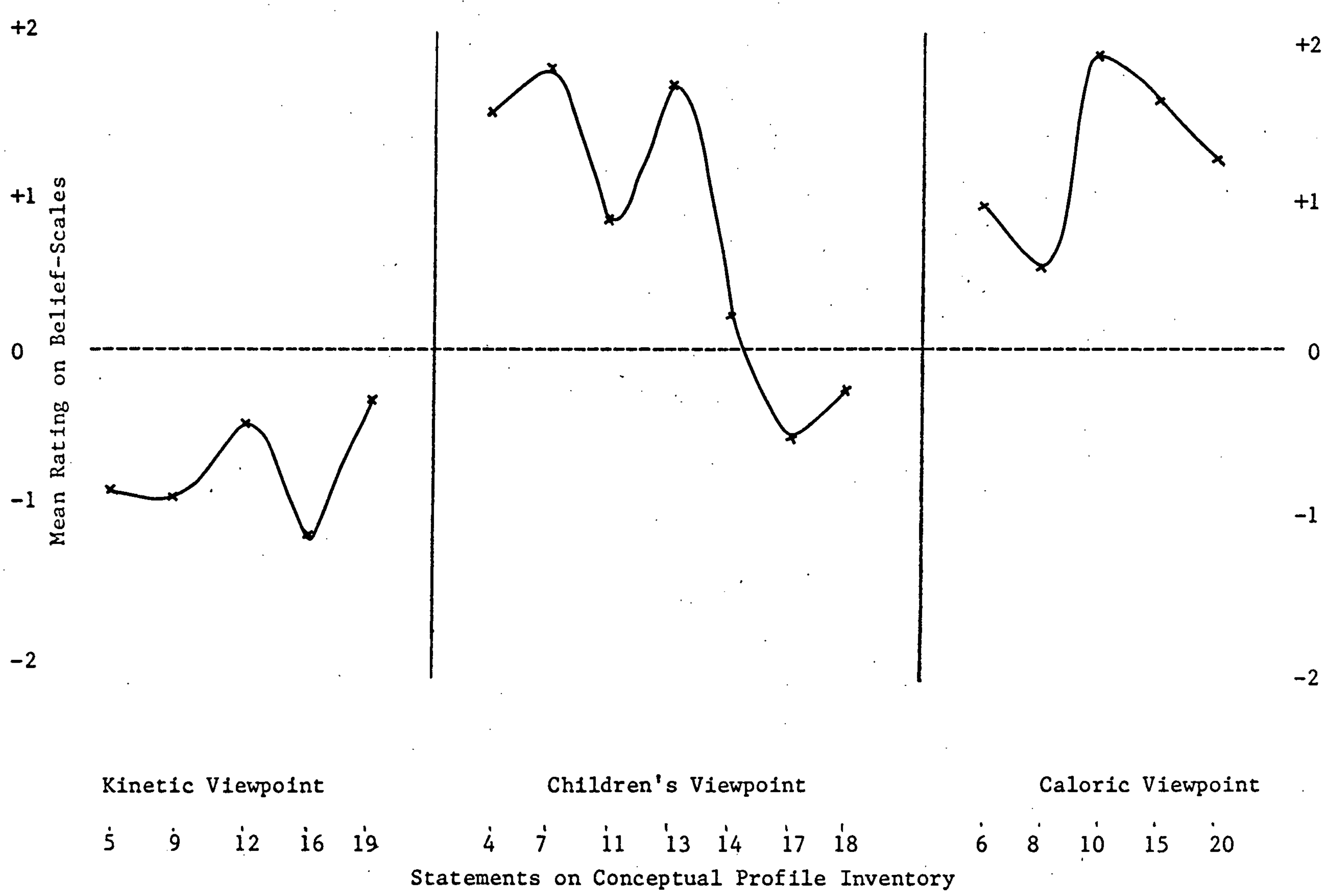


Figure 5-3 Model Conceptual Profile 3 (Belief-Scores; N = 46 Subjects)



the familiarity-scores obtained from the C.P.I. As before, several items on the C.P.I. were excluded from the analysis because they failed to load highly on the three heat Viewpoints for the familiarity-scores described in Section 4.42. These items were 1, 2, 3, 6, and 20.

TABLE 5-3

A List of the Statements in Each Viewpoint Used
in the Profile Analysis of the Belief-Scores

KINETIC VIEWPOINT

5. The whole rod gets hot because: THE FASTER MOVING METAL PARTICLES BUMP INTO EACH OTHER ALL THE WAY THROUGH THE ROD.

9. The wax melted because: THE WAX PARTICLES WERE MOVING ABOUT SO FAST THAT THEY COULD NOT HOLD ON TO EACH OTHER SO WELL.

12. The metal cubes were hotter than the wood or sugar because: THE METAL PARTICLES ARE EASIER TO MOVE.

16. The temperature of the water decreased when an ice cube was added because: THE WATER PARTICLES LOSE SOME OF THEIR SPEED BY BUMPING INTO THE ICE PARTICLES.

19. The red liquid in the tube went up because: THE LIQUID'S PARTICLES MOVED MORE QUICKLY AND SO TOOK UP MORE SPACE.

CHILDREN'S VIEWPOINT

4. The whole rod gets hot because: THE HEAT BUILDS UP IN ONE PART UNTIL IT CAN'T HOLD ANYMORE AND THEN THE HEAT MOVES ALONG THE ROD.

7. The wax melted because: IT WAS A SOFT SUBSTANCE.

11. The metal cubes were hotter than the wood or sugar because: IT WAS MORE DIFFICULT FOR THE AIR TO GET INSIDE THE HARD METAL CUBES TO COOL THEM.

13. The metal cubes did not melt because: THEY WERE NOT HEATED LONG ENOUGH.

14. The temperature of the water decreased when an ice cube was added because: THE ICE CUBE ATTRACTED SOME OF THE HEAT PARTICLES AWAY FROM THE WATER.

17. A large ice cube takes longer to melt than a small ice cube because: THE LARGE ICE CUBE HAS A COLDER TEMPERATURE THAN THE SMALL ICE CUBE.

18. The red liquid in the tube went up because: THE HEAT MAKES THE RED LIQUID LIGHTER AND SO IT RISES.

CALORIC VIEWPOINT

6. The whole rod gets hot because: THE HEAT PARTICLES FROM THE FLAME ARE ATTRACTED TO ALL PARTS OF THE ROD.

8. The wax melted because: THE HEAT PARTICLES WENT INSIDE AND FORCED THE WAX PARTICLES APART.

10. The metal cubes were hotter than the wood or sugar because: THE METAL CUBES DREW IN MORE HEAT PARTICLES THAN THE OTHER CUBES.

15. The temperature of the water decreased when an ice cube was added because: SOME OF THE COLD LEFT THE ICE CUBE AND WENT INTO THE WATER.

20. The red liquid in the tube went up because: THE HEAT PARTICLES TAKE UP SPACE INSIDE THE LIQUID AND FORCES THE LIQUID OUT THE TUBE.

The eigenvalues from a principal factor analysis of the inter-profile matrix of familiarity-scores are given in Table 5-4. Although the first factor is by far the most predominant it was decided

TABLE 5-4

The Eigenvalues from the Principal Factor Analysis of the Inter-Profile Correlation Matrix of Familiarity-Scores

1.	61.92	7.	16.67
2.	27.25	8.	14.76
3.	22.56	9.	13.85
4.	21.46	10.	13.28
5.	19.73	11.	11.81
6.	17.73	12.	11.03

to rotate two factors on the basis of the "slope criterion."

Factor analysis of the D-matrix for both of the Shape Family Factors of the familiarity-scores again indicated that no further

Figure 5-4 Model Conceptual Profile 4 (Familiarity-Scores; N = 94 Subjects)

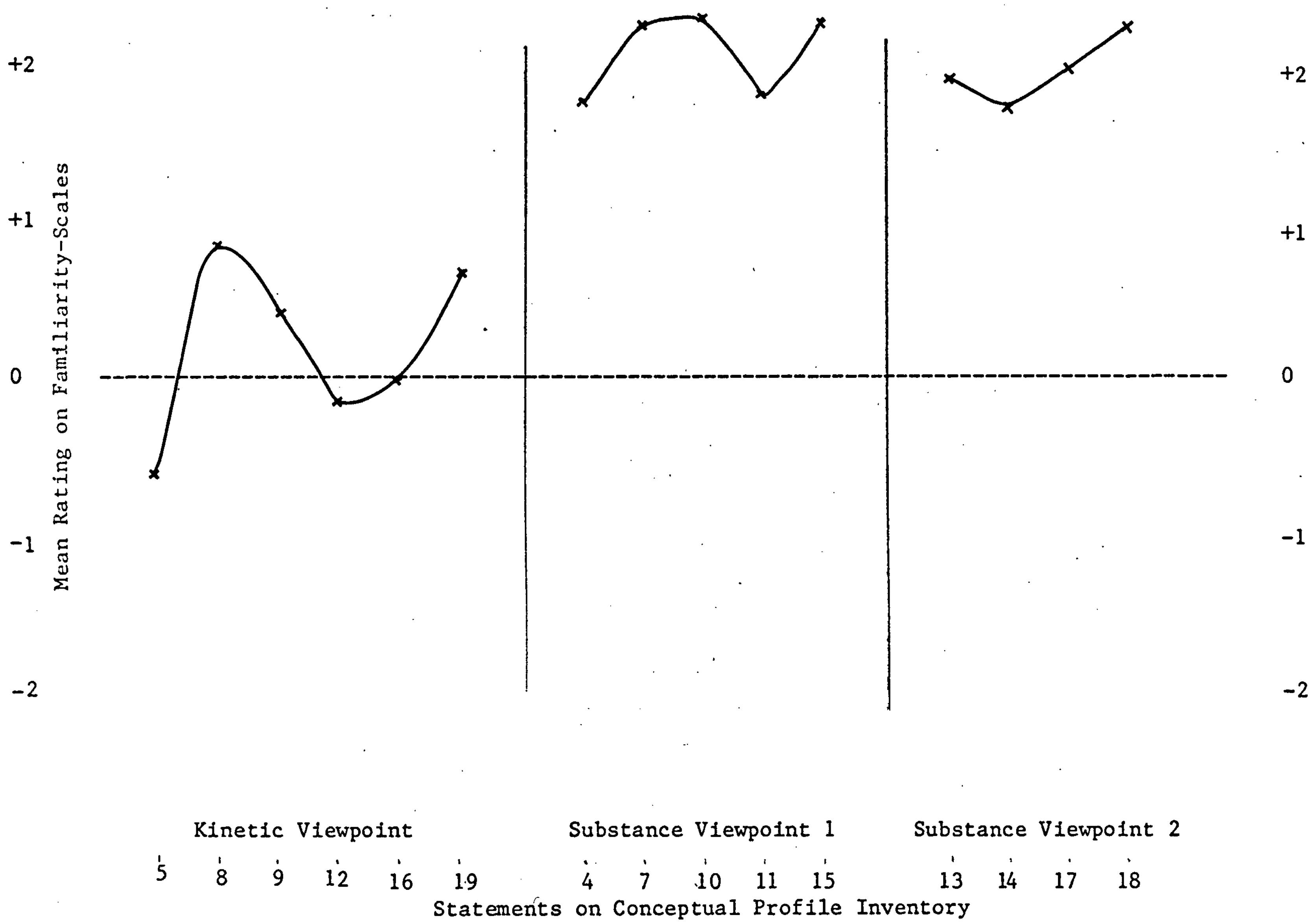
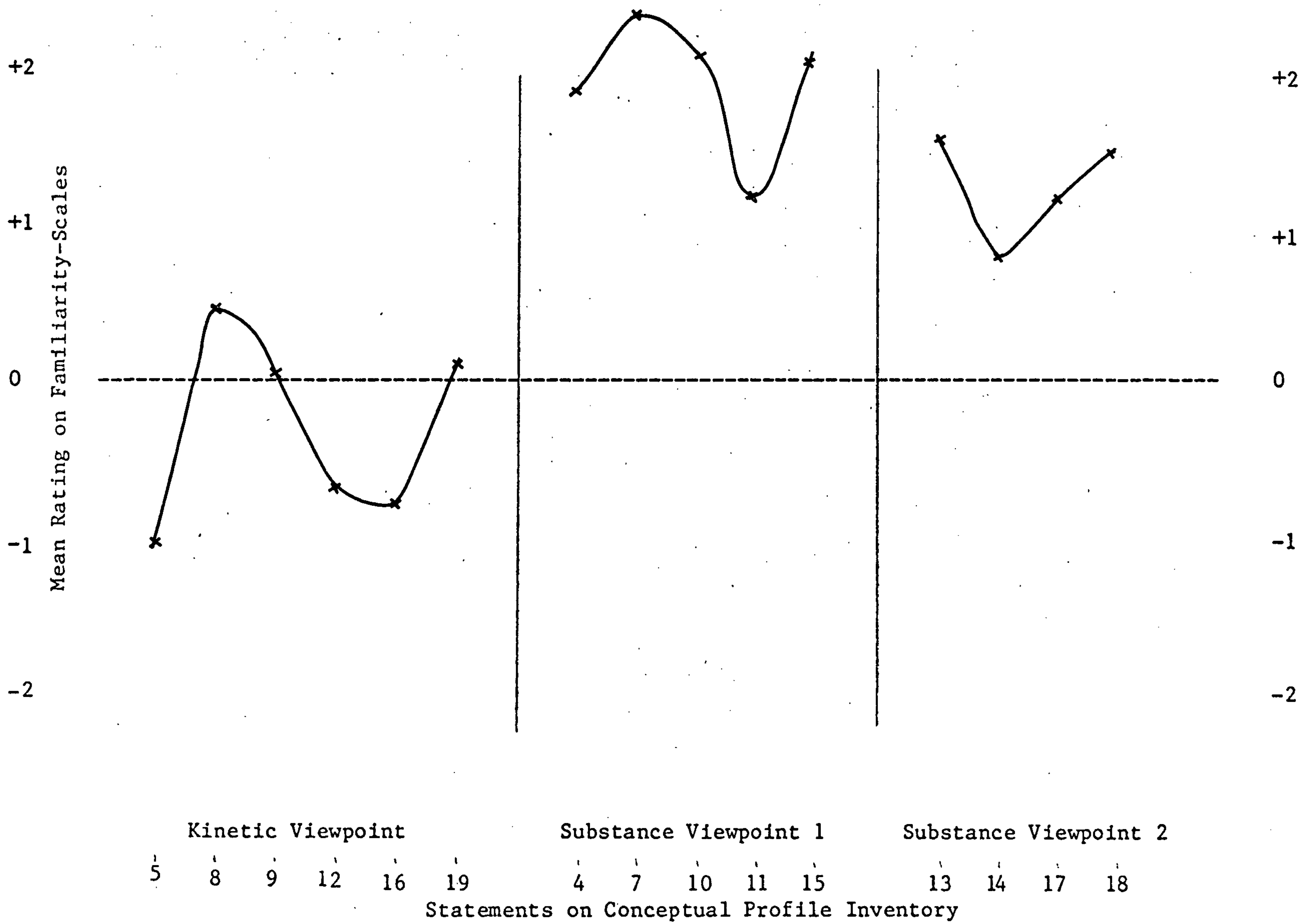


Figure 5-5 Model Conceptual Profile 5 (Familiarity-Scores; N = 44 Subjects)



separation could be obtained in the profile clusters. Thus two Model Conceptual Profiles representing the subject's familiarity with the statements are given in Figures 5-4 and 5-5.

5.20 Interpretation of the Model Conceptual Profiles

In Chapter Four the function of the profile analysis was to determine a set of general patterns, or models, that describe children's conceptions of heat phenomena. On the basis of these profile-clusters it was reasoned that it would be possible to speculate about potential teaching strategies that might be appropriate for the groups of individuals portrayed by each of these Model Conceptual Profiles. A set of general descriptions of Model Conceptual Profiles, which are linked to instructional activities, spares the teacher the impossible task of trying to diagnose and design an instructional program for each individual in the class. This section, then, will provide a general description and an interpretation of each of the Model Conceptual Profiles obtained from the analysis.

5.21 The Belief Profiles Model Profile 1

The first three Model Conceptual Profiles in Figures 5-1 to 5-3 were derived from the subjects' belief-scores on the C.P.I. In examining the general shape of all three it is apparent that the first Profile differs markedly from the other two. The most obvious difference is the positive response towards the Kinetic Viewpoint in contrast to the other two Profiles. A second feature of Profile 1 is the generally negative reaction towards the statements which define the Children's Viewpoint.

More specifically, the 58 subjects who are portrayed in Profile 1 appear to be embracing a notion of matter that is particulate in nature as indicated by all those statements in the Kinetic Viewpoint that were rated higher than +1 on the belief-scales. However, the very high ratings given to statements 10, 15, and 20 (all of which represent a Caloric Viewpoint) would suggest that little differentiation is being made between the nature of these particles. That is, the subjects represented by this Profile appear to subscribe to the notion that heat consists of particles similar in some respects to particles which make up matter.

Another prominent feature of this Conceptual Profile is the strong rejection of those statements (namely 13, 17, and 18) which reflect what might be called common-sense ideas about heat. These ideas, which may be based in part upon a set of physical intuitions evolved from early childhood encounters with heat phenomena, were prevalent in many of the interviews conducted. For example, ideas relating the size and weight of an object to its temperature were frequently expressed.

