THE UNIVERSITY OF ALBERTA

THE PREDICTING ABILITIES OF ELEMENTARY SCHOOL CHILDREN

by

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(C)

A THESIS

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If you don't have predictions,

not too many things could be real.

(Lynn, Grade Four)

THE UNIVERSITY OF ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled

THE PREDICTING ABILITIES OF ELEMENTARY SCHOOL CHILDREN

submitted by Kathleen W. Melville in partial fulfillment of the requirements for the degree of Master of Education.

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ABSTRACT

This study was undertaken for three purposes: to identify the course of development through the elementary grades of children's ability to make predictions; to gather information regarding evaluation of the process of predicting; and to gain insight into children's understanding of the process of predicting. The study involved observing the performance and assessing the achievement of 168 children on a paper and pencil test and a physical manipulation test; interviews with each child were also conducted.

Results indicate that children's ability to make predictions shows a marked increase between grades one and two, and continues to show gradual, progressive growth throughout the grades. Reasons for the low achievement of the grade one children are explored in the study. The findings suggest that opportunities for elementary school children to practice the process of predicting should be provided across the grades.

Although both tests may serve as indicators of children's predicting ability, the physical manipulation test seems to be the more useful test. Further, it appears that the predicting ability of children might be most meaningfully assessed within a more natural setting than a test situation.

The pattern of growth and development in children's knowledge and understanding of the process of predicting seems to parallel their growth in ability to make predictions. Children seem to understand predicting to be an internal process in which one uses knowledge to anticipate a future event, and to regard predicting as a way of being intellectually involved with the world. Thus, it is important to deal with children's efforts in prediction tasks in a sensitive, caring manner, with respect for their intellectual endeavors.

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Introduction to the Study

Background

Over the last twenty-five years or so, since the revolution in science education brought about by the Sputnik era, educators have attempted to clarify for themselves the nature of science that should be taught in school. Many educators found it helpful to regard science from the point of view of its dualistic nature, as not only a body of information--product--but also as a method of investigation--as inquiry and discovery, or "process". Historically, product rather than process had been stressed when teaching science in the elementary school, and other aspects of science instruction, such as the affective, had been all but ignored. Efforts to change this began in the 1960's (Martin 1983, Matala 1961).

Programs developed in the 1960s emphasized process over concept development in science and offered a delineation and a description of the processes thought to be important enough to teach. The processes identified by the American Association for the Advancement of Science as appropriate to young children were those thought to characterize the work of the scientist, processes such as observing, classifying, measuring, and predicting. (These are discussed in relation to the Science-a Process Approach program in Chapter Two.) Science programs developed in the 1970s differed slightly from earlier programs in the balance of emphasis on concepts and processes but continued the inquiry-oriented, hands-on, child-centered approach of the sixties programs. These changes, and more recent changes, seem to reflect a search for something more likely to be accepted by teachers and to be more widely used in the classroom; there is less concern now for further comprehensive change to the foundation of the program (Martin 1983).

The Alberta Elementary Science Curriculum Guide of 1983 recognizes the dualistic nature of science but with added attention to the psychomotor and affective aspects.

> Science is at one and the same time, a body of knowledge and a process of inquiry. Science experiences should be based on enquiry and should involve students in developing and practicing the process skills, in learning new concepts, in developing psychomotor abilities and acquiring positive attitudes toward science and itself. The science program reflects the importance of all these components in its curriculum and instruction. (p ii)

The emphasis in science curriculum intended for implementation in Alberta schools is evident from the following suggestion:

> The teaching of science as inquiry is the basic instructional strategy recommended in the Alberta elementary science program of studies. (p. 4)

The guide goes on to indicate that:

> Inherent in the process of inquiry is the development of those skills and strategies that lead to abilities in gathering and applying information toward answering questions and solving problems. (p. 4)

Alberta curriculum guidelines indicate that processes similar to those delineated by the American Association for the Advancement of Science are to be considered central to the nature of inquiry; these processes are emphasized in some of the recommended Alberta curricula. A mandate has thus been given to Alberta teachers to develop the abilities of children not only in the area of content acquisition but, additionally, in the process component of the scientific enterprise.

The process approach gained a certain amount of popularity in the 1960s and is still reflected in the activity orientation of virtually all modern science programs. The process approach to teaching at the elementary level has been shown to improve student's performance in general achievement, analytic skills, process skills, reading, mathematics, social studies, and communication skills (Shaymansky, Kyle, & Alport, 1983). Research also demonstrates a positive relationship between practice in science process skills and development of logical or formal thinking abilities (Linn & Thier, 1975; Padilla, Okey, & Dillashaw, 1983).

Predicting is one of those skills, or processes, that contributes to the more general "process of inquiry" that is now such an accepted part of elementary science programs. The ability of children to predict is but one of the process skills that must be fostered, but it is of special interest and importance considering its potential application to life experiences.