The more neutral responses to the other statements in the Children's Viewpoint might be interpreted in terms of the tendency of the subjects to adopt a substance view of heat, even though heat is described in these statements in broad qualitative terms rather than as a particle as is the case in the Caloric Viewpoint.

In summary, Model Conceptual Profile 1 suggests that the subjects who fit into this type of pattern tend to believe ideas about heat that are less dependent on common-sense or everyday experience. Thus, a combination of personal experience along with some more abstract notions about the nature of heat might well account for this group of subjects who strongly rejected such beliefs about heat as: (1) a steel or copper cube will melt if it is left under a candle long enough; or (2) the larger the ice cube the colder is its temperature. Furthermore, they consistently responded in a positive way to those statements that portray heat to be the motion of particles of matter. Although, as indicated earlier, they also responded favorably to those statements in which heat was depicted as unique particles capable of interacting with matter. One possible explanation for this dual-particle view is that they did not differentiate between the two types of particles mentioned in the statements (that is, heat particles and particles of matter). Or, alternatively, they may have indeed perceived the difference and chose to think of heat as a type of subtle particle, like air, that could also affect the motion of the particles of matter. With the available data it is not possible to check out either of these hypotheses.

Model Profile 2

The second Model Conceptual Profile differed significantly from the first. Most evident is the shift of the statements from the Kinetic Viewpoint townwards to a point below the neutral position. A second significant shift occurred with four out of the six statements from the Children's Viewpoint moving upwards. Three of these statements (7, 17, and 18) moved over two scale divisions in the direction of a stronger belief rating. Although there was a small trend downwards with most of the Caloric statements, none of the shifts were much larger than one-half of a scale division.

Hence, for the purposes of interpretation the focus is on the downward shift of the Kinetic statements and the upward shift of the three Children's statements. It is interesting to note that in the latter, the three statements are all in the general class described earlier as children's "common-sense" ideas about heat. As they tend to appear at a rather early age it would seem as though they are the products of a rather intuitive perception of heat phenomena based largely upon immediate sense data. For example, a six-year interviewed by the investigator indicated that large ice cubes are at a lower temperature than small ice cubes because they have more cold. These "common-sense" beliefs about heat are likely formulated at a rather early age and then are never brought into doubt at a later age when the child would be capable of systematically checking out their intuitive feelings about the phenomena.

To explore this line of thought further, consider the previous example whereby the criterion for coldness (temperature) was the size of the ice cube. If a child ever had occasion to hold a large piece of ice in one hand and a small piece of ice in the other, then the sensation would likely be one leading the child to assume that the larger one was colder. This same sensation would have likely had a greater opportunity to occur when estimating the temperature of different amounts of water (for example, a cupful versus a sink-full versus a bathtub-full). In fact, it was in a situation where children were judging the temperature of different amounts of water that the investigator was first alerted to this 'amount criterion' for judging temperature.[3]

The other two Children's statements are also amenable to an interpretation suggesting a somewhat primitive notion of heat emanating from early encounters with a variety of physical phenomena. Thus, statement number seven, which suggests that soft substances are easier to melt, can be frequently verified around the home -- butter, shortening and wax being prime examples. Because the child rarely has an opportunity to observe the melting behavior of substances, it is unlikely that this belief would ever be questioned by the child. It might be questioned, for example, if the child set up a melting race between a hard substance such as ice and a somewhat soft substance such as synthetic rubber, or even a soft metal such as lead.

The other Children's statement of note, number 18, was based upon the notion that heat makes things rise. While it is not immediately obvious as to what direct contact a young child would have with this type of phenomenon, the phrase, 'heat always rises', was heard on a number of occasions while interviewing the younger children in the pilot sessions. The only obvious examples that were mentioned by the twelve-year olds were the heat rays rising above a toaster,or over a hot road. Nevertheless, in the C.P.I. this notion represents a genuine explanation acceptable to some of the children to account for the rise of the liquid in the tube.

The significant downward displacement of the five statements from the Kinetic Viewpoint suggests that the subjects tend to reject these more complex ideas portraying heat as the motion of particles of matter in favor of the more "common-sense" view described above. Accordingly, it might be argued that the ideas in the Children's Viewpoint and the

Caloric Viewpoint represent a position somewhat closer to the concrete world that the child actually experiences, whereas those ideas contained in the Kinetic Viewpoint represents a level of abstraction somewhat removed from this experiential world.

In summary, it has been suggested that the subjects who contributed to this second Model Profile held a somewhat more intuitive or primitive view of heat than those subscribing to the first Model Profile. The evidence for this interpretation was based largely upon the decline of all the Kinetic concepts and the large increase towards a positive ratings on three of the Children's concepts. It must be emphasized that these interpretations are speculative in nature, the only supporting evidence being the experience obtained from the in-depth interviews carried out earlier by the investigator.

Model Profile 3

The third family of profiles bears a striking resemblance to Model Conceptual Profile 2 (both having similar response patterns for the Kinetic and Caloric Viewpoints) and also bears some similarity to Model Conceptual Profile 1. As most of the significant differences between the two profiles occur in the Children's Viewpoint, these will be used to focus the description of Model Conceptual Profile 3.

In comparing Model Conceptual Profile 3 with Model Conceptual Profile 2 the most obvious difference is the upward shift of statement 13 and the downward shifts of statements 17 and 18. Statement 13 suggests that if you heat things (in this instance the metal cubes) long enough they will melt. The underlying view of heat that seems to be implied (similar to that in statement 4) is that the heat will accumulate in the object until there is a sufficient quantity of heat to melt the object. While this attempt to reconstruct the subject's interpretation of statement 13 has some intuitive appeal, it does not account for one very prominent observation. Why does statement 13 have a reasonably positive rating in Model Profile 3 and yet very negative ratings in the other two Model Profiles? One possible explanation of this anomaly is based upon a conversation held with two grade nine students after they had finished responding to the C.P.I.[4] They indicated that they responded favorably to statement 13 because they thought that the cubes had indeed been heated long enough, but they would not melt since the candle flame simply could not supply enough heat. In other words, they were responding more to the observational part of the statement than the explanatory part -- an instance of the problem discussed earlier in Chapter Four under the general topic of concept-scale interactions. Thus the discrepant response patterns to statement 13 may simply be an artifact of the ambiguity of the wording in the statement.[5]

Two other statements in the Children's Viewpoint, statements 17 and 18, have shifted markedly downward from their position in Profile 2. Both of these statements have been earlier discussed under the label of "common-sense" ideas about heat. Thus, on the basis of the trend emerging in the Children's Viewpoint (with the exception of the anomalous concept 13) it would seem that there is a tendency away from "common-sense" ideas towards the somewhat more abstract view of heat exemplified in Model Profile 1. Although this has not yet been manifest in the

Kinetic Viewpoint, the general decrease in the dispersion of scores in the Children's Viewpoint also suggests that Model Profile 3 might be a kind of transition state to a more abstract level of understanding of heat phenomena.

To pursue the matter of shifts in understanding a bit further, one would expect, on the basis of both in school and out of school experience, that the grade five students should have a higher membership in the Model Profile which has the most positive set of belief-scores on the "common-sense" statements (that is, Profile 2). And conversely, more grade nine students ought to be attracted to the more abstract particle notion of heat (Profile 1). If Profile 3 represents those students in a type of transition stage, then it ought to contain a mixture of students from all the grades.

Table 5-5 provides information of grade membership in each Profile. Since there were an unequal number of subjects from each grade level completing the C.P.I., the percentages in brackets are the most appropriate index. These percentages are calculated by taking the number of subjects in a particular grade who subscribed to a given Profile, multiplying by 100 and dividing by the total number of subjects in that grade who completed the C.P.I. For example, there were eight subjects in grade 5 in Model Conceptual Profile 1. As there were a total of 76 subjects in grade 5 who completed the C.P.I. only 10% of these subjects subscribe to a view of heat characterized by Model Profile 1. Thus neither of the totals in the row nor the columns sum to equal 100% as only 53% of all the subjects are accounted for by the three profiles.

TABLE 5-5

Model Conceptual Profile Membership by Grade Level

(Percentage of Students in that Grade Representative of each Model Conceptual Profile is Given in Brackets)

Model Conceptual Profile	Grade 5	Grade 7	Grade 9	Totals
No. 1 (Belief-Scores)	8 (10%)	26 (22%)	24 (29%)	58
No. 2 (Belief-Scores)	21 (28%)	16 (14%)	6 (7%)	43
No. 3 (Belief-Scores)	7 (9%)	22 (19%)	17 (21%)	46
No. 4 (Familiarity Scores)	33 (43%)	31 (27%)	30 (36%)	94
No. 5 (Familiarity Scores)	7 (9%)	26 (22%)	11 (13%)	44

As predicted above, the grade nine subjects have the highest percentage for Profile 1 and the grade five subjects have the highest percentage for Profile 2. While Profile 3 does indeed have a mixture, it is somewhat surprising to note the rather high number (21%) of grade nine subjects in this Profile.[6] Thus these figures do provide some *prima facie* evidence for the levels posited above.

Although it is tempting to speculate about the existence of developmental stages or levels of understanding, it must be realized that the evidence presented has been circumstantial at best. Much more in-depth exploration into the nature and generality of these Model Conceptual Profiles would be required to support any serious claim of a genuine developmental trend.

5.22 <u>The Familiarity Profiles</u>

When the C.P.I. was being constructed it was felt that a judgmental dimension ascertaining the subjects' familiarity with the concepts would be useful when interpreting the final results. And like the belief-scores it was thought that a number of different shape families could be identified through the profile analysis procedures. However, a cursory examination of Figures 5-4 and 5-5, which illustrate Model Conceptual Profiles 4 and 5 respectively, indicates that there is only a very slight difference between these two shape familes. This would seem to indicate that only one factor should have been rotated.

This apparent uniformity in the responses to the familiarity-scales across all three grade levels is an interesting observation in itself. It indicates the lack of evidence for a developmental trend as had been hypothesized for the subjects' belief-scores. Furthermore, a glance at Table 5-5 indicates a fairly even distribution across all the grades for both of the profiles based upon the familiarity-scores. Thus the information that will be of interpretive value is the relative ratings for each of the Viewpoints.

Although the ratings of the statements in the Model Conceptual Profiles which are based upon the familiarity-scores differ from those obtained by an analysis of the belief-scores, some comparisons can be drawn between the two judgmental dimensions. The first obvious difference is the small dispersion of ratings on the statements for a particular Viewpoint. In other words, there was little differentiation between the statements in a given Viewpoint on the basis of familiarity.

But the feature of real interest in Model Profiles 4 and 5 is the relative familiarity rating on each of the Viewpoints. In both of these profiles the Kinetic statements are very close to the neutral mark while those statements constituting the two substance Viewpoints are significantly higher. In Model Profile 4 they are around the +2 mark. It is therefore clear from these data that the statements in the Kinetic Viewpoint were perceived by many of the subjects to be less familiar than those concepts which depicted heat as a type of substance or particle. This finding lends some support to the argument advanced earlier regarding the developmental trend in Viewpoints of heat. As the "common-sense" ideas likely derive from early, concrete experiences with heat phenomena, one would expect the statements representing the Children's Viewpoint to be more familiar than the abstract notions of the Kinetic Viewpoint.[7]

NOTES FOR CHAPTER FIVE

1. The principal factor analysis was carried out using a computer program in Guertin (1970) which was labelled, "ED 777 -- Profile Analysis Package." This program was subsequently altered by Page (1974) to increase the investigator's flexibility in manipulating each of the various sub-routines and to increase the number of profiles that could be computed. It was this revised version that was used in the study.

2. "Optimal profile membership" is taken to mean a sufficient number of profiles to establish a significant and hopefully generalizable pattern of scores. However, the number of profiles should not be so large as to eliminate genuine differences between the profiles when they are averaged in the last analytical step.

3. When the 12 year-olds in the final interview were faced with the situation requiring them to judge the temperature of two different amounts of water from the same source, four out of ten employed this 'amount criterion'. Several of those who did not use this criterion replied that the container with the larger amount of hot water would take longer to cool down. Hence, they were beginning to make the distinction between the temperature of an object and the amount of heat possessed by that object.

4. The investigator attempted to discuss the responses of several subjects at each grade level after they had completed the C.P.I. This was done with a group of four grade five students and two grade nine students. Unfortunately the meeting that was arranged with the grade seven students did not take place due to circumstances beyond the control of the investigator.

5. A further reason for suspecting the validity of statement 13 is that it was one of the extra statements from the Children's Perspective that was included in the C.P.I. and no parallel statements from the other two Perspectives were constructed. It is feasible to suggest that the subjects did not perceive the connection between this statement and the demonstration that was performed.

6. Although there is considerable amount of diversity among the topics taught in Science 8 and 9 in British Columbia schools, the recommended course of study does include a section on the kinetic molecular theory of heat. Hence one would expect a more significant grade 9 membership in Profile 1 than was in fact observed. An attempt was made to determine the subjects' previous school experience with heat phenomena by asking them to indicate if they had studied heat before in school. Many of the grade 5 and 7 subjects indicated that they could not remember and so no formal figures were kept. However, in grade 9 over one-half of the subjects indicated that they had previously done a unit on heat and temperature.

7. The assumption here is that the subjects were indeed using two different judgmental dimensions in responding to a statement. That is, a subject was capable of distinguishing between <u>being familiar</u> with the idea being presented in a statement and <u>believing</u> the idea. The facts

that two distinct dimensions emerged from the analysis of the scales and that the Model Profiles differed significantly between the belief-scores and the familiarity-scores would appear to support this assumption.

CHAPTER SIX

ILLUSTRATIVE APPLICATIONS OF THE STUDY

This chapter is devoted to an examination of some of the issues and problems associated with the third phase of the study -- the application of the results to an educational setting. Two distinct ways in which knowledge of this kind can be applied are identified and discussed in separate sections, using illustrative examples of each type of application.

6.00 Two Ways of Applying the Study

Broudy *et al*. (1964) have delineated four different ways in which knowledge can be used. These are for the purpose of replication, association, interpretation and application. Since the last two are of concern to this study, they are the subject of discussion in this section. In using knowledge in an interpretative manner, one is attempting to gain a better understanding of a problem by categorizing it according to some existing theoretical framework or at least according to a hypothesized set of relationships. To put it another way, the interpretive use of knowledge can be thought of as an endeavor to locate a problem on some appropriate cognitive map and so make the phenomenon more intelligible by clarifying and organizing it in terms of familiar set of categories.

On the other hand, an applicative usage of knowledge goes beyond merely rendering the problem intelligible; it entails the combination of theory along with a set of specific techniques to actually solve the problem. Thus, a body of theoretical propositions, or "systems of meanings" as Broudy calls them, is essential to both usages. However, if these theoretical entities are to be used applicatively to solve meaningful problems of practice then a set of supporting techniques must be developed.

An illustration of how the results of the study might be used in both an interpretive and an applicative manner is presented in the section to follow.

6.10 Illustration of an Interpretive Use of the Study

One of the recurring themes of this dissertation has been the emphasis upon carrying out a type of structural analysis of children's beliefs. It has been argued that the real value of a structural perspective lies in its potential to embed instructional problems in a broader theoretical context. The theoretical structure, or "system of meanings" being used in the present discussion is that obtained from Chapters Three and Five.[1] These chapters outlined an hypothesized set of beliefs typically held by children and a set of proposed relationships among those beliefs.

To briefly review these results, it was reported that many children subscribe to a set of beliefs that view "heat", and sometimes "cold", as a type of subtle, material substance with some properties similar to that of air. Heat, or cold, was conjectured to be capable of movement from one object to another with a consequent change in temperature of the objects in question. Some types of objects, like metals, were thought to be inherently able to attract heat and so they naturally would get hot more rapidly than other substances such as wood, glass, or synthetics when placed on a hot plate. When these beliefs are considered along with the results from the profile analysis in Chapter Five, then, the teacher has available a potential structure for interpreting the behaviors and ideas expressed by a group of children engaged in investigations of heat phenomena.

For example, one of the most difficult problems encountered by most children, and many adults, is distinguishing between the concepts of heat and temperature. In considering heat to be a type of substance that can accumulate in an object (and thus raise its temperature) one can readily understand why a great deal of conceptual confusion exists in this area. According to this view, which seems to be prevalent in many children, temperature is simply a measure of the amount of heat held by an object. In other words, no distinction is made between the intensity of heat and the amount of heat possessed by a body.[2]

Now if teachers are aware of this substance viewpoint of heat held by many children, they ought to better understand the basic nature of the difficulty. Possessing this understanding, the teacher is in a much better position to make decisions regarding the most fruitful approach to pursue. The teacher may allow the children to continue to work with their present ideas with the expectation that they will resolve the difficulty through guided discovery. Or, the teacher may attempt to point out the differences between heat and temperature using concrete examples designed to do so.[3] Another alternate pathway, recommended by one elementary science program, is to have the teacher "invent", after suitable preparatory experiences with heat and temperature, the concepts of "heat" and "temperature."[4]

While the strategy to be employed depends in part upon such factors as the children's previous experience with heat and temperature and whether they are presently aware of conceptual difficulties, a knowledge of children's perceptions of heat is useful for deciding upon a particular approach and then developing it into a viable teaching strategy.

Given this very brief illustration of how knowledge of children's conceptual commitments can be used to understand a serious problem of practice frequently encountered when children are studying the topic of heat, the next step entails the development of techniques to resolve such problems.

6.20 Illustration of an Applicative Use of the Study

To use knowledge in an applicative manner the teacher must first understand the basic nature of the problem. Second, he should possess a set of techniques that will enable him to seriously address the problem. Perhaps one of the most useful techniques from the teacher's point of view is a set of teaching strategies. Thus, the following two sections discuss the implicit problems that must be resolved prior to designing a series of teaching strategies, and a brief illustration of one such strategy.

6.21 Problems of Designing Teaching Strategies

Before any serious planning can commence in designing a teaching strategy a clear vision of the desired instructional goals is a necessity. This is implied in the very conception of a strategy -- a prescribed set of moves or maneuvers in order to attain some specified goal or end state.

There is disagreement among science educators with regard to goals, and in particular the means to be employed for attaining a set of prescribed goals. Most, however, would agree that one desirable outcome of science education is students who have inquiring and inquisitive minds. That is, students who have both the skills and the desire to try and seek out more encompassing and powerful ways of looking at the world. Thus, the teaching functions employed in evolving a set of teaching strategies must be supportive of the above goal.

In considering the topic of heat, one can speculate about a number of potentially effective teaching functions, or maneuvers as they will be called, which comprise an overall teaching strategy. To begin with, the teacher must encourage the students to become familiar with a wide range of phenomena associated with heat and temperature and in so doing, develop a set of intuitive ideas or beliefs about heat. These encounters should be of sufficient depth to allow the students to clarify their ideas such that they have the confidence to begin making predictions about the outcomes of subsequent investigations.

Given that students have attained a somewhat stable set of beliefs, another teaching maneuver might involve the creation of a situation that leads to an unexpected outcome for the students. This anomalous event is designed to introduce an element of uncertainty into the student's beliefs, with the expectation that the uncertainty will eventually be resolved with a type of reorganization or restructuring of the child's intuitions and beliefs which contributes to the attainment of instructional goals. If a child is now able to understand a wider range of phenomena, then this shift could be considered as proceeding towards a more powerful and encompassing conception of heat.

The teaching maneuvers just sketched out above can be formalized into a teaching strategy wherein each maneuver is described in terms of the teaching functions that it performs.

Hence, the first teaching function may be introducing the students to a variety of situations involving experiences with the effects of heat and temperature -- that is, a set of experiential maneuvers. These might be followed by clarification maneuvers, the purpose of which would be to have the students carefully think about their ideas. The willingness and ability to make predictions about the outcomes of novel investigations would be an indication of the success of the clarifying maneuvers.

Another series of maneuvers could be directed toward creating situations which would lead to results that are unexpected or perhaps even contradictory to those beliefs presently held by the class or a particular group of students. The impact of an anomaly maneuver is directed towards getting the students to reconsider their previous position. This may entail students adopting an entire new set of ideas about heat. The restructuring involved may take considerable time and likely some guidance from the teacher. Another possible outcome of an anomaly maneuver is the modification by the students of some part of their existing framework. In either case, it is apparent that these maneuvers have to be selected to fit the particular pattern of beliefs expressed by the students.

Finally, one last set of maneuvers might be employed to assist the students in accommodating to the unexpected outcomes. As with each of the above, these restructuring maneuvers could be accomplished in many different ways ranging from class discussion and other peer group interactions to more direct intervention procedures by the teacher.

Returning now to the central issue of using the results of this study in an applicative manner, it should be evident that the C.P.I., in conjunction with the Model Conceptual Profiles, could play a very prominent role in terms of the design and selection of appropriate teaching strategies. With the assistance of the C.P.I. and the Model Conceptual Profiles, the teacher is assisted in the difficult task of diagnosing the existing conceptions of heat held by individual members of the class.

Since teaching strategies can be designed for each Model Conceptual Profile, the teacher can administer the C.P.I. and then match or categorize individuals, or groups of individuals, according to one of the Model Profiles. The remaining step involves a decision to choose an appropriate maneuver, or set of maneuvers, from among those listed for a particular Model Profile, say, in a guidebook accompanying the C.P.I.

6.22 <u>An Example of an Applicative Use</u>

In an endeavor to further clarify the types of teaching maneuvers and the matching of an individual student to one of the Model Conceptual Profiles, this section will illustrate these procedures by taking the scores obtained by one individual on the C.P.I. and map out potential instructional activities.

In Figure 6-1 the scores for a grade seven subject are graphed in a similar fashion to the Model Conceptual Profiles in Chapter Five. To better visualize the match between the individual profile and the Model Conceptual Profile judged to be most similar, Figure 6-2 is immediately below and is simply a reproduction of Model Conceptual Profile 2.[5] The list of statements used is also reproduced in Table 6-1 for ready reference.

TABLE 6-1

A List of the Statements in Each Viewpoint Used in the Profile Analysis of the Belief Scores

KINETIC VIEWPOINT

5. The whole rod gets hot because: THE FASTER MOVING METAL PARTICLES BUMP INTO EACH OTHER ALL THE WAY THROUGH THE ROD.

9. The wax melted because: THE WAX PARTICLES WERE MOVING ABOUT SO FAST THAT THEY COULD NOT HOLD ON TO EACH OTHER SO WELL.

12. The metal cubes were hotter than the wood or sugar because: THE METAL PARTICLES ARE EASIER TO MOVE.

16. The temperature of the water decreased when an ice cube was added because: THE WATER PARTICLES LOSE SOME OF THEIR SPEED BY BUMPING INTO THE ICE PARTICLES.

19. The red liquid in the tube went up because: THE LIQUID'S PARTICLES MOVED MORE QUICKLY AND SO TOOK UP MORE SPACE.

CHILDREN'S VIEWPOINT

4. The whole rod gets hot because: THE HEAT BUILDS UP IN ONE PART UNTIL IT CAN'T HOLD ANYMORE AND THEN THE HEAT MOVES ALONG THE ROD.

7. The wax melted because: IT WAS A SOFT SUBSTANCE.

11. The metal cubes were hotter than the wood or sugar because: IT WAS MORE DIFFICULT FOR THE AIR TO GET INSIDE THE HARD METAL CUBES TO COOL THEM.

13. The metal cubes did not melt because: THEY WERE NOT HEATED LONG ENOUGH.

14. The temperature of the water decreased when an ice cube was added because: THE ICE CUBE ATTRACTED SOME OF THE HEAT PARTICLES AWAY FROM THE WATER.

17. A large ice cube takes longer to melt than a small ice cube because: THE LARGE ICE CUBE HAS A COLDER TEMPERATURE THAN THE SMALL ICE CUBE.

Figure 6-1 An Individual Profile of Belief-Scores For a Grade 7 Subject

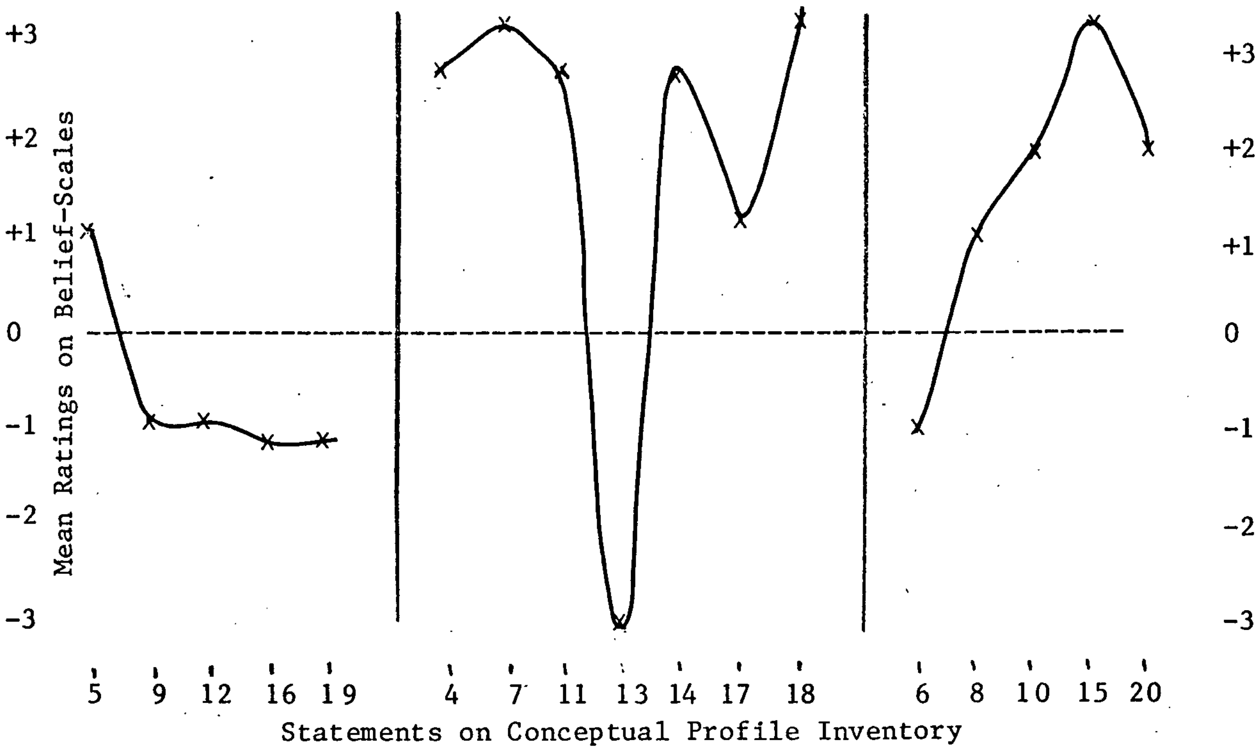
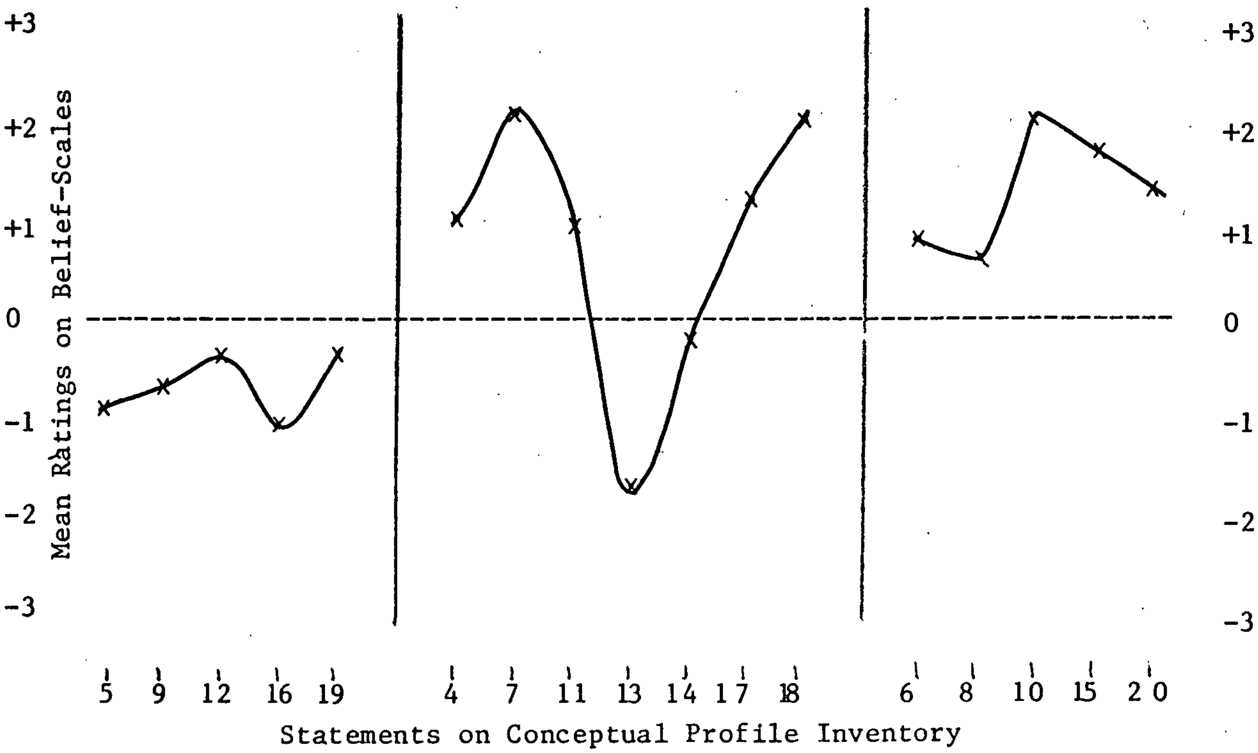


Figure 6-2 Model Conceptual Profile 2 (N= 43 Subjects)



18. The red liquid in the tube went up because: THE HEAT MAKES THE RED LIQUID LIGHTER AND SO IT RISES.

CALORIC VIEWPOINT

6. The whole rod gets hot because: THE HEAT PARTICLES FROM THE FLAME ARE ATTRACTED TO ALL PARTS OF THE ROD.

8. The wax melted because: THE HEAT PARTICLES WENT INSIDE AND FORCED THE WAX PARTICLES APART.

10. The metal cubes were hotter than the wood or sugar because: THE METAL CUBES DREW IN MORE HEAT PARTICLES THAN THE OTHER CUBES.

15. The temperature of the water decreased when an ice cube was added because: SOME OF THE COLD LEFT THE ICE CUBE AND WENT INTO THE WATER.

20. The red liquid in the tube went up because: THE HEAT PARTICLES TAKE UP SPACE INSIDE THE LIQUID AND FORCES THE LIQUID OUT THE TUBE.

Having categorized the individual profile according to one of the available Model Conceptual Profiles, in this instance Model Conceptual Profile 2, the teacher could then consult a guidebook which could be prepared containing a list of suggested teaching maneuvers cross-referenced according to the Model Conceptual Profiles. An illustration of some typical activities under each teaching maneuver is given for Model Conceptual Profile 2 in Table 6-2.

These are but a few of the possible activities and they are based in part upon the interpretations given to Model Conceptual Profile 2 in Chapter Five. It would be desirable to have a large diversity of activities so as to insure that the teacher could find some that would be compatible with the past experiences and present interests of the students in his class.

The various teaching maneuvers outlined in Table 6-2 are very general in nature and are meant to orient the reader to potential

Table 6-2

List of Possible Teaching Maneuvers to Accompany Model Conceptual Profile Two

I. Experiential Maneuvers

(a) Basic thermometry activities
- (i) measure the temperature of common classroom objects
- (ii) measure the temperature of objects in all three states -- gas, liquid, and solid
- (iii) create activities for hard-to-measure objects such as the inside of an ice-cube.

(b) Change of state activities
- (i) observe different substances melting on a tray -- like butter, sugar, wax, lead, etc.
- (ii) hold ice-cube races to see who can melt an ice-cube the fastest and who can keep an ice-cube from melting the longest.

II. Clarification Maneuvers

(a) Class discussion of results
- (i) After doing several activities call the class or group together to discuss the results. Those results which are in doubt could be repeated as a group activity.
- (ii) Ask group members to think about the results and to express their ideas to account for them.

(b) Competing viewpoints of heat
- (i) If different students or groups have different ideas to account for the results, encourage them to discuss and debate these ideas among each other.

III. Anomaly Maneuvers

(a) Temperature change activities
- (i) Engage students in water mixing experiments; altering first the temperature between the two original containers and then the amounts of water in each container.
- (ii) Observe the temperature effects of adding different objects at the same temperature (say 100° C.) to given quantities of liquid.

(b) Heat versus temperature activities
- (i) Have an ice-cube melting race between air at 25° C. (or higher if there is access to an oven) and water at a lower temperature.

(ii) Observe the temperature of 50 ml. of water heated by a standard candle and 100 ml. of water heated by a similar candle.

(c) Specific heat activities

(i) Place similar sized objects made of different substances (wood, metals, sugar, glass, etc.) in a tray over a hot plate for a short while and then observe the results when they are placed on a block of wax.

IV. Restructuring Maneuvers

(a) Group Discussions

(i) Discuss unexpected results from the anomaly maneuvers and encourage them to think of possible explanations.

(ii) Encourage individuals or groups with different beliefs to explore them more fully either in discussion or further investigations.

(b) Teacher Intervention

(i) The teacher introduces a competing viewpoint (providing it is clear that the students are under no obligation to accept it on the basis of authority).

(ii) The teacher attempts to point out inconsistencies between student;s ideas and the actual observations.

activities and discussions. However, the individual profile could also be used by the teacher in a diagnostic capacity. For example, the profile in Figure 6-1 indicates some very strong beliefs in those statements which were earlier referred to as "common-sense" ideas about heat (notably numbers 4, 7, 11, 15, and 18). Several of these might be used as the basis for a series of investigations to be undertaken by this student and others who responded in a similar manner.

Taking statement 7 as an example, the expressed belief is that soft things melt more readily than hard things. On the basis of this belief, a student could then examine the melting behavior of a number of hard and soft objects (an experiential maneuver). The teacher might also encourage the students to think about why soft things appear to melt more readily -- the first steps toward the possible formulation of a position regarding the relationship between heat and matter. An anomaly maneuver might be introduced by the teacher by exposing the student to some soft materials that do not melt easily (for example, substances like styrofoam, putty, play-dough, etc.) and some hard substamces that do melt easily (like ice, some plastics, etc.).

Thus it can be seen that the individual statements on the C.P.I. can also be used in a diagnostic capacity. Providing that the teacher has sufficient time, those students who indicated strong beliefs about some of the common-sense ideas could be engaged in investigation using those ideas expressed about heat as a starting point.

Im summary, then, using either the specific statements from the C.P.I. as the point of departure, or the maneuvers contained in a teacher's guidebook, the teacher's role is that of getting the students to think more critically about the beliefs that they hold. And in so doing, the students should attain a more powerful way of looking at heat and temperature phenomena.