The Process of Predicting

The nature of predicting will be discussed in more detail in Chapter Two but here some definitions will be considered.

Predicting and prediction have been defined in a multiplicity of ways and it is possible that children's abilities in predicting and their understanding of what it is all about may reflect this variety. The following definitions are representative of predicting from both a general and a specific point of view:

> To predict is usually to foretell with precision of calculation, knowledge, or shrewd inference from facts or experience, e.g.: The astronomers can predict an eclipse. (Random House Dictionary, p. 1133)

> A prediction can be formulated only after a series of observations and measurements have been made, and their relationships have been determined. On the basis of the analysis of previous data, one can predict or forecast what future observations will be. (Trojcak, 1979, p. 158)

> Prediction is a specific forecast of what future observation will be. (AAAS Program, p. 109)

> [Prediction is] the use of existing data, information and perceptible patterns and trends in order to suggest future outcomes and occurrences. (Alberta Education Curriculum Guide, 1983, p. 8)

> A prediction is a forecast of what a future observation will be. It is based on observation, measurements, inferences and involves communicating. A prediction that is not based on observation is a guess. (Alberta Education Elementary Curriculum Guide, 1983, p. 84)

Wynne Harlen (1985) includes predicting within a more general process skill which she identifies as interpretation of information. In this case a prediction is a type of inference that is based on observed patterns in data.

For the purposes of this study, predicting will be defined as the use of existing data, information, and perceptible patterns and trends in order to make a specific forecast of what a future observation will be.

Focus of the Study

Assisting children in the acquisition of skills involves a wide range of tasks for teachers. Among these tasks are the problems of choosing appropriate learning experiences for children and responding to their efforts in a supportive way. In her book concerned with the intellectual growth of children and the relation of this growth to their school experiences, Donaldson (1978) concludes that:

> A very important part of the job of a teacher . . . is to guide the child towards tasks where he will be able to objectively do well, but not too easily . . . . This means assessing his skills with sensitivity and accuracy, understanding the levels of his confidence and energy, and responding to his errors in helpful ways. (p. 114)

Fulfilling this role in relation to teaching the process of predicting means that a teacher needs a knowledge of the course of development of children's predicting ability and a sense of what kinds of experiences would encourage that growth. Insights to children's knowledge and understanding of the process of predicting could help to develop the sensitivity and understanding that teachers need in order to respond in a helpful way to children's efforts at predicting.

Teachers also need methods to assess levels of abilities in process skills as they develop. Report #36 of the Science Council of Canada (1984) drew the conclusion that evaluation techniques and procedures are crucial to ensuring quality in science education:

> Assessment techniques must be developed and implemented for <u>all</u> the objectives of science education .... Yet the examinations and tests of science courses, whether set by ministries of education or by teachers, have continued to focus on how much scientific knowledge has been acquired by the student. The effect of this has been that both teachers and students treat other objectives as unimportant extras to be attended to if time allows. And, as every teacher knows, time rarely does allow. (p. 43)

The report goes on:

> The Science Council wishes to register its concern that students be assisted towards their educational goals by means of reliable measures of their progress and that the public be given evidence that ministries of education and school systems are indeed monitoring the effectiveness of their science programs. Both of these require reliable instruments and appropriate policies and, in most parts of Canada, the development of both of these is lagging far behind the curriculum developments to which they should be related. (p. 44)

Since improving children's facility with science process skills is a major objective for Alberta schools, valid instruments to measure achievement in such skills are important for teachers to have. Information concerning both child achievement and the appropriateness of the inclusion of specific process instruction at specific grade levels could be provided by the development of such instruments and associated testing techniques. Such instruments and techniques should also provide criteria for the direct comparison of student performance with an established norm.

This study is intended to assess the ability of elementary school children in the process of prediction. It is hoped that this assessment will indicate something of the course of development of predicting abilities in elementary school children through the grades, and also indicate the grade levels at which an emphasis on experiences that develop the ability to predict would be most effective. Two methods of measuring predicting abilities --a paper and pencil test and a physical manipulation test--will be used in this study. The time taken for each child to complete the paper and pencil test will be used to determine a predicting ability speed score. It is hoped that comparing these tests and the resulting scores will provide teachers with criteria with respect to which they may evaluate the predicting abilities of their pupils. It is also hoped that insights about what children know and understand about predicting will be gained through an interview with each child, and contribute to teacher's understanding of the thinking of children. This deeper understanding of how children view the process of predicting may assist teachers in deciding how best to help children improve their skill at predicting.

Hypotheses

The null hypotheses designed to permit examination of the possible differences and relationships among the variables relating to this study are:

1. There is no significant difference between grade levels in predicting ability scores on the paper and pencil test, predicting ability scores on the physical manipulation test, or predicting ability speed scores.