NOTES FOR CHAPTER SIX

1. While the discussion in this section is restricted to the results obtained from this study, one could also consider the implications of using the body of literature on structural growth in an interpretive sense. That is, the sets of beliefs identified in the study can be construed as one type of structure and so ought to be subject to the same types of conditions employed by others in seeking to promote structural change. See, for example, Kuhn (1963); Palmer (1964); Siegel (1969); and Furth and Wachs (1974).

2. That this distinction is most difficult to intuit directly from the phenomena can be seen from its rather late historical appearance. Black is generally given credit for being the first to clearly draw the distinction between the intensity of the caloric fluid surrounding the particles of matter (a measure of its temperature) and the total amount of caloric possessed by a body (a measure of its heat). This conception was first published as part of a series of lectures by Black in 1803 which indicates that the distinction had eluded many who were very familiar with heat and temperature phenomena during a period of over one hundred years.

3. This procedure might well resemble the "teaching moves" described by Smith _et al_. (1961) for teaching a particular concept.

4. The _Science Curriculum Improvement Study_ first introduces the children to the topic by engaging them in several activities with heat phenomena. However, the teacher then "invents" the terms "temperature" and "thermal energy" (heat) in order to assist the children to understand and interpret these phenomena.

5. The actual matching procedure is probably accomplished most easily by plotting the individual's scores on a transparent sheet and then laying this over the Model Conceptual Profiles for a direct comparison.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.00 Overview of the Study

The three specific problems addressed in this study were discussed in Chapter One. Investigations of these problems corresponded to three distinct phases of the study. Phase One sought to identify and document the range of substantive beliefs about heat and temperature held by children. The procedures used to investigate this problem consisted of interviews with children ranging in age from 6 to 13 years. Only the set of ten formal interviews, conducted with 12 year-olds, were reported in Chapter Three. The information obtained from the interview data formed the basis for the investigations of the next two phases.

Phase Two attempted to establish some evidence for the existence of a set of relationships among the beliefs about heat and temperature held by children. To this end a measuring instrument was constructed reflecting beliefs about heat obtained from: (1) the interview data, (2) a current scientific theory of heat (the kinetic theory), and (3) an earlier scientific theory (the caloric theory). The instrument was administered to twelve classes of students: four classes in grades 5, 7, and 9 respectively.

An analysis of the data collected with the instrument resulted in the identification of several typical belief patterns, which were labelled Model Conceptual Profiles. These Profiles, discussed in Chapter Four and Five, served as one component of the empirical foundation used in the last phase of the study.

Chapter Six addressed the third specific problem -- the application of the study to an educational setting. Two ways in which the results could be used to increase the effectiveness of the classroom teacher were discussed and illustrated. The chapter concluded with the presentation of a brief outline of a possible set of teaching maneuvers that were keyed to the Model Conceptual Profiles. Thus the techniques developed in Phase Two of the study were shown to be of potential diagnostic value to the classroom teacher.

7.10 Conclusions of the Study

A number of tentative conclusions can be offered in response to the three problems that have provided direction for the study. These conclusions, however, can best be interpreted as tentative hypotheses suggesting further empirical work, rather than firm answers to the questions posed in Chapter One.

The intent of Phase One was to identify the substantive beliefs about heat and temperature held by children. It was argued that the methodology most appropriate for this task was a series of open-ended interviews. From the analysis of the interview data several conclusions appear to be justified.

> (1) Most young children between the ages of six and twelve possess a body of beliefs about heat and temperature that can be identified in an interview situation.

This was, of course, an assumption that was made by the author prior to the investigation. And while the subjects interviewed varied greatly in terms of knowledge and their ability to express that knowledge, it can be said that the unstructured interview technique is a fruitful method for identifying children's intuitions about physical phenomena.

The remaining two conclusions for Phase One represent an attempt to distill from the interview data clusters of beliefs about heat and temperature that appeared to be shared by most of those children interviewed.

(2) Heat was thought to be a type of substance which possessed its own unique properties.

This substance view could be identified in many of the interviews. Many of the children sought to describe heat in terms of fumes, rays, waves, or used an analogy -- something like air. In most instances heat was considered to be a mobile or active agent capable of independent movement through space and also able to penetrate most objects. Although the mechanism for penetration is not at all clear, it may be that air spaces in objects (which were frequently mentioned) provided a type of passageway. Beliefs about the potency of heat were revealed when some children described its ability to "break apart cells" of certain objects and so cause them to melt.

The next prominent set of beliefs centered around their conception of temperature. The conclusion might be expressed as:

(3) Temperature is a measure of the hotness of an object and is a result of the amount of heat that is added to it.

All of the children interviewed were familiar with the term, "temperature", and were aware of the relationship between the hotness of an object and its temperature. However, this physical intuition may also be responsible for the set of beliefs surrounding the change of temperature in objects. For example, several of the children claimed that the temperature of water was lowered when some of the water was poured out. Also when hot and cold water were mixed the final temperature of the mixture was determined by many children using a simple addition or subtraction operation of the two initial temperatures. Both of the above can be understood in terms of a view that suggests the temperature of an object is determined by the amount of heat possessed by the object.

As was illustrated in Chapter Six, the intuitions and beliefs that constituted these two broad areas may be largely responsible for the difficulties encountered by many children when they are introduced to the kinetic theory of heat in a school setting.

In Phase Two the emphasis shifted towards identifying a pattern of relationships or a structure in children's beliefs. To accomplish this end, an instrument was constructed and data were collected and analyzed for 276 subjects.

The first important result of this analysis indicated that:

(4) The subjects were able to distinguish between the statements representing each of the three different perspectives of heat.

This result was obtained by performing a principal component analysis on the belief ratings of statements in the C.P.I. The three interpretable components obtained from the analysis indeed corresponded to the heat Perspectives that were originally used to design the statements, giving some support to the construct validity of the instrument.

A second analytical procedure was employed to determine if there were any similarity in the response patterns among the subjects. This profile analysis yielded the following result:

(5) Three distinct patterns of belief-scores were obtained for the subjects. These patterns were interpreted in terms of different levels of understanding of heat phenomena.

On the basis of the results summarized in conclusions (4) and (5) it was inferred that a unique set of structural relationships among children's beliefs could be determined using the analytical procedures outlined earlier. Further, it was reasoned that these relationships should form the nucleus of an effort to develop curricular materials or teaching strategies in the area of heat and temperature.

The last phase of the study was speculative in nature and was directed towards outlining the potential applications to an educational setting. Two different ways of using the results were illustrated. Although no empirical work was done in this phase, it was concluded that:

(6) The knowledge obtained from the study could be used to develop a set of teaching strategies that could have application in the classroom.

These six conclusions, then, represent condensed statements of the contributions made by the present study. Although most of these refer to substantive results, the underlying methodological procedures are also noteworthy. That is, the open-ended interview procedures, the development of the semantic-differential classroom instrument and the analytic techniques used to generate the Model Conceptual Profiles all appear to be useful ways of collecting and processing information on children's beliefs and intuitions about natural phenomena.

7.20 Recommendations for Further Research

Given the exploratory nature of the study several potential follow-up studies might be suggested. This section includes an outline of the broad problems to be addressed and contains brief comments on some of the issues accompanying each of these problem areas. The recommended studies can be thought of as falling along a type of continuum defined at one end by a type of study which is directed towards elucidating the theoretical issues raised by this study and at the other end by a study which is aimed at evaluating the effects of the study upon classroom practice.[1]

Some questions worthy of further investigation are listed below, beginning at the elucidation end of the continuum and proceeding toward the evaluation end.

(1) Can the genesis and subsequent development of the underlying conceptual structures be more clearly identified and mapped out?

(2) How valid is the hypothesized Children's Viewpoint of heat? Is the substance notion of heat as pervasive as suggested by the present study?

(3) Can more evidence be obtained regarding the hypothesized developmental trend from a common-sense level of understanding heat phenomena to one which is more abstract in nature?

(4) Are there any significant differences in heat viewpoints that can be attributed to specific variables such as: age, sex, geographical location, etc.?

(5) How might the existing methodology be applied to an investigation of children's ideas about other relevant topics?

(6) Can a set of appropriate teaching strategies be created to match the Model Conceptual Profiles?

(7) Are these teaching strategies effective in bringing about the desired aims of the program?

Having set out this abbreviated list, it remains to provide a little more substance for at least some of these prospective studies. Because the procedures employed in this study (specifically the open-ended interview technique along with the development of the C.P.I. and methods of analysis) were judged to be satisfactory by the author, it is recommended that some combination of these procedures be seriously considered in any follow-up studies.

The first two questions in the above list are mainly concerned with generalizing the results of the present study to a larger sample of subjects. Hence, it is suggested that a type of open-ended interview technique be used with a much larger sample of subjects, ranging from 6 years to 16 years of age. Some of the tasks used in the present study could be utilized, however, with the suggested age range some work would be required to modify the interview so that it would be appropriate for both the younger and older subjects. Since the research hypotheses are already defined to some extent, there would be no need to engage in the extensive pilot work described in this study.

Question (4) could also be approached in a similar manner if careful attention were paid to the sampling procedures used to ascertain the causes of any observed differences in response patterns. That is, if it were being hypothesized that boys have a more abstract view of heat than girls, then one would have to be careful to match the samples on other variables that might affect the results (for example, age, school achievement, intelligence, interest, etc.).

On the other hand, these two questions could also be addressed using the C.P.I., or some alteration of it. Extensive use of this type of classroom instrument would also allow a set of norms to be established and so produce a more reliable and valid instrument. As before, the sampling problem would be very important if one were attempting to test certain hypothesized relations.

The last two problems are directed at an implementation of the existing results into a classroom situation, and follow-up studies evaluating the effects of such a program. The results reported in this dissertation are believed by the author to be of sufficient validity and interest to warrant the initiation of an instructional program designed to translate the procedures outlined in Chapter Six into a form suitable for use by the classroom teacher. While it would obviously be desirable to base the program upon a well-established theoretical basis, it is argued here that work on both ends -- the theoretical and the practical -- could take place using the present results as a starting point. If and when alterations are made in the theoretical perspective, these could be incorporated into the practical program.

The work in developing a suitable instructional program would entail the creation of a set of teaching maneuvers that is cross-referenced to particular levels of understanding, or Model Conceptual Profiles. Suggestions were made in Section 6.32 as to issues that might be involved in a task of this nature. Furthermore, these teaching maneuvers must conform to the usual constraints upon the classroom teacher, such as time and equipment.

Once the development and implementation of an appropriate instructional program is accomplished, the last question becomes more important. How does one determine the value or effectiveness of the program? Very little of this type of evaluative research is actually carried out in educational research because it is so difficult to define and control the relevant variables.

The author's opinion is that it is exactly this kind of research that has the greatest potential for making a significant contribution to classroom practice and to our understanding of how the child acquires increasingly complex knowledge of his physical environment.

On a concluding note, it would seem quite obvious that if the recommended program outlined in this dissertation, matching instructional maneuvers to the diagnosis of the child's understanding of heat phenomena, proves to be successful then the basic methodological techniques should also be applied to other areas of interest in the curriculum (question 5 above). In this way a catalogue could be assembled which would serve as a type of instructional resource for the teacher. This catalogue might contain information on typical beliefs held by children at different ages (or levels) along with lists of suggested activities. The activities might take the form of some predetermined or empirically established teaching strategy designed to achieve a particular aim. Alternatively, these activities could also be simply categorized according to the interests and ideas held by children thus allowing the teacher, or the student, to make the decision regarding the usage and the sequence of the activities.

NOTE FOR CHAPTER SEVEN

1. For a further description of the distinction between elucidatory and evaluative types of research studies, see Glass (1971).

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APPENDIX A

A Transcript of Ron's Interview

Age: 12 years 8 months

Notes:

(1) E = experimentor

S = subject

(2) ( ) = an explanation of some non-verbal action judged to be important to the inverview.

(3) For a description and/or picture of the materials used in each of the tasks see Appendix B.

Ron's Interview

(S was brought into the interview room and the first few minutes were spent making him comfortable and answering any questions that he posed about the room and the microphones. He was then shown the liquid expansion apparatus used in the first task.)

Task Number One

S: What's this?

E: I don't know. What do you suppose that is?

S: A colored wire? (Referring to the red liquid in the stem)

E: Okay, it might be a colored wire. What do you suppose it looks like?

S: This is the temperature here ins't it? No. (S points to the top of the red liquid in the stem)

E: What do you mean it's a temperature?

S: Well what's that there? That pink line can you see it? Is that the water in there?

E: Do you suppose there's anyway that we could find out?

S: Take it off.

E: That's one way, yes. I was going to ask you a question about that. Have you ever seen anything that looks like that before?

S: This? No, well a thermometer.

E: You think it looks like a thermometer? What does a thermometer do?

S: Measures temperature.

E: How?

S: Well the temperature outside and inside a room.

E: Can it tell you the temperature of anything?

S: I think so, yes.

E: What I was going to ask you, do you think you could maybe get that liquid to go down, only by touching this bottom part here. Just the glass.

S: Can you heat it or anything?

E: Sure, do you think that might make it go down?

S: I thought that would make it go up. When you heat something does it expand or what?

E: Like what did you have in mind?

S: Like an ice cube. If you melt it will it expand or go smaller? Like say I have a handful of ice and you let it melt. Will the water be bigger than the ice was?

E: I don't know. I've never tried that. How do you suppose we could find out?

S: Get a pyrex, put in a thing full of ice and melt it.

E: So we have ice in a glass like that and then what?

S: And then melt it.

E: And then what would happen?

S: And see if, I know, it goes either up or down. I can't remember though. Say I have that much ice (S points to a spot half way up on a beaker sitting on the table) and when it melts, whether it will lose or whatever. Or this might be at a certain temperature it might go up that high, like if it was put in the fridge or anything, not long enough to freeze, it might go farther down. I don't really know what that is.

E: We have some water here. Should we try putting it in some water and see what happens? Can you tell me anything about that water? What about the temperature?

S: Cool, not hot.

E: Do you think that the liquid would go up or do you think it would (S interrupts)

S: This is warmer. (the apparatus) Is that water, that's liquid in there isn't it?

E: I'm not really sure what it is. We can call it red liquid.

S: This is warmer, it isn't hot and it isn't this temperature (S points to the beaker of water) This is quite cool.

E: So what do you suppose will happen if we put that (apparatus) in there? (beaker of water)

S: This (S points to red liquid) might go down?

E: You think it might go down?

S: It is. It's going down.

E: How far down do you think it will go?

S: It's stopped now. I think. No it hasn't stopped. I think it will go about that far.

E: That far?

S: Yes, half an inch or quarter of an inch. The water is getting warmer.

E: Do you want to mark where you think it will go?

S: Oh no, it's going down a long way.

E: Do you want to revise your estimate?

S: Maybe it will go as far as that is to there. (S points to the bottom of the stem)

E: To where?

S: There, where the water is to there, but I don't think so.

E: What do you suppose is happening to the water? You mentioned something about the water earlier.

S: It's getting warmer.

E: Why is it getting warmer?

S: Because of the heat of the, not the heat but, just because of the other water around it in this glass here.

E: What about the glass, unfortunately we've got two glasses and two sets of liquid here so we'll have to try sorting that out. Shall we take it out for a second? And this way you can point to the one that you are referring to. You thought that this water (in the beaker) was getting warmer?

S: Yes.

E: And why was it getting warmer again now?

S: Because of this water. (S points to apparatus)

E: Because of the water in the glass there.

S: Hey, now this (liquid in the stem) will go up, right?

E: You think that will go up? Why?

S: Because it will get warm. I mean this, it doesn't feel any colder than it already was. It would be (inaudible) so I figured it would go up and maybe. You have hot water there don't you?

E: Yes.

S: We can put this (the apparatus) in hot water and see if it goes up.

E: You want to try putting it in hot water. I'm very interested in why you thought this water was getting warmer. And you were about to tell me.

S: Cause when this (apparatus) was in that (beaker of water) the temperature of this glass would be a little warmer than this water, and so all this water in here would warm this glass and the warmth in this glass would warm this water.

E: The warmth from the glass?

S: Like if you've got a boiling hot spoon and you put in in the water it would go warm. Just like on the beach you know when the tide goes out and the sun heats the sand and then the tide comes in and the water's warmer because of the hot sun.

E: Let's see, this (a metal plate) isn't quite the same, but it's something like a spoon. And if I put it, do you know what this is?

S: Yes, it's a hot plate.

E: Now if I left it on there for a long time and it got really hot. We haven't got time to do that but let's just say it is, then I take it and I put it in here (a beaker of water). Is that what you said? Then what's going to happen?

S: This water will get warmer.

E: And how would it get warmer?

S: From the heat of that. (the plate)

E: From the heat of that. Where does this heat come from?

S: The hot plate

E: And it goes into here is that it?

S: Yes. It warms up and now when it's warm it goes into there (the plate) and it warms the water.

E: How does the heat go from the hot plate into here? (the plate)

S: Well, it's attached.

E: Yes, it's touching it.

S: Yes it's touching it and I guess metal attracts heat.

E: Well what about when we put in in here, what happens? When we put it in the water?

S: The water attracts the heat from that. That cools down. Because the water is a colder temperature.

E: So the heat is leaving this (plate) is it? And going into the water. What do you suppose heat looks like?

S: You can see it on some very hot days rising from the road sort of you know in waves? If you're driving on the road. It just sort of looks like fumes.