2. There is no significant relationship between predicting ability scores on the paper and pencil test, predicting ability scores on the physical manipulation test, and predicting ability speed score.

Interview Guidelines

Interviews exploring children's understanding and knowledge of the process of predicting will be guided by the following questions:

1. What does predicting mean to children?

2. How do children perceive the process of predicting within their daily lives?

Some Limitations to the Study

1. It will not be possible to consider prior experience or background of the children in this study.

2. Although every effort will be made to standardize procedures in administering and evaluating each prediction test, experimenter bias may influence the evaluation and administration of the tests.

3. Individual teachers may vary considerably in their approach and ability in teaching the science program. This variation could be reflected in the performance of their pupils in completing the tests involved in this study.

4. Children's perceptions of predicting will be explored solely through an individual interview. Their responses could be considerably affected by their ability to articulate experiences and their comfort with the interview situation.

5. Some evidence to support the predictive validity of the paper and pencil test will be gathered in relation to the physical manipulation test but it will not be possible to firmly establish the validity of the paper and pencil test during this study.

6. The arbitrary choice of schools selected for this study may mean that a representative sample will not be obtained and this must be carefully considered when

attempting to generalize any of the results to the larger population.

Chapter Two

Review of Related Literature

The literature pertaining to this study will be discussed under four main headings: The Process Skills Approach, Growth and Development of Process Skills in Children, Evaluation of Process Skills, and Children's Knowledge and Understanding of the Process of Predicting.

<u>The Process Skills Approach.</u>

> Science is a human activity that has evolved as an intellectual tool to facilitate describing and ordering the environment. Once one accepts the idea that science does not exist in any other realm but the mind, it ceases to be a "thing," an entity with its own existence. Though scientific truth or fact is ideally objective, it is subject to human perception and logic . . . . As a method, science is relatively stable and universally applied, while as a body of knowledge, it is constantly changing. (Woodburn, 1967)

The so-called "process approach" to teaching science reflects Woodburn's definition of science. "Method" is considered to be a set of recognizable processes comprising the intellectual activities of scientists. Gagne (1964) presented a statement of the psychological foundations of the <u>Science - A Process Approach</u> program to writing teams developing exercises for the program. In this presentation he outlined the main premises of the process approach to the teaching of elementary science:

1. The scientists' behaviors constitute a highly complex set of intellectual activities which can be broken into simpler activities.

2. These intellectual activities or processes may be learned, beginning with the most simple and building the more complex from them.

3. These intellectual activities or processes are generalizable across scientific disciplines.

4. A sequence of instruction aimed at having children acquire process skills can be constructed.

5. This instruction will not necessarily give the student a strong background in any one content area but will give a general understanding of science and the ability to grasp and study scientific phenomena in general. (p. 4)

For educators, the second premise is key. It is now fairly generally accepted that science processes can be learned and that instruction can be developed in order to facilitate their acquisition (Carin & Sund, 1980; Gega, 1977; Trojcak, 1979). The process approach, then, is one in which learning is brought about in a systematic way so that a child's performance of scientific activities, using a wide variety of subject matter, becomes increasingly complex, competent, and sophisticated.

Gagne (1964) also noted that modern psychological studies of learning and transfer of training show that high levels of transfer or generalizability are <u>not</u> produced solely by practice of a single task or a series of narrowly defined tasks. Studies of conceptual development in children show that the growth of scientific concepts and logical thinking require considerably more than practice of procedures. Gagne then described two main conditions of the learning situation that are necessary to maximize the learning of processes:

> 1. Practice of performance relevant to each newly acquired knowledge should involve the use of a wide variety of materials in many different situations.
>
> 2. Learning situations should ensure that overt activities required of the student result from the individual's own internal processes, rather than being tied to specific stimuli provided by the teacher. (p. 12)

The process approach does subordinate the acquisition of content knowledge but does not propose that inquiry occurs without it. Gagne (1975) suggests two other components of instruction important to science: generalizable knowledge and incisive knowledge. Broad, generalizable knowledge can be thought of as knowledge of principles:

> Knowledge of principles is not what is usually referred to in a deprecating manner as "knowledge of mere facts," nor is such knowledge best acquired under conditions of sheer repetition. But knowledge of principles is prerequisite to the successful practice of techniques of enquiry. (p. 90)

Incisive knowledge provides the capability of discriminating between a good idea and a bad one.

> Enquiry which cannot be checked against estimates that hypotheses are probably good or probably bad will be undisciplined enquiry . . . likewise, the practice of enquiry which lacks the discipline of self criticism may be expected to be of no positive value to the development of the individual . . . . (Gagne, 1975, p. 98)

Many of the science programs presently being used in classrooms show the influence of Gagne's process approach in their "hands-on", activity-oriented teaching methods. They also, however, reflect the psychological theories of Piaget and Bruner. The emphasis that Piaget places on the importance of active participation by children as essential for their progression through stages of intellectual development is consistent with Gagne's "hands-on" philosophy. Evidence of Bruner's point of view is seen in the aim of many programs to have children learn through "discovery" and to develop an understanding of the underlying structure of the subject. Process skill development is thus only one component of the broader goals of most currently used programs. Indeed, the majority of science programs developed concurrently with or subsequent to the AAAS programs (Science-A Process Approach I and II) can not strictly be considered to embody a true process approach to teaching science; more correctly they use an activity approach, which emphasizes involvement of children in 'hands-on' experiences.

Growth and Development of Process Skills in Children

A limited amount of research exists on the growth and development of children's abilities in process skills.

A series of studies has been conducted at the University of Alberta relating to the ability of elementary children to classify, quantify, infer, and hypothesize. Blackford (1970) determined that a growth in classification abilities occurs between grades one and three and gradually tapers off from grades four through six. Additionally, he noted that children in grades one and two prefer the criterion of color and that children in grades four through six prefer the criterion of liquid versus solid state when classifying objects.

In his study of the quantification abilities of elementary school children, Kellough (1971) found that a rapid growth in children's quantification abilities occurred between grades one and two, followed by a gradual growth that continued through grade six.

Plester (1972) conducted a study to discover the average inference ability levels of elementary school children with respect to visual and auditory-haptic tasks. He determined that visual inference ability increased rapidly from grade one through grade three and showed gradual growth from grade four through grade six. Results of the auditory-haptic task suggested that children in primary grades prefer different criteria in characterizing the properties of objects than do children in upper elementary grades.

Pearson (1975) identified a general growth in the ability of children to formulate hypotheses as the grade level increased, with the exception of grade five, which showed a decreased ability level. This study of hypothesizing abilities was the only study in the series to find a significant difference between ability levels of boys and girls. This difference was noted in grades three and four. These studies offer some insights to the development of children's abilities in process skills but in general all that can be said is that children's abilities to classify, quantify, infer, and hypothesize do seem to improve, and to grow and develop throughout the elementary school grades.

Elsewhere in North America, a study of the abilities of children to observe and compare (Dietz & Barufaldi, 1975) revealed that children in all elementary grades have higher skill levels in observing than comparing.

Efforts to determine factors related to science process skill performance levels have identified the combined effects of age, grade, and experience as important (Pettus & Haley, 1980; Smith & Padilla, 1977; Theil and George, 1976). When studying the effects of instruction on integrated science process skill achievement, Padilla, Okey, and Garrard (1984) showed that both sixth- and eighth-grade children can learn to use specific integrated process skills. They also found that a two-week introductory unit on integrated process skills followed by one period-long process skill activity for each of fourteen weeks was more favorable for growth in skills than either the two week introductory course alone or content-oriented instruction.

Only one study seems to exist in the literature relating specifically to the process of prediction in elementary school children. Theil and George (1976) undertook to determine the effects of four variables on elementary children's ability to use prediction. They identified these variables as experience, inferring or using rules, types of rules, and the dimensionality of the task. They defined prediction as the "acquired ability to use one or more rules from the same or different rule classes to determine the outcome of an event or series of events without prior observation of the outcome of that event or series of events" (p. 155). They found that for elementary children in grades three, four, and five, the skill of prediction depends on "the differences between classification and seriation rules" and "the number of attributes or dimensions contained in the prediction task" (p. 164). While their findings are of interest, prediction is so technically defined that it does not seem to be of much real value in helping teachers understand or evaluate the predicting abilities of their pupils.

When developing the <u>Test of Process Skills</u>, Robert Tannenbaum (1971) wrote a statement of behaviors which students needed to exhibit in order to demonstrate competence in each process. A number of tests of process skills will be described in the next section, but only Tannenbaum so clearly identifies what constitutes competence in predicting:

In order for a student to demonstrate competence in using the process of predicting, he should be able to do the following:

Behaviors

1. Be able to detect or demonstrate trends in data (presented in many different ways) and be able to use these trends to predict by extrapolation and/or interpolation.

2. Devise and use simple means of checking the accuracy of the predictions made.

3. Recognize and use pertinent arguments, reasons, or principles to justify a prediction.

4. Demonstrate an operational knowledge of the necessity for multiple and reliable observations prior to prediction and an unwillingness to offer predictions in the absence of such observations. (p. 135)

This statement is intended to describe the behaviors of middle and high school students but, although Tannenbaum did not so indicate, it seems that it may be applied (less rigorously, perhaps) to elementary school children as well.