E: So you think that is what goes on when you put this (the plate) on the hot plate. The heat goes from the hot plate to there?

S: I don't know how that machine works but probably there's something warming the metal up, and then the metal.

E: The top of the hot plate you mean?

S: Yes, the top warms that. (the metal plate)

E: Now you wanted to try the experiment didn't you? Do you think that's (a beaker of hot water) fairly hot or is it not very hot?

S: It's hot enough.

E: Now what do you think is going to happen?

S: This (the apparatus) here sort of, could I put my finger on there, put my hand around there with my body heat to see if it raises. Hey it's raising. O.K. now I'll put it in here. (the cold water beaker) It raised for a second, but now it's going down gradually.

E: Now what do you think's going to happen when you put it in here? (hot water)

S: It'll raise.

E: Do you think it will go very fast?

S: Yes.

E: Why?

S: Because of the heat in the water. Cause it went up fairly fast just with the heat of my hand. I think it would go all the way up to the top.

E: You think it would go all the way to the top?

S: Yes. Unless this doesn't, this temperature here doesn't cool down that water. See it could happen.

E: I'm not sure what you mean.

S: The temperature of this glass (the apparatus) is colder than the temperature of this water here and so the temperature of this glass might cool down the water.

E: How does it do that?

S: Well it might we'll see.

E: When something cools something else down, what do you suppose happens? When we say that this water cooled down this (the apparatus) you said. How does that happen?

S: I don't know.

E: You were talking something about the heat or when you put this in there, it cooled down.

S: I know how it warms up.

E: How does it warm up?

S: I told you. How it cools down, guess it does the opposite.

E: O.K. Let's try this experiment here and see what happens.

S: It dropped and then it rose quite fast.

E: Boy, is it ever going fast. (5 second pause) Yes. Yes it looks like you're right. What's going to happen?

S: It's going to raise to the top quite fast and then it will come out. When that cools down now, it will stop, maybe. That's what I think.

E: How long do you think it will take to cool down?

S: Is that dyed water? No it couldn't be dyed water could it?

E: Why?

S: Cause it's got some chemical in it cause dyed water doesn't rise I don't think. Can I taste it?

E: Well just a little bit. Shall we take it out now. What do you think would happen if we just used ordinary water in there?

S: I don't think it would do anything. If it got hot enough it would start bubbling and the water would rise. If it got hot enough it would start boiling, then the water would rise up here. No it wouldn't. You'd have to, the hot air, or the steam would go up here and then you put a really cold cloth or have this tube bent into cold water and then when the steam hit the cold water it would go through the tube. It would turn back into water, and then we'd have it into the top of the jar and there would be water going into the jar.

E: Have you done that before?

S: Yes we did it in a science report, a science experiment.

E: But if we just had ordinary water and put in in this jar of hot water, what do you think it would do then?

S: I don't think it would do anything.

E: What about if we used milk?

S: I don't think it would do anything

E: I'm just trying to think of some other liquid that we might put in there. What liquid do you think would work?

S: If I knew what that was, I'd tell you.

E: Why do you think that works? Why do you suppose that happens? What do you think is happening there?

S: I know! That could be just plain water. But the water is getting hotter so it rises right. The more it rises, the more it goes up.

E: Now why does the water rise?

S: I know. I know that thing that I was thinking of now. If you had a glass of water say that high and froze that. The water would go down a bit and when you melted it, it would go up to the same thing. Remember I was talking about that? So I know now. That's what I think.

E: Would you like to try explaining that to me again.

S: When it gets hotter, the water rises and as it rises it goes up the tube.

E: Why does the water rise when it gets hot? (5 second pause) What do you suppose water is like? What is it made out of?

S: Ice? I don't know, water.

E: You think ice is made out of water?

S: Yes, well water is made out of water. Like the clouds are made out of water going across the ocean.

E: Well I was wondering, why when it gets hot does it rise?

S: Why does it rise when it gets hot. I don't know.

E: I think you told me why it gets hot. I'm still interested to know how the heat goes from this water (in the beaker) into that water. (in the liquid expansion apparatus)

S: Through the glass. It just warms the glass and then the glass warms that.

E: Does it go right through the glass?

S: No. Well it warms the whole glass up and then the glass warms the water just like this (a pair of tongs), if you had this hot it would warm the water.

E: Now you said the heat, there's heat in here (E picks up the tongs) and then when you put it in there, the heat leaves this and goes into the water. Does that mean that there's heat in this water?

S: Yes. That's definitely cooler than it was, but maybe that's just because it was sitting.

E: If we use this water it's fairly hot. Is there heat in that water?

S: Yes.

E: And if we put that (the apparatus) into there (the water), what would happen to the heat?

S: It would cool down. If it was off the hot plate.

E: You put this into here and you say it would cool down eh? What would the heat do? What would happen to the heat?

S: Well this (the apparatus) would take some of the heat up.

E: So where would the heat go?

S: Into this. (the apparatus)

E: How would it do that?

S: By warming the glass and the glass warms the water, or whatever the substance is in there.

E: Is there heat down in there? Would there be?

S: Yes.

E: Do you suppose the heat's got anything to do with the water rising?

S: The heat yes. Yes definitely cause I held my hand there.

E: How do you suppose the heat makes it rise?

S: I don't know.

E: Yes that's a tough question cause I'm not really sure.

S: I couldn't even guess at that.

E: You don't have any ideas. I'm interested in any ideas that you may have at all. You can think about it for awhile and we can go on and do some other things if you want.
Do you think you can tell me how hot this water is?

S: It's quite hot. I think we could use that as a thermometer. Because we could measure how fast it would go up for a certain heat. First we'd have to get a real thermometer and test the heat of this water and then we put in here and test how fast it would go up and then we'd get an idea. Then we'd have to have cooling water but it would have to be warmer than this for it to go up and test the heat of the water. Then put this up and see how slowly it goes up and then we can just get some different water that has to be a little hotter than this, put this in without no temperature or nothing and see how fast it goes up and we could estimate it and put the thermometer into the water and see how close we are. Do you want to do that?

E: Unfortunately we probably need a stop watch wouldn't we? I'll tell you what, there's some other things that I want to do, that I want to talk to you about and if we have some time we'll try that. Now. That's (the metal plate that was resting on the hot plate) fairly hot now. Do you know what this is?

S: It's sort of a hot plate too.

E: It's asbestos actually.

S: Just like at home, when you come in with the dinner on a hot plate.

E: Now what do you suppose is going to happen if I were to put this on top of that plate? (E places hot metal plate on asbestos pad and motions as if to put the expansion apparatus on the hot metal plate)

S: It would raise the level. First, let's cool this down and get it right down. (Referring to the level of the liquid in the apparatus)

E: I'm not going to actually put it on cause I think it might crack this it's too hot. Just tell me what you think might happen. What about the temperature?

S: This would go up quite fast.

E: And what about the temperature of this water here?

S: It would heat.

E: And what about that, the temperature of the metal?

S: It would cool down because it's giving some of it's heat into that.

E: So it's the heat that's doing it, and if we sat it on there and left it on there for about 15 minutes what do you suppose would happen to the temperatures?

S: They'd both cool down probably. This (the metal plate) would cool down anyway if you just left it there cause the heat is going into the air.

E: Just disappears into the air? How do you suppose it does that?

S: It just lets off the fumes I was talking about like heat was. Probably there's all sorts of fumes in that metal that lets it out gradually.

E: Do you think that fumes go inside here (the apparatus) when it heats up?

S: Yes. How about just leaving that for about 15 minutes and then we'll see if it cools down or not.

Task Number Two

E: Now I have this hot water. You were going to tell me, you want to guess how hot that is?

S: I don't know. About 180 degrees. Which is boiling temperature again?

E: For water I think is 212 or something like that.

S: Yes I think it's about 180 or 160.

E: Is there any way we could find out?

S: Get a thermometer.

E: I just happen to have one which is very handy. Now you notice there's two scales on that.

S: Yes. This is the scale we're looking at right?

E: Well no you were talking about the other scale. Do you know what the name of that scale is?

S: No.

E: That's called a Fahrenheit scale.

S: It seems to be 145.

E: Well you guessed 160 didn't you. That's pretty close. Now what about this one (cold water) in here? Do you want to guess first?

S: I'd say 50 to 70 degrees.

E: You're giving yourself a little bit of range this time.

S: It's stopped now. I'm taking the temperatures from a pool. You know that a pool's heated to 80 degrees. I feel the water in the pool and feel this.

E: Yes it's about 60. O.K. and what was this 145?

S: It's probably about 140 now. It's cooling down (S measures the temperature of the hot water again)

E: Well it looks like you're right. You must have studied temperatures quite a bit before. O.K. let's say it's 140. Now I want you to tell me what the temperature of that will be, this water. (E pours a small amount of hot water out into another small beaker) Without touching it (as S started to put his hand into the water)

S: 100 to 120.

E: And this one? (S pours more hot water into a second small beaker -- about twice as much as in the first small beaker)

S: 130.

E: Why do you think that one is higher than that one?

S: Cause there's more in it.

E: And what about this water? (the hot water in the original large container)

S: That's 140. There's more of that.

E: How did that water go from 140 to 120? (the water in the first small beaker)

S: Because the glass is cooler.

E: Have you ever seen anything like that before? (E brings out the two chamber mixing box)

S: No.

E: Do you want to take a look at it?

S: Does this rise? (S points to the barrier in the box)

E: It's just a little tight. What we're going to do, I'm going to pour some of this water that was 140 into there and pour an equal amount into that side. And that was what -- 60 was it? It is equal, about the same? Now what do you think the temperature of this water would be right now?

S: Did you pour it from the big glass? O.K. 110.

E: And this water would be?

S: That was 60 right? 70.

E: Why do you think 70?

E: Cause this glass (the beaker) here would probably be the same temperature and this glass (S points to the mixing box) would be warmer. Therefore it would warm the water a bit.

E: This glass (the beaker) would be the same temperature as?

S: The water, and this (the mixing box) would probably be room temperature or probably warmer than that.

E: How let's say that we let this sit for about ten minutes what do you think, would this (E points to the hot water side) temperature be the same?

S: No.

E: What would it be?

S: Probably about 80 to 90 degrees.

E: And this temperature? (E points to the cold side)

S: Around 80 degrees, around there.

E: About the same? Why do you suppose it would be the same?

S: Because they would go to room temperature?

E: You thought this would be 80 or 90 and you thought this would be about 70 or 80. Would they go higher than room temperature?

S: No. I don't think so.

E: So you think it would be 70 more than 80.

S: Yes.

E: Why did you think it might be 80?

S: Well it might be a little warmer because of the glass.

E: Do you think it makes any difference having that barrier there? Do you think any heat will go?

S: Well yes that's why. I think they'll be the same degrees.

E: No I don't want to influence you, but why do you think they'll be about the same?

S: Because they might just, they're almost right together now. It is almost as if you mixed them with that barrier.

E: What do you think that barrier does?

S: It just takes the hot water into the cold water just like I was talking about before.

E: It takes the hot water into the cold water?

S: Well it takes the heat, the cold heat into the warm heat.

E: So is some heat cold and some heat warm?

S. Um, yes.

E: How do you suppose it would do that? Does it go through that? (E points to the barrier)

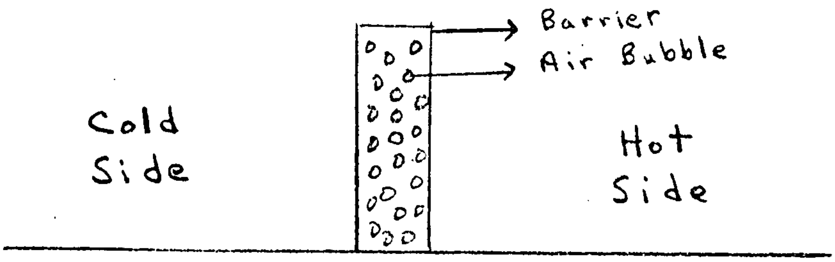
S: Yes, unless this is a special glass.

E: No I think it's just made out of green material so it would look differently. Let's just pretend here for a minute that we have, have you ever seen a microscope before?

S: Yes.

E: Let's say we had a real powerful microscope and suppose that we could look at the inside of that barrier. What might it look like inside? Do you suppose that you could draw for me on the blackboard how you think that the, when you say the cold heat would go this way and the warm heat would go the other way. How might that look? Do you think you might be able to do something like that for me?

S: Yes. I know exactly how it would look. Here's the barrier and inside is sort of bubbles like that, air bubbles, small small, small air bubbles. (S draws the following diagram on the blackboard)



E: This is inside the barrier? Which is the cold water and which is the hot water?

S: This is the cold water.

E: And this is the hot. So, inside the barrier there's tiny air bubbles. You think you could see those? How do you suppose the, how does the cold heat and the warm heat go through there?

S: Well this heat (S points to hot side) heats the -- I'll draw some bubbles down here too (at the bottom of the barrier). This hot water heats this (the barrier) and it travels through here. And this cold water cools this (the barrier) and it travels through here and it just meets and then this would be all the same temperature, this barrier.

E: Is this the cold water that's travelling through or is it the heat?

S: It's the heat.

E: What do you suppose the, what happens to the air bubbles?

S: I don't know. I guess nothing. Unless the heat, like there might be hot air in this one and cold air in this one. (S points to different bubbles in the diagram) I know. Cold heat travels faster than hot heat, right? It's more powerful, because when you turn on the tap at the same speed, say you have two nozzles, you turn on both taps and you put in the plug in the sink. Then you have them both going at the same speed, cold and hot, and when you stop them, it will be more cold than hot, the water.

E: So you think cold heat is what?

S: So this will obviously cool. This might grow a little warmer.

E: Do you think those bubbles have anything to do with it though?

S: No I don't think so.

E: If we had this real powerful microscope, do you suppose that we could see this heat? Do you think we could see heat? Would the cold heat look any different from the warm heat?

S: No I don't think so. Yes maybe it would. Yes it would, but I don't know what it would look like.

E: So why did you put the air bubbles in?

S: Cause I know that's what it looks like in the glass.

E: Does all glass have air bubbles in it?

S: Yes, everything does.

E: Everything?

S: Yes I think so.

E: Does water have air bubbles in it?

S: Yes. It has to, how do fish breathe? Unless it's cut off. If you keep a fish in a container of water so it can live in that water you know, it can't be fresh water unless it's a fresh water fish, then cut off the air, you know, put a seal over this, have a couple of fish in there and in a couple of days they'd use up all the air bubbles and they'd die cause there would be no air getting into the water.

E: Have you ever tried that or you just think that's what would happen.

S: I know that, I think I know.

E: I'm interested in what you think might happen if we pull that barrier up. O.K. let's pull that barrier up. Now what do you suppose is going to happen?

S: It will mix, the water. It will all be the same temperature. It won't be the same temperature, it will be a different temperature but it will be a little hotter than the cold water was to start with but the hot water will be colder than it was to start with.

E: So what do you think? The temperature on this side was 140 did we say?

S: That was 140 and that was 60.

E: And what do you think the final temperature of that mixture might be?

S: Between 80 and 90. Probably 95.

E: How did you arrive at that?

S: Wait, I'll figure it out another way. The hot water was 140 and the cold water was 60 so what's in between that? So in between that is I guess 100. And then the cold water will cool down the heat so I think it will be exactly what I said between 90 and 95, that's what I think now.

E: You lost me in that last bit, you said first it would be 100 and then you said the cold water will do what?

S: Cool down the heat a bit.

E: I don't understand what you mean by that.

S: Well the cool water sort of rules the hot water, so it would be a little cooler than half way.

E: Do you want to try it?

S: Yes. Well I was wrong about that. It is 82 degrees.

E: Let's try a little different mixture this time. Why do you suppose it was 82?

S: The cold water would rule it. I guess the cold water rules it a little more than I expected. Do you want me to put this (the barrier) back in?

E: Yes. Now let's try a little different one this time. That's cold water yes. Put that much cold water in there. Is there an experiment you'd like to try? Do you see what I'm trying to do? One of them has twice as much. (the hot side has twice as much water) Now let's ask the same sort of questions. What do you think will happen after 10 minutes or so? What do you think the temperature of this (hot) water will be?

S: After 10 minutes? Do you take this out? (S points to the barrier)

E: No with it in.

S: It will be around 100 degrees.

E: And it was originally about 140. And what do you think that water (cold) will be?

S: About 80 degrees. No 70.

E: And why do you think it will be 70?

S: Because the hot water will warm this. (S points to the cold side) And the other water will cool the hot.

E: And it wouldn't get any hotter than the 70? O.K. let's, do you want to pull it again. What do you think the temperature of that water will be now?

S: 95 to 100 no 95 to 105.

E: Now why do you think that?

S: I know it will be a little hotter than it was before because there's more hot water, that's why.

E: O.K. do you want to try it. It looks like you were right on that time.

S: It's 102 or 103.

Task Number Three

E: O.K. What do you think some of those things are? (E brings out an aluminium tray containing a number of different objects)

S: Cubes and sort of circles round you know.

E: Can you tell me what those cubes and round things are made out of?

S: Sugar.

E: Which one is sugar?

S: This one. (S points to a mothball)

E: Do you want to smell that sugar? Does it smell like sugar?

S: No, what is it?

E: Have you ever smelled that smell before?

S: Yes, I can't remember what it is.

E: Have you ever seen them in a trunk that your mother keeps closed? To protect them against moths.

S: Oh yes, that's right.

E: Now do you know what it is?

S: No, I uh mothballs?

E: That's right. What about these other things?

S: Metal, butter, wood, tin, brass, sugar.