When discussing the development of children's ideas, Wynne Harlen (1985) suggests that ideas generally develop through the use of the children's suggested explanation of a phenomenon to predict something will occur and then checking to see whether or not it does. She makes a distinction between a scientific and a spontaneous or "everyday" approach to predicting, describing a scientific approach to predicting as one that "involves a prediction which is a logical result of applying the idea . . .; the test of it involves doing something to obtain relevant evidence"(p. 64). The spontaneous or "everyday" approach, Harlen maintains, "does not extend the prediction beyond what is already known; a circular argument replaces a logical prediction"(p. 64). Harlen sees the development of the process of predicting as flowing from using an "everyday" approach toward using a scientific approach.

Evaluation of Process Skills

Along with a concern for teaching the process skills in science comes the problem of evaluating the ability levels of children and the effectiveness of instructional methods in developing the ability of children to enquire. The Science Council of Canada, however, observes that,

> The development of new forms of evaluation for science education corresponding to the more complex objectives is still in its infancy. (Science Council of Canada, 1984, p. 4)

This is true, in part, because of limited research dealing with skill development in science processes at any level of education, and sporadic efforts to develop valid and practical evaluation strategies for measuring the process skill abilities of elementary school children in particular.

In 1974, Mayer conducted a study of assessment instruments in science and found 119 instruments for assessing level of science knowledge, 32 for assessing level of achievement in the skills and processes of science, and 25 that assessed affective objectives of science teaching. A review of assessment instruments in science by Mayer and Richmond in 1982 refers again to the large volume of tests developed to assess children's attainment of knowledge in science. They review one instrument that assesses both science concepts and process development at the junior high level and three instruments assessing process skill attainment, but only one of these (Fyffe, 1971) was developed for use with elementary school children.

There have been other efforts to evaluate children's performance in the process skills of science. Many of the science programs developed in the last twenty-five years which emphasize the development of science process skills also suggest evaluation procedures to determine both content and skill development. Nevertheless, an emphasis on evaluation of children's content acquisition prevails throughout these programs, regardless of their professed emphasis in goals. Clearly, many programs available to teachers display great discrepancies between stated objectives, recommended procedures for teaching the processes, and the manner in which the supposedly acquired skills are to be measured. The validity of those measurement strategies which are provided is generally supported only by reports from teachers of their own experience with the procedure.

One of the early programs that does provide a direct method for assessing the process skill development of children is Science - a Process Approach. This program provides a "competency measure" for each exercise related to a process skill, the measure being intended to assess achievement with respect to the specific behavioral objectives of the exercise. The measures do measure student performance of specific processes. Unfortunately, they are directly useful only in a situation where the Science a Process Approach program is being used, and neither the program nor its competency measures are in general use in classrooms today.

Instruments have also been developed to assess the effectiveness of other programs emphasizing process skills (Allen, 1973; Anderson, DeMelo, Szabo, & Toth, 1975; Hill, 1962; Jones, 1959; Riley, 1973; Suchman, 1960, 1961). These consistently show improvements in student performance after the particular program being evaluated has been in use. These tests are not useful to classroom teachers, however, because they are relevant only to specific curricula that are not in wide use.

Tests that have been developed independent of specific curricula usually measure performance in a combination of basic skills, or performance in one of the complex, so-called "integrated" science process skills. The Tab Science Test (Butts, 1964), for example, was designed to evaluate problem solving in science through examining student participation in solving specified problems. Participants were presented with one problem, then offered a choice of specific and general information on request. The choice of information and path to the solution that the participant followed was charted and analyzed after the completion of the task. This kind of complex analysis seems to be effective in measuring children's ability in problem solving. However, it is not practical for use by classroom teachers because special materials and training are needed, and the procedure is very difficult and time consuming.

McLeod, Berkheimer, Fyffe, & Robinson (1975) wrote test items for four of the integrated science processes: controlling variables, interpreting data, defining operationally, and formulating hypotheses. They validated these items by correlating the items with the children's ability to perform selected, appropriate competency measure tasks in an experimental setting. These test items show promise as an efficient means of evaluating children's abilities in these processes; unfortunately, it seems that the refinements which the authors deemed necessary before they could be used by teachers were not completed.

An instrument to evaluate the performance of children in grades four, five, and six in the skills of inference and verification was developed by Molitor and George (1976). This is a multiple choice test in which items and item distractors are presented in the form of illustrations. This instrument could be of value to teachers but is not readily available and is not commonly in use.

Tests have also been developed to measure process skill performance by middle school, high school, and even college level students. The TIPS (Dillashaw & Okey, 1980) and TIPS II for middle and high school students (Burns, Okey, & Wise, 1985) use multiple-choice items to test for integrated science skills that are non-curriculum specific. The Test of Science Processes (Tannenbaum, 1971) also uses a multiple-choice format; scoring on this test yields a total score and a sub-score for each of the processes of observing, comparing, classifying, quantifying, measuring, experimenting, inferring, and predicting. The Group Test of Integrated Science Processes (Tobin & Capie, 1982) is intended for use with students in middle school through college. Questions relate directly to 12 specific skills used in planning and conducting an investigation. Berger (1982) made a rather unique use of computers to present data and record student responses to measure changes in the use of the process of estimating over minutes and days. These tests are not useful to elementary school teachers but do demonstrate that interest in developing process skills extends beyond the elementary level of education.

Very few of the tests referred to above have received much use. At the same time, their infrequent use, and use with small samples has not generated extensive development or refinement. This could be due, in part, to the failure of researchers to communicate effectively with the science education community at large about the types of instruments developed. It might also be an indication that the tests developed do not address the evaluation needs of teachers in a practical manner.

The Nature of Predicting, and Children's Knowledge and Understanding of the Process Itself

Definitions of predicting and prediction refer to the use of information in order to forecast a future observation. Considering how this information is processed reveals that inductive reasoning is involved in predicting. Blackburn (1973), in his book concerned with reason and prediction, discussed what constitutes a valid reason for making a prediction by considering Paul Edward's (1951) justification of induction. Edward stated,

> . . . what we mean when we claim that we have a reason for a prediction is that the past observations of this phenomenon or of analogical phenomena are of a certain kind: they are exclusively or predominantly positive, the number of positive observations is at least fairly large, and they come from extensively varied sets of circumstances. (p. 11)

Blackburn points out that the "reason" for the prediction does not have to be logically conclusive but, rather, need only to favor the view that the expectations (predictions) are likely to be fulfilled.

Cohen and Hansel (1956) conducted a series of studies with both children and adults designed to discover the underlying principles of the way we actually choose, estimate, predict, judge, or take risks and to describe the characteristic changes in these activities during the period of development. From these studies they concluded that,

> From the youngest child onwards, predictions and judgments follow an intricate system of preference and pattern seeking, varying in complexity from age to age. On the basis of this system, the child makes his choices. He interprets what has happened, decides what to expect, and makes up his mind what to do. (p. 31)

This conclusion highlights the complex nature of the growth and development of the process of predicting in children and suggests that predicting is an integral part of thinking at all ages.

George Kelly (1955) proposes that each person makes sense of the world through formulating personal constructs and testing them against the reality of the world in terms of their predictive efficiency.

> Constructs are used for predictions of things to come, and the world keeps rolling along and revealing these predictions to be either correct or misleading. This fact provides the basis for revision of constructs. (p. 14)

Kelly stresses that straightforward testing of constructs is not only a feature of the experimental method, it is also a characteristic of any alert person. For Kelly, then, predicting is an integral and extremely important part of everyday life.

During a case study of the experience that girls have in elementary science, Gustafson (1985) identified predicting as a main theme in the girls shared meanings of school science. She noted the positive reaction of the girls to those occasions when the teacher encouraged them to predict the outcome of an activity. The girls indicated that this enhanced their interest in the activity and challenged them to be involved creatively in the learning. Gustafson wrote:

> But what is it about declaring in advance, or foretelling on the basis of observation or experience, which results in the girls describing it as "neat," "interesting," and "fun"? Maybe one reason is the intellectual challenge and pleasure . . . as interconnected with the girls' preference for active participation. Another possibility is that life itself is always directed toward a future. In our everyday life we constantly anticipate the future and try to plan our lives accordingly. We predict social, economic and political trends and attempt to make decisions about career, family, and finances. Perhaps when this characteristic of human life is incorporated into the school science program, the girls are drawn to it because it is similar to an activity that is already part of their lives. . . .
>
> Donaldson (1978) concurs that involvement with the world enables us to "build up . . . a kind of system of inner representations, the value of which is to help us anticipate events and be ready to deal with them" (p. 67). Perhaps by taking part in hands-on activities, the girls begin to construct their own reality in a personal way which allows them to subsequently extend this information to other life situations and make predictions about future events.
>
> Additionally, perhaps predictions reveal the tentative nature of both science and life. We can only make the best decisions possible based upon past experiences and subsequent observations. There are no guarantees that we will always be right and successful. Life and science present a challenge to our creativity, ability to adapt, and wisdom to

> accept outcomes regardless of whether they are correctly anticipated. Perhaps encouraging prediction in science class not only parallels a characteristic activity of science, but is constitutive of life itself and the tentativeness with which we all walk upon this earth. (p. 59)

The ability to make sound predictions is considered one characteristic of scientists, but prediction can also be recognized as a skill commonly used by everyone throughout a lifetime. For children, prediction is an integral part of everyday life, and they develop and refine this skill as they mature. One intent of a process skill oriented program is that the child's skill level in prediction will be improved through conscious attention to it and practice with it. It seems most appropriate that the ability to predict is an important process skill in science curricula.