E: Now I'm just going to move a few of these things here so that we can keep them separated. What do you suppose we're going to do with these?

S: I don't know. I guess that's just the weight of it, it felt like a magnet a bit.

E: What do you suppose that is? (E places another object on the tray)

S: I can't see it. Ice cubes?

E: Yes. Now do you know what I'm going to do with it? (the tray full of objects)

S: No.

E: Do you know why I put this up here? (E places the tray on the hot plate)

S: Are you going to melt it?

E: I don't know, do you suppose that would

S: You're going to put all these on there (the hot plate) right?

E: Yes.

S: You're going to see which melts first and see which heats first. Now I think the ice will melt first, then the butter, and then the sugar and the wood will, well it will heat first.

E: What about the mothball?

S: What is a mothball made out of?

E: I don't know. What's it feel like?

S: Sort of salty. How are these made?

E: I really don't know.

S: What makes them?

E: I think they're manufactured some place.

S: Why to you put mothballs in a trunk?

E: To keep moths away. You know what moths do to clothes.

S: Well I never knew that before. I always thought a mothball was something that moths made.

E: So you think, which is going to melt first?

S: The ice.

E: The ice cube and then?

S: The butter, the sugar and then the mothball if it does melt at all.

E: Do you think it might not melt at all?

S: Yes, I don't know, does salt melt? Do you want to try it?

E: I haven't got any. Maybe you could try it some other time. What about brass?

S: O.K. Now it won't melt.

E: You don't think it will melt?

S: It will if it gets to a certain extent. You know, how do you think they moulded this? It will but I don't think it would melt a lot. And the wood will get hot I suppose, I don't think it will burn.

E: What about the wire? (solder rolled up into a ball)

S: Well it will get hot. I'll show you what get's hot first. The wire will get hot first, no the tin will get hot first, the wire and the brass last. And then, no the wood last, then the brass and then the wood.

E: When you say get hot, what does that mean?

S: Heat up.

E: And how will we know?

S: Feel it.

E: Just by feeling it, and we wouldn't see it melt?

S: No.

E: Why don't these other things melt?

S: You mean these things? They are solid substances.

E: This (sugar) is solid. So is this (ice cube)

S: They have got air bubbles. I don't know.

E: Have you any idea why some things melt and others don't?

S: Because they have, uh I don't know.

E: Do you want to put it on? (S puts tray on the hot plate) Now what's happening?

S: The ice is melting and the mothball is melting. The sugar isn't.

E: Well it looks like you were right. I didn't notice which melted first did you?

S: Well you can't really tell with the water and the butter.

E: Now how about those other things, do you suppose they are getting hot? I wonder how we'd find out. (S attempts to take the temperature of the wood with a thermometer) Can you see the temperature?

S: It's 95 degrees right now.

E: What about some of the other things? Actually I think we'd better take it off. What is going to happen when I take it off?

S: It will cool down.

E: What about (S interrupts)

S: The butter is hotter (S proceeds to touch some of the 32 objects) Now it isn't so hot. That (brass) is the hottest, that's (steel) the second hottest, that's (wood) the coolest. This doesn't even melt. The sugar.

E: Why do you suppose it doesn't melt? Why did you think it would melt?

S: I know. I always thought it was the heat in the coffee that would melt the thing (the sugar) but I guess it's just the liquid.

E: Melt the?

S: Melt the sugar in the coffee.

E: I suppose there's a way we could find out that couldn't we?

S: Yes.

E: How would we do that?

S: Get the water back again.

E: That's something you could try at home. Why do you suppose the sugar cube didn't melt? No, let's try it the other way around. Why did you think it would melt?

S: Because of the heat. Like I always thought it was the heat in the coffee, that would make it melt. But now I know it's the liquid.

E: You think it's the heat that makes the butter melt and the ice cube?

S: Yes.

E: How does it do that, do you suppose?

S: I know that from making fresh buttered popcorn you melt the butter. And ice cubes melt in the sun.

E: How do you suppose the heat does that? (10 second pause) Could you use our powerful microscope again and tell me how you think, say something like a piece of ice melts, take a look at a piece of ice here.

S: It will melt because of the room temperature.

E: And what's making it melt?

S: The room temperature or the temperature of that. (the paper towel on which the ice cube was resting)

E: How does it do that?

S: Because this (ice cube) is on the surface.

E: How does the room temperature make it melt?

S: Just from the heat waves.

E: And what do the heat waves do?

S: They transfer into that (ice cube) and make it water, cycle it back to water, I guess that's what you call it. Just like when you take the steam into water, first you have water, then make it into steam, then you have water again. What do you call that again?

E: It's not important. Do you suppose we could measure the temperature of that ice cube?

S: Yes.

E: What do you think the temperature of that might be?

S: What is freezing temperature? Oh yes 32 degrees. I think that will be 32 degrees. No. I think it will be 15 degrees.

E: Why do you think it will be colder?

S: I just think it is.

E: What do you think the temperature of that would be? (E brings out a much larger ice cube)

S: Around 15 degrees. Same temperature.

E: Same temperature even though it's bigger?

S: Yes.

E: Now if we put that, if I take this and I put this ice cube into here (a beaker of water) what do you suppose will happen?

S: It will melt.

E: Why will it melt?

S: Because of the,that water. It's hotter than 15 degrees cause it is 60 degrees. So it is warmer than the ice cube and the heat rays in the water will transfer into the ice cube and melt it back to water. And that water will raise.

E: That water will what?

S: Raise what it was.

E: Which water?

S: The water in there, because of the ice cube melting.

E: Oh I see, you mean the level. I thought you meant raise the temperature. What will happen to the temperature of the water?

S: This (the water) will get colder.

E: The water. What about the temperature of the ice cube, what will happen to it?

S: It will get warmer. That's why it will melt.

E: How hot do you think we can get that ice cube?

S: Without melting it?

E: Well if we leave that ice cube sitting in warm water for 10 minutes, how hot do you think the ice cube will get?

S: Well before melting you mean or just before it disintegrates?

E: Just how hot do you think the ice cube is now?

S: The same temperature. No it's 32 degrees or more, you know 33, 34, something like that.

E: Now could we get the temperature of ice to go up even higher, let's say if we put this (the ice cube) on the heat.

S: Yes I guess so. Before it disintegrates, it would get hot.

E: How hot do you think it would get?

S: What is the body temperature?

E: I think it's 90 something.

S: I think it would get up to 100 degrees, it would probably get up to boiling.

E: And then what would happen?

S: Then it couldn't get any higher. Until it disintegrates and then it would boil.

E: And what would happen to the temperature of the water?

S: It would get hotter too. It's the water that is getting hot and transferring into the ice cube. If it is in the water but if you put the ice cube on the hot plate alone, then it would be the ice cube itself that was getting hot.

E: Now if I put this onto the hot plate by itself, what's getting hotter now?

S: The ice cube.

E: And how hot do you think we can get it? If we put a thermometer in the middle of the ice cube say to measure it.

S: What's boiling temperature?

E: 212.

S: O.K. it would get up to 212 degrees.

E: What about, now you were saying something about the water? Is that the water that's coming off the ice cube?

S: No it's the water in there. (the beaker)

E: So the water in here, what will happen to it?

S: It got hot and then the ice cube gets hot at the same time because the water has fumes of heat and it goes into the ice cube.

E: That's what I wanted to know. Let me just draw this here so I can see if I understand. There's the jar and here's the water and here's the ice cube. Now can you show me what you mean when you say what's getting hot.

S: Shall I draw a hot plate too.

E: No let's not put it on a hot plate so it's not on a hot plate.

S: The water is 70 degrees.

E: Let's say the water is 70 degrees. Before we put the ice cube in.

S: Now the fumes from here (the water) go into that (the ice cube). While the fumes in here (the ice cube) are about 70 degrees.

E: So the ice cube then becomes 70 degrees. And then what happens to the water?

S: It gets cooler.

E: Oh the water gets cooler. I thought you said it got hotter.

S: If it's on a hot plate it would.

E: I see what you were meaning, it was on the hot plate. No I meant if it was just standing out. So what would the temperature of the water get to?

S: It would be lower.

E: Why is that?

S: Because of the ice cube.

E: Let's say the ice cube melts down to that size, so we'll just draw a small ice cube in here, now how hot do you think that ice cube is, first of all, this is 10 minutes, how hot do you think that water would be now?

S: 55 - 60 degrees.

E: O.K. let's put that down. Let's say 55 degrees O.K? Now how hot do you think the ice cube is?

S: The same temperature.

E: You think it would be the same temperature?

S: No it would be around 45 degrees. Cause it's getting hotter while this (the water) is getting cooler.

E: I thought that the ice cube was 70 degrees before.

S: I was wrong. Say it was 30 degrees before. No, it was 35 degrees before.

Task Number Four

E: What do you suppose is going to happen if I heat that up? (E initiates a new task by bringing out a rod with three pins attached using wax)

S: The rod? The wax will melt and the pins will drop.

E: Have you done this before have you?

S: No.

E: How did you know that would happen?

S: Cause I knew that was wax on there and that it would melt as the rod got hot.

E: Why is that?

S: Because if you transfer the heat into the wax, the wax melts.

E: Now what transfers the heat into the wax?

s; The rod.

E: But I'm heating the rod way over here.

S: I know but the whole rod will get hot.

E: Why is that?

S: Cause it's all joined together, the same thing. How about if we heat it over there. (S points to a place on the rod close to the pins)

E: Where?

S: Right there. You see if those drop off, then we'll know. Right? Then we'll know if the rod get's hot.

E: Why do you think the whole rod gets hot?

S: Cause it's all one substance. It's all joined together. It keeps on transferring the heat to there and to there and there.

E: How do you suppose it does that?

S: It just travels through the rod. Just from the heat rays, you know.

E: Yes. Does it travel through all things?

S: No.

E: Does it travel through the air?

S: Yes.

E: What things doesn't it travel through? (10 second pause)

S: I guess it does travel through all things.

E: Can't think of anything that it doesn't?

S: No. (S starts to touch the rod near the first pin)

E: Is it hot there? I guess that's a way of finding out isn't it? Just by feeling it. Which pin do you think will fall? (pin nearest the candle flame drops)

S: I was just about to say that.

E: Why?

S: Cause it travels along and so it goes to there and it travels to there and there. (S motions along the rod)

E: I see. (E places a number of different sizes and types of rods. on the table in front of S) Have you ever seen anything like these before?

S: This is copper. This is metal I suppose. (S picks up an aluminium rod)

E: Now I haven't put pins on all those rods but what do you suppose this one here is exactly the same as that one there (a copper rod similar to the one used in the demonstration) Which do you think will travel fastest in which rod? (E also hands S a much thicker aluminium rod)

S: This one (copper) Cause it's smaller. It doesn't have as much rod to get the heat to.

E: What about between these two? (E hands S a copper rod and an aluminium rod of the same size)

S: This one. (copper) Cause we did that in the other experiment to see which one got hotter and the copper one did. Remember?

E: With the cubes?

S: Yes. So this one (copper) definitely.

E: Did we use one, we didn't use this type did we?

S: That's metal isn't it?

E: I think it's a type of metal, yes.

S: We used it, we had a metal tube.

E: Yes maybe we did. So, why do you think it travels faster in the copper?

S: Cause it's just a certain kind of chemical.

E: Do you know why it might travel faster here (copper rod) than in here?(aluminium rod)

S: No.

E: Do you want to feel it?

S: Well this (copper rod) is definitely heavier. It might just because it is bigger.

E: You said it would travel faster in the smaller rod, when you had these two.

S: That's because they were the same substance.

E: O.K. let's take a look at these two (E hands S a solid copper and a hollow copper rod)

S: Are they the same substance?

S: Yes.

S: Then it will travel faster in this one (hollow copper rod)

E: Why?

S: Because it doesn't have to fill in the hole. It's hollow. Because just the same as this, only this is smaller, it doesn't have to fill as much and that one is smaller than that one I think.

E: It's smaller because?

S: Because it's hollow.

E: What about these two? Do you think it would travel in these? (E hands S a solid and a hollow glass rod)

S: Yes.

E: Do you know what these are?

S: Glass.

E: Which do you think it will travel faster in?

S: Are they both hollow?

E: No, this one's solid.

S: The hollow one.

E: You think it will travel faster in the hollow one.

S: No I don't. I've changed my whole thing around. Now, because the air can get in there and cool it down. Correct?

E: I don't know. I should try that. What do you think?

S: That's what I think. This (solid glass rod) will travel faster and this (solid copper rod) will travel faster.

E: Let's try the glass ones first. You think it will travel faster in the hollow one or the solid one?

S: The solid one.

E: And the reason why?

S: Is because the air can get in the hollow one and cool it down.

E: You think the air will cool it down? Why would it do that?

S: From the rays, just like in the water, the room temperature water and the hot water.

E: And so that would be also the case here too?

S: Yes.

<u>Task Number Five</u>

E: O.K. we're just going to take a real quick look at another thing here. I'm curious to see what you might think of this. Do you want to just take a look at that and see.

S: What is it? It's a metal bar. With, I don't know what that is.

E: That's the dial. And can you see what's on the back of the dial?

S: A pin.

E: A pin on it. Now watch what happens when I, I'm going to rest the metal rod on the pin O.K? Now watch what I'm going to do now. (E slowly moves the metal rod with his hand so that the dial turns) See I'm just going to move the rod along there like that. Can you see what happens to the dial? And then I move it back. So if you move it that way, the dial turns that way and if you move it this way it turns that way. Now I'm going to take and put that rod on the needle. Is that just about zero? (E lines up dial to zero point)

S: Yes. There, that's pretty good.

E: Now what do you think we're going to do?

S: Heat the rod?

E: Yes, then what's going to happen?

S: It will heat the pin.

E: Why do you think it will heat the pin?

S: Cause it transfers heat.

E: And then what do you suppose might happen?

S: Heat the paper I guess.

E: Is anything happening?

S: Yes, it's getting dark.

E: Did you set the dial at zero?

S: Yes. It moved. It's moving. It's at 10. It's moving, it's at about 12 now. How does that do that? I can't understand it.

E: I gave you some clues.

S: Well is the rod moving? I guess it's melting and stretching.

E: How do you think it might do that?

S: From the heat. I see it melting in one place sort of. It's 20 now. I guess that's the temperature, it measures how hot that bar is eh?

E: Well how do you think it does that though? Why does that move?

S: I guess it melts that and it stretches and then it turns the thing.

E: Is there something we could do to that to find out?

S: No.

(E blows out the two candles that were heating the rod)

E: Is anything happening to the dial now?

S: No. Hey it's going back. It's going back to zero. I guess because the rod is cooling off. It must shrink.

E: How do you suppose the heat makes it do that?

S: I don't know.

E: Can you dream up any ideas? (E places ice cube on rod)

S: It's going back to zero (15 second pause as E and S watch the effect of the ice cube on the rod) It's at zero.

E: Are you waiting to see what happens when it cools down?

S: Does that raise and go down?

E: What?

S: The rod.

E: No. Why?

S: I thought when you do that, I thought I saw it raise.

E: No I moved it and it moved back like that. Do you think all metals would do that?

S: Yes.

E: What happens when you heat liquids up?

S: When you heat liquids? It rises.

E: How does it do that?

S: Just from the heat. I know! When you heat something like hot water, it gets bubbles in it right? And when the bubbles come in, it takes up space and that's why the water rises.

E: Where do the bubbles come from?

S: I knew you were going to ask that. I don't know.

E: Could you apply that idea to the rod here?

S: Maybe the rod raises no. I can't understand it. This has stumped me.

E: Well it is late so we had better be getting you back to school now.