Chapter Three

Design of the Study

The Sample

The population from which the sample used in this study was selected consisted of all the elementary students in eight schools, of which three were from the Edmonton Public School System, two from the St. Albert School District #6, two from the County of Strathcona #20, and one from the Edmonton Separate School System. The schools were selected at random from within each system. A sample of 192 students, stratified on the basis of gender was selected from the schools such that only 24 were chosen from each school. Four students were randomly selected from each grade level at each school using a random number list generated by the IBM program in appendix 1. This provided a final sample of 32 students from each of the grades one through six.

Of the original 192 students chosen for the study, 168 were administered the Paper and Pencil test, 166 took part in the Physical Manipulation test, and 163 completed the individual interview. Table 1 shows a breakdown of the sample by school, grade, sex, and prediction tests administered.

Table 1

Distribution of Children in Sample

System	St. Albert #6		Strathcona County		Edmonton Public			Edmonton Separate	TOTAL PPT	TOTAL PMT
School	1	2	3	4	5	6	7	8		
Grade One										
PPT	4	4	4	3	3	3	4	4	29	
PMT	4	4	3	3	3	3	4	4		28
Grade Two										
PPT	4	4	4	4	4	3	2	4	29	
PMT	4	4	4	4	4	3	2	4		29
Grade Three										
PPT	4	4	4	3	3	4	4	4	30	
PMT	4	4	4	3	3	4	4	4		30
Grade Four										
PPT	4	4	4	4	2	4	2	4	28	
PMT	4	4	4	4	2	4	2	4		28
Grade Five										
PPT	4	4	4	4	3	3	3	4	29	
PMT	4	4	3	4	3	3	3	4		28
Grade Six										
PPT	4	4	4	4	0	3	1	3	23	
PMT	4	4	4	4	0	3	1	3		23
School Total										
PPT	24	24	24	22	15	20	16	23		
PMT	24	24	22	22	15	20	16	23		

Total N - Paper & Pencil Test (PPT)..............168
- Physical Manipulation Test (PMT)......166

Instrumentation

Two separate tests of predicting ability and a set of interview questions were developed for use in this study. Each test needed to meet the definition of predicting described in chapter one and had to relate to the hierarchical development of intellectual processes of Gagne's (1965) process approach. Both of the tests used in this study provided children with the opportunity to make a series of observations from which a relationship between relevant variables could be inferred. Children could then make predictions of what a future observation would be.

The Pencil and Paper Test of Predicting Ability consisted of 48 questions selected from items in the "Abstract Reasoning" subtest of the Differential Aptitude Test (Bennett, Seashore & Wesman, 1972). Each of the questions consisted of a series of four drawings in which a dynamic change seemed to be occurring in part or parts of the figures. These "question" drawings were the source of observations from which the child could infer relationships and "predict" the next step in the sequence. The child indicated the prediction by choosing, from five "answer" figures, the one deemed to best represent the next step in the series of figures. A stopwatch was used to measure the amount of time required by each child to complete the test. This test was intended to be a test that could be easily administered to a group in the classroom setting. A copy of the test is included in Appendix 4.

The Paper and Pencil Test of Predicting Ability was not substantially different from the "Abstract Reasoning" subtest of the Differential Aptitude Test from which it was drawn; therefore it can reasonably be considered to maintain more or less the same degree of reliability. It was intended that correlations and comparisons of scores on the Paper and Pencil Test with scores on the Physical Manipulation Test would contribute toward establishing the predictive validity of the Paper and Pencil Test.

The Physical Manipulation Test was structured such that children were involved in the observing and manipulating of materials through a series of operations intended to direct their attention to relevant variables. Children were then asked to make a prediction about the same materials in a different but closely related situation. For example, in the weights and spring activity, the children were asked to identify the change in position of the bottom of the spring as weights were added to it. Then they were asked to predict where the bottom of the spring would be if a weight was removed. This test was designed to measure predicting ability through immediate evaluation of behavior and of answers given while the child was actually engaged in the process of predicting. The tasks used in this test are adaptations of the Individual Competency Measures identified as measures of predicting ability taken from the Science a Process Approach program . These tests are probably the most valid of all tests of the process of predicting because the child actually performs the process under supervision (McLeod, Berkheimer, Fyffe, and Robinson, 1975).

An interview was designed to explore children's understanding and knowledge of the process of predicting. The interview was scripted with five general questions guiding the dialogue. The questions were:

1. What is predicting?
2. Do you need to use or know anything to make a prediction?
3. Do you do predicting at school?
4. Do you do predicting at home?
5. Is it important to be able to predict? Why or why not?

Although these questions served as the framework for every interview, other questions were used to pursue a deeper understanding of the responses each child gave.

Procedures

Pencil and Paper Test of Predicting Ability. The pencil and paper test was given to groups of eight to twelve students in a spare classroom in each school. The children were shown two sample questions and given instructions as to what was required to answer each question on the test. They were then encouraged to choose an answer for each sample question in turn and individuals were asked to explain why they chose the answer they did. The timing procedure was then explained to the group and they were seated to begin the test.