APPENDIX B

Diagrams of the Interview Room and the Apparatus Used in Some of the Tasks

Figure B-1 Diagram of Room Used to Interview the Subjects

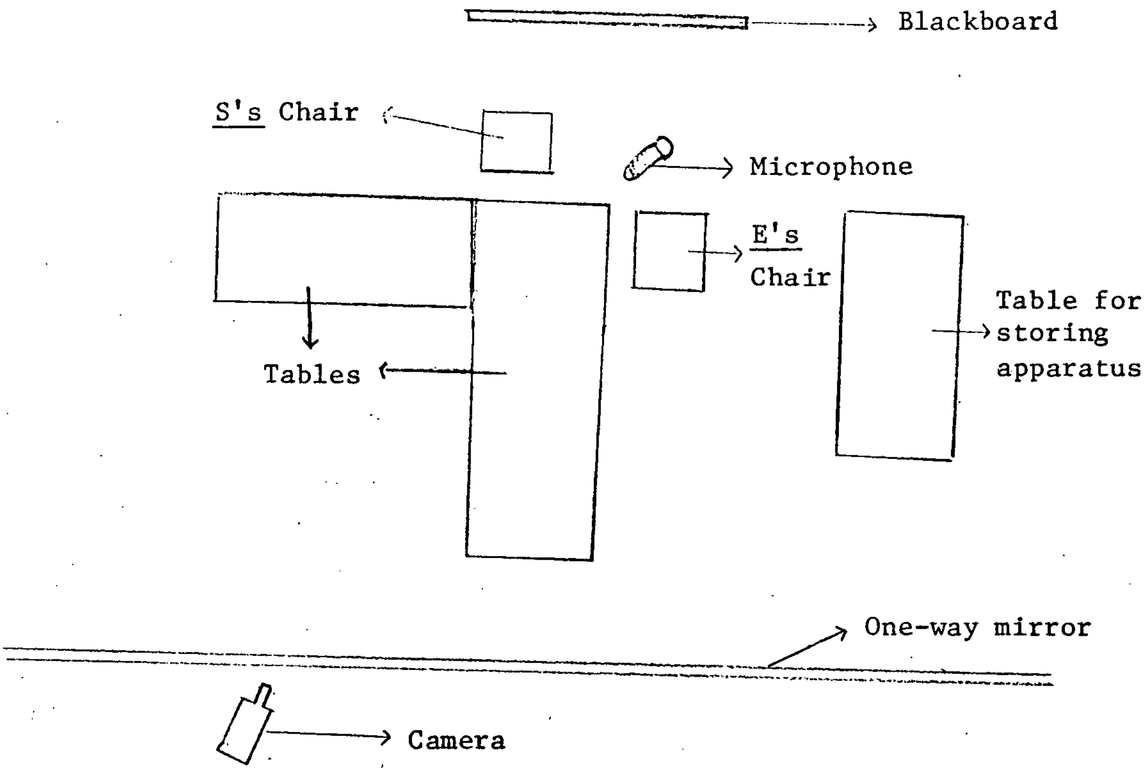
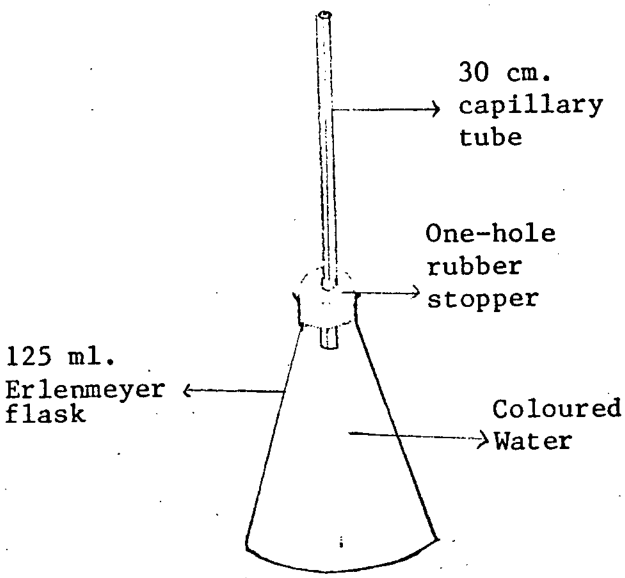


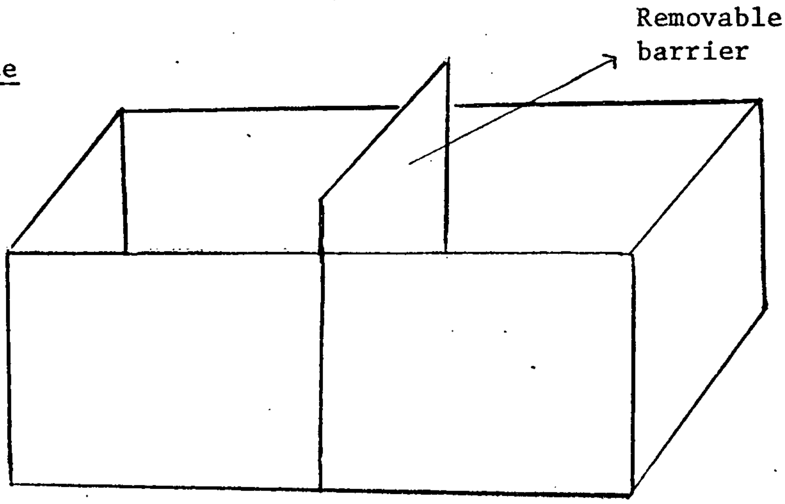
Figure B-2 Diagrams of the Apparatus Used in Some of the Interview Tasks

Task One



The Liquid Expansion Apparatus

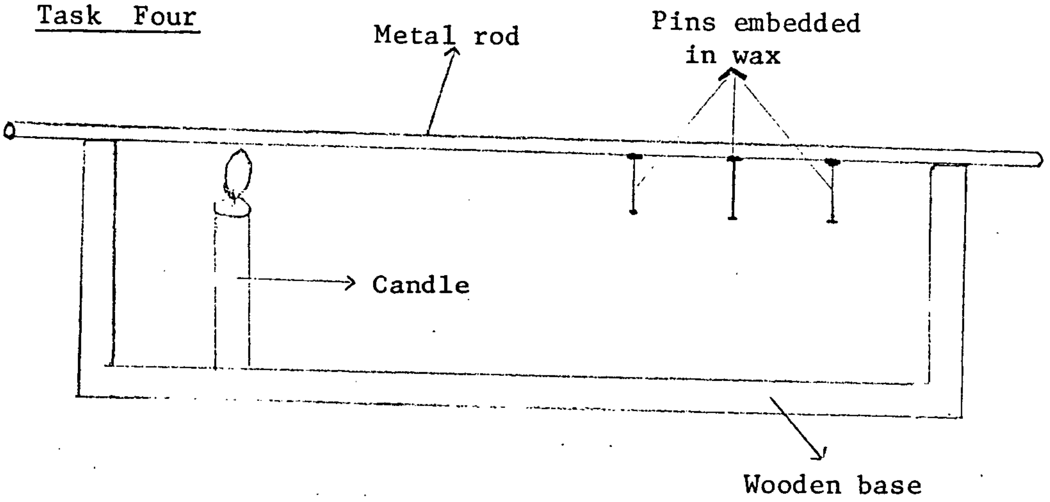
Task Three



Water-Mixing Apparatus

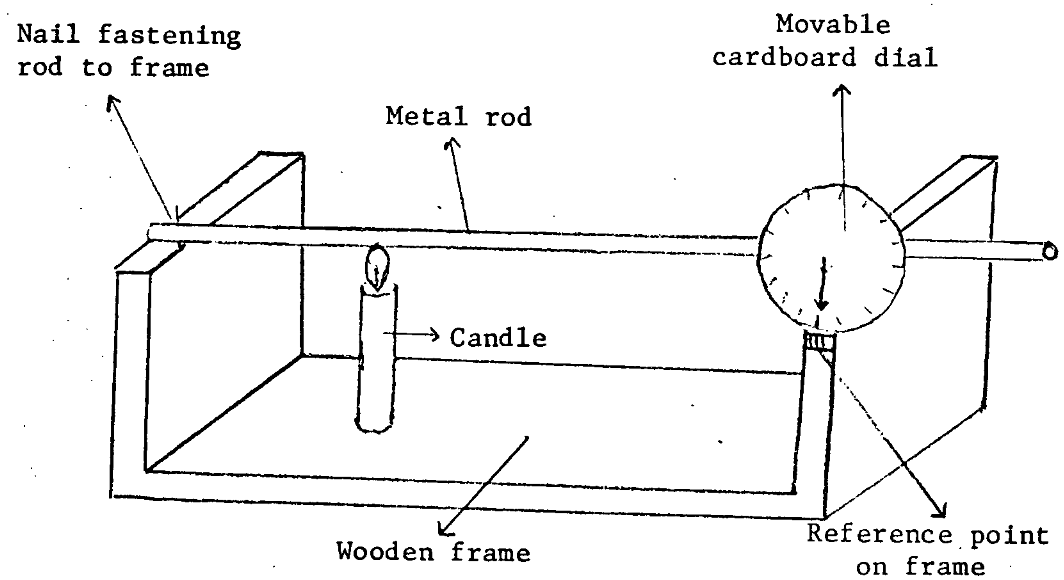
Figure B-2 Continued

Task Four



Transfer of Heat Apparatus

Task Five



Linear Expansion Apparatus

APPENDIX C

A Copy of the Conceptual Profile Instrument

Information Sheet

Name of School ______________________________

Your Grade _________

Your Age __________

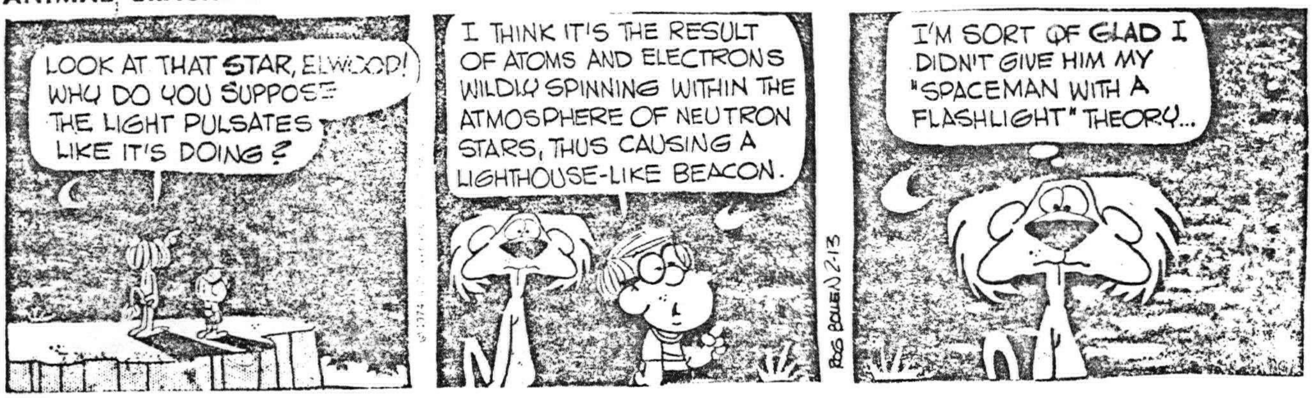
Have you ever studied about heat and temperature in school? _________

If yes, how long did you study it? _______________

In what grade(s) did you study it? ________________

Today we are going to do some experiments on heat and temperature and play a type of word game about these experiments. Before we do the experiments I want to explain how to play the game.

ANIMAL CRACKERS



Just as Elwood and Lyle had different ideas to explain a star in the cartoon, people often have different ideas to explain heat and temperature. In the word game after the experiments you will be shown a number of different statements that some people have used to explain what happened. I want to know how <u>YOU FEEL</u> about the ideas in these statements.

To practise, let's take a look at a statement about 'sickness' and I'll show you how the game works. Suppose the statement was:

People get sick because

THEY DO NOT GET ENOUGH VITAMINS.

As you can see there are 2 parts to this statement. The first part in small print tells us what the statement is about. In this example it is about people getting sick. The second part is in the box and is in CAPITAL LETTERS. It is an <u>IDEA</u> explaining why people get sick. I want you to tell me how you feel about this idea. After reading and thinking about the idea in the box suppose that you decide that people <u>always</u> get sick when they do not get enough vitamins. Then you should put a mark in the blank above "Very Much Agree" as shown below:

X						
Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree

But suppose you felt that people <u>often</u> get sick when they do not get enough vitamins. Then you should put a mark in the blank above "Somewhat Agree" as shown below:

______ :	X :	______ :	______ :	______ :	______ :	______
Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree

Or, you might feel that people <u>only sometimes</u> get sick when they do not have enough vitamins. Then you should mark the blank above "Slightly Agree" as shown below:

______ :	______ :	X :	______ :	______ :	______ :	______
Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree

Suppose that you really cannot decide if vitamins are related to sickness or not. What blank would you mark?

REMEMBER that you should only mark one blank in each row.

I am also interested in other ways you feel about the same idea. For example, in the second row on each page you are to decide if the idea is clear or confusing. There are six rows which ask you how you feel about the idea in the box at the top of the page. You are to put ONE mark in each row.

Let's work through two other ideas on sickness to see if you understand how this game works. We will discuss any questions you may have after you have completed the next two pages.

People get sick because

GERMS ENTER THEIR BODIES AND CAUSE INFECTIONS.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

People get sick because

THEY GET TOO MUCH SLEEP.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The large rod heated up faster than the small rod because

THE LARGE ROD ATTRACTS MORE HEAT PARTICLES THAN THE SMALL ROD.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The large rod heated up faster than the small rod because

THE LARGE ROD HAS MORE METAL PARTICLES TO MOVE AROUND.

____ Very Much Agree	: ____ Somewhat Agree	: ____ Slightly Agree	: ____ Neither Agree nor Disagree	: ____ Slightly Disagree	: ____ Somewhat Disagree	: ____ Very Much Disagree
____ Very Clear	: ____ Somewhat Clear	: ____ Slightly Clear	: ____ Neither Clear nor Confusing	: ____ Slightly Confusing	: ____ Somewhat Confusing	: ____ Very Confusing
____ Very Easy	: ____ Somewhat Easy	: ____ Slightly Easy	: ____ Neither Easy nor Difficult	: ____ Slightly Difficult	: ____ Somewhat Difficult	: ____ Very Difficult
____ Very True	: ____ Somewhat True	: ____ Slightly True	: ____ Neither True nor False	: ____ Slightly False	: ____ Somewhat False	: ____ Very False
____ Very Familiar	: ____ Somewhat Familiar	: ____ Slightly Familiar	: ____ Neither Familiar nor Unfamiliar	: ____ Slightly Unfamiliar	: ____ Somewhat Unfamiliar	: ____ Very Unfamiliar
____ Very Much Like My Ideas	: ____ Somewhat Like My Ideas	: ____ Slightly Like My Ideas	: ____ Neither Like My Ideas nor Unlike My Ideas	: ____ Slightly Unlike My Ideas	: ____ Somewhat Unlike My Ideas	: ____ Very Much Unlike My Ideas

The large rod heated up faster than the small rod because

THE LARGE ROD HAS MORE AIR SPACES INSIDE FOR THE HEAT TO TRAVEL THROUGH.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The whole rod gets hot because

THE HEAT BUILDS UP IN ONE PART UNTIL IT CAN'T HOLD ANYMORE AND THEN THE HEAT MOVES ALONG THE ROD.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The whole rod gets hot because

THE FASTER MOVING METAL PARTICLES BUMP INTO EACH OTHER ALL THE WAY THROUGH THE ROD.

______ Very Much Agree	: ______ Somewhat Agree	: ______ Slightly Agree	: ______ Neither Agree nor Disagree	: ______ Slightly Disagree	: ______ Somewhat Disagree	: ______ Very Much Disagree
______ Very Clear	: ______ Somewhat Clear	: ______ Slightly Clear	: ______ Neither Clear nor Confusing	: ______ Slightly Confusing	: ______ Somewhat Confusing	: ______ Very Confusing
______ Very Easy	: ______ Somewhat Easy	: ______ Slightly Easy	: ______ Neither Easy nor Difficult	: ______ Slightly Difficult	: ______ Somewhat Difficult	: ______ Very Difficult
______ Very True	: ______ Somewhat True	: ______ Slightly True	: ______ Neither True nor False	: ______ Slightly False	: ______ Somewhat False	: ______ Very False
______ Very Familiar	: ______ Somewhat Familiar	: ______ Slightly Familiar	: ______ Neither Familiar nor Unfamiliar	: ______ Slightly Unfamiliar	: ______ Somewhat Unfamiliar	: ______ Very Unfamiliar
______ Very Much Like My Ideas	: ______ Somewhat Like My Ideas	: ______ Slightly Like My Ideas	: ______ Neither Like My Ideas nor Unlike My Ideas	: ______ Slightly Unlike My Ideas	: ______ Somewhat Unlike My Ideas	: ______ Very Much Unlike My Ideas

The whole rod gets hot because

THE HEAT PARTICLES FROM THE FLAME ARE ATTRACTED TO ALL PARTS OF THE ROD.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The wax melted because

IT WAS A SOFT SUBSTANCE.

____ Very Much Agree	: ____ Somewhat Agree	: ____ Slightly Agree	: ____ Neither Agree nor Disagree	: ____ Slightly Disagree	: ____ Somewhat Disagree	: ____ Very Much Disagree
____ Very Clear	: ____ Somewhat Clear	: ____ Slightly Clear	: ____ Neither Clear nor Confusing	: ____ Slightly Confusing	: ____ Somewhat Confusing	: ____ Very Confusing
____ Very Easy	: ____ Somewhat Easy	: ____ Slightly Easy	: ____ Neither Easy nor Difficult	: ____ Slightly Difficult	: ____ Somewhat Difficult	: ____ Very Difficult
____ Very True	: ____ Somewhat True	: ____ Slightly True	: ____ Neither True nor False	: ____ Slightly False	: ____ Somewhat False	: ____ Very False
____ Very Familiar	: ____ Somewhat Familiar	: ____ Slightly Familiar	: ____ Neither Familiar nor Unfamiliar	: ____ Slightly Unfamiliar	: ____ Somewhat Unfamiliar	: ____ Very Unfamiliar
____ Very Much Like My Ideas	: ____ Somewhat Like My Ideas	: ____ Slightly Like My Ideas	: ____ Neither Like My Ideas nor Unlike My Ideas	: ____ Slightly Unlike My Ideas	: ____ Somewhat Unlike My Ideas	: ____ Very Much Unlike My Ideas

The wax melted because

THE HEAT PARTICLES WENT INSIDE AND FORCED THE WAX PARTICLES APART.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The wax melted because

THE WAX PARTICLES WERE MOVING ABOUT SO FAST THAT THEY COULD NOT HOLD ON TO EACH OTHER SO WELL.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The metal cubes were hotter than the wood or sugar because

THE METAL CUBES DREW IN MORE HEAT PARTICLES THAN THE OTHER CUBES.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The metal cubes were hotter than the wood or sugar because

IT WAS MORE DIFFICULT FOR THE AIR TO GET INSIDE THE HARD METAL CUBES TO COOL THEM.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The metal cubes were hotter than the wood or sugar because

THE METAL PARTICLES ARE EASIER TO MOVE.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The metal cubes did not melt because

THEY WERE NOT HEATED LONG ENOUGH.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The temperature of the water decreased when an ice cube was added because

THE ICE CUBE ATTRACTED SOME OF THE HEAT PARTICLES AWAY FROM THE WATER.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The temperature of the water decreased when an ice cube was added because

SOME OF THE COLD LEFT THE ICE CUBE AND WENT INTO THE WATER.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The temperature of the water decreased when an ice cube was added because

THE WATER PARTICLES LOSE SOME OF THEIR SPEED BY BUMPING INTO THE ICE PARTICLES.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

A large ice cube takes longer to melt than a small ice cube because

THE LARGE ICE CUBE HAS A COLDER TEMPERATURE THAN THE SMALL ICE CUBE.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The red liquid in the tube went up because

THE HEAT MAKES THE RED LIQUID LIGHTER AND SO IT RISES.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The red liquid in the tube went up because

THE LIQUID'S PARTICLES MOVED MORE QUICKLY AND SO TOOK UP MORE SPACE.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

The red liquid in the tube went up because

THE HEAT PARTICLES TAKE UP SPACE INSIDE THE LIQUID AND FORCES THE LIQUID OUT THE TUBE.

______ Very Much Agree	: ______ Somewhat Agree	: ______ Slightly Agree	: ______ Neither Agree nor Disagree	: ______ Slightly Disagree	: ______ Somewhat Disagree	: ______ Very Much Disagree
______ Very Clear	: ______ Somewhat Clear	: ______ Slightly Clear	: ______ Neither Clear nor Confusing	: ______ Slightly Confusing	: ______ Somewhat Confusing	: ______ Very Confusing
______ Very Easy	: ______ Somewhat Easy	: ______ Slightly Easy	: ______ Neither Easy nor Difficult	: ______ Slightly Difficult	: ______ Somewhat Difficult	: ______ Very Difficult
______ Very True	: ______ Somewhat True	: ______ Slightly True	: ______ Neither True nor False	: ______ Slightly False	: ______ Somewhat False	: ______ Very False
______ Very Familiar	: ______ Somewhat Familiar	: ______ Slightly Familiar	: ______ Neither Familiar nor Unfamiliar	: ______ Slightly Unfamiliar	: ______ Somewhat Unfamiliar	: ______ Very Unfamiliar
______ Very Much Like My Ideas	: ______ Somewhat Like My Ideas	: ______ Slightly Like My Ideas	: ______ Neither Like My Ideas nor Unlike My Ideas	: ______ Slightly Unlike My Ideas	: ______ Somewhat Unlike My Ideas	: ______ Very Much Unlike My Ideas

Objects rubbed together get hot because

THE PARTICLES INSIDE THE OBJECTS MOVE FASTER.

____ Very Much Agree	: ____ Somewhat Agree	: ____ Slightly Agree	: ____ Neither Agree nor Disagree	: ____ Slightly Disagree	: ____ Somewhat Disagree	: ____ Very Much Disagree
____ Very Clear	: ____ Somewhat Clear	: ____ Slightly Clear	: ____ Neither Clear nor Confusing	: ____ Slightly Confusing	: ____ Somewhat Confusing	: ____ Very Confusing
____ Very Easy	: ____ Somewhat Easy	: ____ Slightly Easy	: ____ Neither Easy nor Difficult	: ____ Slightly Difficult	: ____ Somewhat Difficult	: ____ Very Difficult
____ Very True	: ____ Somewhat True	: ____ Slightly True	: ____ Neither True nor False	: ____ Slightly False	: ____ Somewhat False	: ____ Very False
____ Very Familiar	: ____ Somewhat Familiar	: ____ Slightly Familiar	: ____ Neither Familiar nor Unfamiliar	: ____ Slightly Unfamiliar	: ____ Somewhat Unfamiliar	: ____ Very Unfamiliar
____ Very Much Like My Ideas	: ____ Somewhat Like My Ideas	: ____ Slightly Like My Ideas	: ____ Neither Like My Ideas nor Unlike My Ideas	: ____ Slightly Unlike My Ideas	: ____ Somewhat Unlike My Ideas	: ____ Very Much Unlike My Ideas

Objects rubbed together get hot because

THE HEAT PARTICLES INSIDE THE OBJECT ARE FORCED OUT.

____ : Very Much Agree	____ : Somewhat Agree	____ : Slightly Agree	____ : Neither Agree nor Disagree	____ : Slightly Disagree	____ : Somewhat Disagree	____ Very Much Disagree
____ : Very Clear	____ : Somewhat Clear	____ : Slightly Clear	____ : Neither Clear nor Confusing	____ : Slightly Confusing	____ : Somewhat Confusing	____ Very Confusing
____ : Very Easy	____ : Somewhat Easy	____ : Slightly Easy	____ : Neither Easy nor Difficult	____ : Slightly Difficult	____ : Somewhat Difficult	____ Very Difficult
____ : Very True	____ : Somewhat True	____ : Slightly True	____ : Neither True nor False	____ : Slightly False	____ : Somewhat False	____ Very False
____ : Very Familiar	____ : Somewhat Familiar	____ : Slightly Familiar	____ : Neither Familiar nor Unfamiliar	____ : Slightly Unfamiliar	____ : Somewhat Unfamiliar	____ Very Unfamiliar
____ : Very Much Like My Ideas	____ : Somewhat Like My Ideas	____ : Slightly Like My Ideas	____ : Neither Like My Ideas nor Unlike My Ideas	____ : Slightly Unlike My Ideas	____ : Somewhat Unlike My Ideas	____ Very Much Unlike My Ideas

HEAT IS THE MOTION OF AN OBJECT'S PARTICLES.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

TEMPERATURE IS A MEASURE OF THE MIXTURE OF HEAT AND COLD INSIDE AN OBJECT.

____ Very Much Agree	: ____ Somewhat Agree	: ____ Slightly Agree	: ____ Neither Agree nor Disagree	: ____ Slightly Disagree	: ____ Somewhat Disagree	: ____ Very Much Disagree
____ Very Clear	: ____ Somewhat Clear	: ____ Slightly Clear	: ____ Neither Clear nor Confusing	: ____ Slightly Confusing	: ____ Somewhat Confusing	: ____ Very Confusing
____ Very Easy	: ____ Somewhat Easy	: ____ Slightly Easy	: ____ Neither Easy nor Difficult	: ____ Slightly Difficult	: ____ Somewhat Difficult	: ____ Very Difficult
____ Very True	: ____ Somewhat True	: ____ Slightly True	: ____ Neither True nor False	: ____ Slightly False	: ____ Somewhat False	: ____ Very False
____ Very Familiar	: ____ Somewhat Familiar	: ____ Slightly Familiar	: ____ Neither Familiar nor Unfamiliar	: ____ Slightly Unfamiliar	: ____ Somewhat Unfamiliar	: ____ Very Unfamiliar
____ Very Much Like My Ideas	: ____ Somewhat Like My Ideas	: ____ Slightly Like My Ideas	: ____ Neither Like My Ideas nor Unlike My Ideas	: ____ Slightly Unlike My Ideas	: ____ Somewhat Unlike My Ideas	: ____ Very Much Unlike My Ideas

HEAT IS A SUBSTANCE SOMETHING LIKE AIR OR STEAM.

______ Very Much Agree	: ______ Somewhat Agree	: ______ Slightly Agree	: ______ Neither Agree nor Disagree	: ______ Slightly Disagree	: ______ Somewhat Disagree	: ______ Very Much Disagree
______ Very Clear	: ______ Somewhat Clear	: ______ Slightly Clear	: ______ Neither Clear nor Confusing	: ______ Slightly Confusing	: ______ Somewhat Confusing	: ______ Very Confusing
______ Very Easy	: ______ Somewhat Easy	: ______ Slightly Easy	: ______ Neither Easy nor Difficult	: ______ Slightly Difficult	: ______ Somewhat Difficult	: ______ Very Difficult
______ Very True	: ______ Somewhat True	: ______ Slightly True	: ______ Neither True nor False	: ______ Slightly False	: ______ Somewhat False	: ______ Very False
______ Very Familiar	: ______ Somewhat Familiar	: ______ Slightly Familiar	: ______ Neither Familiar nor Unfamiliar	: ______ Slightly Unfamiliar	: ______ Somewhat Unfamiliar	: ______ Very Unfamiliar
______ Very Much Like My Ideas	: ______ Somewhat Like My Ideas	: ______ Slightly Like My Ideas	: ______ Neither Like My Ideas nor Unlike My Ideas	: ______ Slightly Unlike My Ideas	: ______ Somewhat Unlike My Ideas	: ______ Very Much Unlike My Ideas

ALL OBJECTS CONTAIN A MIXTURE OF HEAT AND COLD.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

TEMPERATURE IS A MEASURE OF THE NUMBER OF HEAT PARTICLES IN AN OBJECT.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

HEAT IS MADE UP OF TINY PARTICLES THAT CAN MOVE.

Very Much Agree	Somewhat Agree	Slightly Agree	Neither Agree nor Disagree	Slightly Disagree	Somewhat Disagree	Very Much Disagree
Very Clear	Somewhat Clear	Slightly Clear	Neither Clear nor Confusing	Slightly Confusing	Somewhat Confusing	Very Confusing
Very Easy	Somewhat Easy	Slightly Easy	Neither Easy nor Difficult	Slightly Difficult	Somewhat Difficult	Very Difficult
Very True	Somewhat True	Slightly True	Neither True nor False	Slightly False	Somewhat False	Very False
Very Familiar	Somewhat Familiar	Slightly Familiar	Neither Familiar nor Unfamiliar	Slightly Unfamiliar	Somewhat Unfamiliar	Very Unfamiliar
Very Much Like My Ideas	Somewhat Like My Ideas	Slightly Like My Ideas	Neither Like My Ideas nor Unlike My Ideas	Slightly Unlike My Ideas	Somewhat Unlike My Ideas	Very Much Unlike My Ideas

TEMPERATURE IS A MEASURE OF THE SPEED OF PARTICLES IN AN OBJECT.

____ Very Much Agree :	____ Somewhat Agree :	____ Slightly Agree :	____ Neither Agree nor Disagree :	____ Slightly Disagree :	____ Somewhat Disagree :	____ Very Much Disagree
____ Very Clear :	____ Somewhat Clear :	____ Slightly Clear :	____ Neither Clear nor Confusing :	____ Slightly Confusing :	____ Somewhat Confusing :	____ Very Confusing
____ Very Easy :	____ Somewhat Easy :	____ Slightly Easy :	____ Neither Easy nor Difficult :	____ Slightly Difficult :	____ Somewhat Difficult :	____ Very Difficult
____ Very True :	____ Somewhat True :	____ Slightly True :	____ Neither True nor False :	____ Slightly False :	____ Somewhat False :	____ Very False
____ Very Familiar :	____ Somewhat Familiar :	____ Slightly Familiar :	____ Neither Familiar nor Unfamiliar :	____ Slightly Unfamiliar :	____ Somewhat Unfamiliar :	____ Very Unfamiliar
____ Very Much Like My Ideas :	____ Somewhat Like My Ideas :	____ Slightly Like My Ideas :	____ Neither Like My Ideas nor Unlike My Ideas :	____ Slightly Unlike My Ideas :	____ Somewhat Unlike My Ideas :	____ Very Much Unlike My Ideas

APPENDIX D

AN ITEM ANALYSIS* OF THE THREE HEAT PERSPECTIVES IN THE CONCEPTUAL PROFILE INSTRUMENT

Legend for the Tables

(1) C.P.I. Item: Refers to the number of the item on the Conceptual Profile Instrument.

(2) Belief Scale: 1 = agree-disagree bipolar scale
4 = true-false bipolar scale
6 = like ideas-unlike my ideas bipolar scale

(3) Mean Score: The average score obtained on that scale for all all 276 subjects. It was a 7 point scale.

(4) Standard Deviation: The average deviation of scores on that scale for all of the subjects.

(5) ST Correlation: The correlation coefficient of the scale score and the item score corrected for overlap.

(6) TT Correlation: The correlation coeffieient of the scale score and the total score on all of the items for a particular heat perspective.

(7) Hoyt's Reliability: This is Hoyt's reliability coefficient for a given item.

(8) Standard Error: This is the standard error of measurement for a given item.

* The computer program used to perform the analysis is entitled LERTAP and is available from the statistics laboratory in the Faculty of Education, University of British Columbia.

TABLE D-1

An Item Analysis of the Statements Representing the Kinetic Perspective

C.P.I. Item	Belief Scale	Mean Score	Standard Deviation	ST Correlation	TT Correlation	Hoyt's Reliability	Standard Error
2	1 4 6	3.21 3.04 4.06	1.75 1.47 1.79	.737 .698 .599	.478 .498 .447	.82	1.50
5	1 4 6	3.73 3.56 4.05	2.00 1.81 2.02	.811 .790 .705	.627 .617 .637	.88	1.49
9	1 4 6	3.80 3.63 4.13	1.95 1.80 1.88	.861 .846 .754	.659 .631 .645	.91	1.27
12	1 4 6	3.97 3.76 4.24	1.85 1.58 1.75	.780 .779 .718	.532 .508 .520	.87	1.35
16	1 4 6	4.06 3.90 4.35	1.90 1.77 1.92	.770 .803 .650	.652 .649 .606	.86	1.50
19	1 4 6	3.20 3.17 3.58	1.84 1.77 1.85	.842 .882 .742	.572 .623 .641	.91	1.23
Overall Statictics for Kinetic Perspective (n=276)		67.43	19.24			.89	6.25

TABLE D-2

An Item Analysis of Items Representing the Children's Perspective

C.P.I. Item	Belief Scale	Mean Score	Standard Deviation	ST Correlation	TT Correlation	Hoyt's Reliability	Standard Error
	1	3.86	2.09	.752	.408		
3	4	3.69	1.83	.797	.435	.86	1.56
	6	4.16	1.83	.661	.370		
	1	2.98	1.96	.799	.540		
4	4	3.01	1.79	.795	.430	.88	1.45
	6	3.28	1.88	.697	.444		
	1	3.19	2.12	.863	.515		
7	4	3.09	2.01	.886	.546	.92	1.31
	6	3.23	2.02	.778	.507		
	1	3.14	1.89	.821	.499		
11	4	3.07	1.71	.812	.485	.89	1.32
	6	3.50	1.82	.732	.450		
	1	4.28	2.38	.846	.397		
13	4	4.13	2.34	.888	.459	.92	1.54
	6	3.98	2.27	.757	.448		
	1	3.49	2.02	.821	.531		
14	4	3.55	1.92	.852	.511	.90	1.39
	6	3.75	1.95	.735	.471		
	1	3.72	2.21	.834	.542		
18	4	3.62	2.11	.875	.555	.90	1.50
	6	3.78	2.90	.716	.468		
Overall Statistics for Children's Perspective (=276)		87.06	23.92			.86	8.73

TABLE D-3

An Item Analysis of Items Representing the Caloric Perspective

C.P.I. Item	Belief Scale	Mean Score	Standard Deviation	ST Correlation	TT Correlation	Hoyt's Reliability	Standard Error
	1	2.27	1.37	.616	.393		
1	4	2.37	1.36	.594	.451	.70	1.59
	6	3.60	1.76	.400	.293		
	1	3.43	1.96	.798	.540		
6	4	3.42	1.75	.810	.520	.88	1.43
	6	3.95	1.85	.683	.544		
	1	3.29	1.73	.754	.443		
8	4	3.11	1.49	.736	.490	.85	1.39
	6	3.64	1.71	.659	.505		
	1	1.87	1.10	.765	.510		
10	4	2.09	1.21	.745	.491	.85	1.05
	6	2.46	1.45	.683	.451		
	1	2.33	1.49	.782	.433		
15	4	2.38	1.37	.796	.413	.88	1.11
	6	2.53	1.55	.746	.384		
	1	2.57	1.62	.767	.501		
20	4	2.59	1.48	.838	.499	.88	1.24
	6	3.09	1.79	.725	.542		
Overall Statistics for Caloric Perspective (n=276)		50.98	13.14			.79	5.92

Discussion

The data summarized in the preceeding three tables substantiates the results obtained from the factor-analytic procedures. That is, there is a relatively high degree of inter-correlation between the three belief scales for a particular item as indicated by the ST correlation. (See Section 4.41 in text) There is also a fairly high positive correlation between items for a particular heat perspective -- the TT Correlation.

On the basis of the Hoyt reliability coefficients all of the items would appear to be reliable. However, perhaps the best indicator of how a particular item is functioning (in terms of its contribution to a particular heat perspective) is the TT correlations between the scale responses for an item and the total score on all of the items representing a particular heat perspective. Using this criterion two items on the Caloric Perspective, items 1 and 15 are questionable since they contain TT correlations which are below .40. Also two items on the Children's Perspective contain low correlations on one of the three scales, items 3 and 13. It is interesting to note that two of the above items, numbers 1 and 3, were omitted from the profile analysis because they they failed to load highly on those components identified as the three 'built in' heat perspectives. (See Section 4.42 in the text) While the correlations for the other item omitted from the profile analysis, item 2, are not as low, they are significantly lower than those reported for the other items in the Kinetic Perspective.

Further, the results expressed by the standard error of measurement indicate that the scores obtained from the belief scales of the C.P.I.

are accurate to within plus or minus three-quarters of a scale division (seven scale divisions were used). Hence some confidence can be expressed in interpreting the belief scores from the C.P.I. In summary, the item analysis indicates that the care taken in the preparation and field testing has yielded a fairly reliable instrument.