<u>Physical Manipulation Test of Predicting Ability.</u> The Physical Manipulation Test of Predicting Ability consisted of seven discrete activities. This test was administered to students individually. As far as possible, a common pattern was followed with each child. After the child was greeted and the reasons for the use of a tape recorder and score sheet were explained, the recorder was turned on and the child was questioned about personal data such as age and grade. It was intended that this time would allow the child to adjust to the testing situation. The individual activities were then carried out. The dialogue was guided by a standard, prepared script. Although the crucial questions (for scoring) were standardized, a somewhat flexible approach was used in order to more fully explore the interests and comments of individual students.

For each of the seven activities, the general procedure involved either the child or me in performing a series of manipulations on the stimulus materials during which the child could make observations that could lead to inferences and apparent relationships between stimulant materials. After this information gathering phase of the activity, the child was asked to predict the behavior or qualities of parts of the stimulus materials in a related situation. Finally, the child was asked to justify the response in terms of an explanation of the relationship operating. A list of equipment and a comprehensive description of the dialogue and of procedure for the activities can be found in Appendix 5.

The responses of children and their behavior during the activities of this test were recorded on a specially prepared data sheet. A tape recording was also made during the test to provide a supplement to the written record.

<u>The Interview.</u> The interview was conducted with each child at the completion of the Physical Manipulation Test. Responses during the interview were noted on a record sheet and tape recorded to facilitate later interpretations. A copy of the interview questions and record sheet is included in Appendix 7.

Scoring

<u>The Paper and Pencil Test of Predicting Ability.</u> The Pencil and Paper Test of Predicting Ability was scored according to the key in Appendix 4. The predicting ability speed score was calculated by dividing the score from the Paper and Pencil Test by the number of seconds used to complete the test.

<u>The Physical Manipulation Test of Predicting Ability.</u> The evaluation of each child's responses during the seven activities in the Physical Manipulation Test

was designed to measure performance in three closely related areas of scientific process: accuracy of observation, predicting ability, and explanation. For the prediction and observation type questions, responses were scored simply right or wrong. Those responses which were considered explanation were scored, somewhat subjectively, on a three point scale (2, 1, or 0) according to the logic and completeness of the explanation. For example, during the magnets activity, children who placed the correct two objects in the group designated as "things that a magnet will pick up" and said they "didn't know why" or "just thought it was right" when asked to explain why they had chosen those objects, received a score of 0 for explanation while children who said they had chosen those objects because "they seem to be like the one that was picked up by the magnet before" received 2 points for explanation. Appendix 6 contains the scoring criteria for each question, and the values assigned to different responses. Although these values may seem rather arbitrary, they were dictated somewhat by the conditions of each activity. No attempt was made to try different values in scoring the test because Kellough's (1971) study had shown that alternate scoring procedures yielded essentially the same results. Thus the system described in Appendix 6 was chosen as being representative of the scoring ability of the students for these tasks.

The Interview. Results of the interviews were grouped by grade level and served as data for a descriptive interpretation of children's knowledge and understanding of the process of predicting.

The Pilot Study

A pilot study was carried out in February, 1986, in order to maximize efficiency of the main study. This was conducted with children from a school not involved in the main study.

The pilot study involved four students from each of grades one, two, three, five, and six, and three students in grade four.

The pilot study was undertaken to determine

1. the length of time required for the administration of the Physical Manipulation Prediction Test;

2. the levels of difficulty of each test in order to ensure differentiation of predicting ability within and between grade levels--assuming that a basis for such differentiation exists;

3. the final form of the instructions for each test;

4. the final form of each measuring instrument; and,

5. the administrative problems that might arise during the testing.

The experience of the pilot study showed several things:

1. The time needed for completion of the Physical Manipulation Test varied from 15 to 25 minutes depending on the individual child.

2. Students from all the grades were able to attempt each of the tasks of the Physical Manipulation Test with little difficulty. However, labels and units of measure had to be more boldly displayed before the younger students took note of them.

3. A small room with a large table and few distractions was suitable for administering both predicting ability tests. Groups of eight or less were found to be preferable when administering the Pencil and Paper Prediction Test. Students responded favorably to having the interview for the Physical Manipulation Test tape recorded.

4. At least one week is required to receive parent and child consent for participation in the study, and one full week is required to complete the testing of four students in each of grades one through six. Tape recording the Physical Manipulation Test was found to be necessary for accurate scoring.

Results of the pilot study showed an increase in ability scores across grades one to six, with the exception of grade four. The mean scores by grade of the three measures is displayed in Figure 1. Concurrent observations of students performance on the Physical Manipulation Test also suggested a discernible growth in predicting ability of children across the grades and suggested there may be some important differences between the two tests being used. The interview also seemed to be providing information that could be valuable in gaining insights to children's understanding and knowledge of the process of predicting. These findings encouraged me to proceed with the main study.

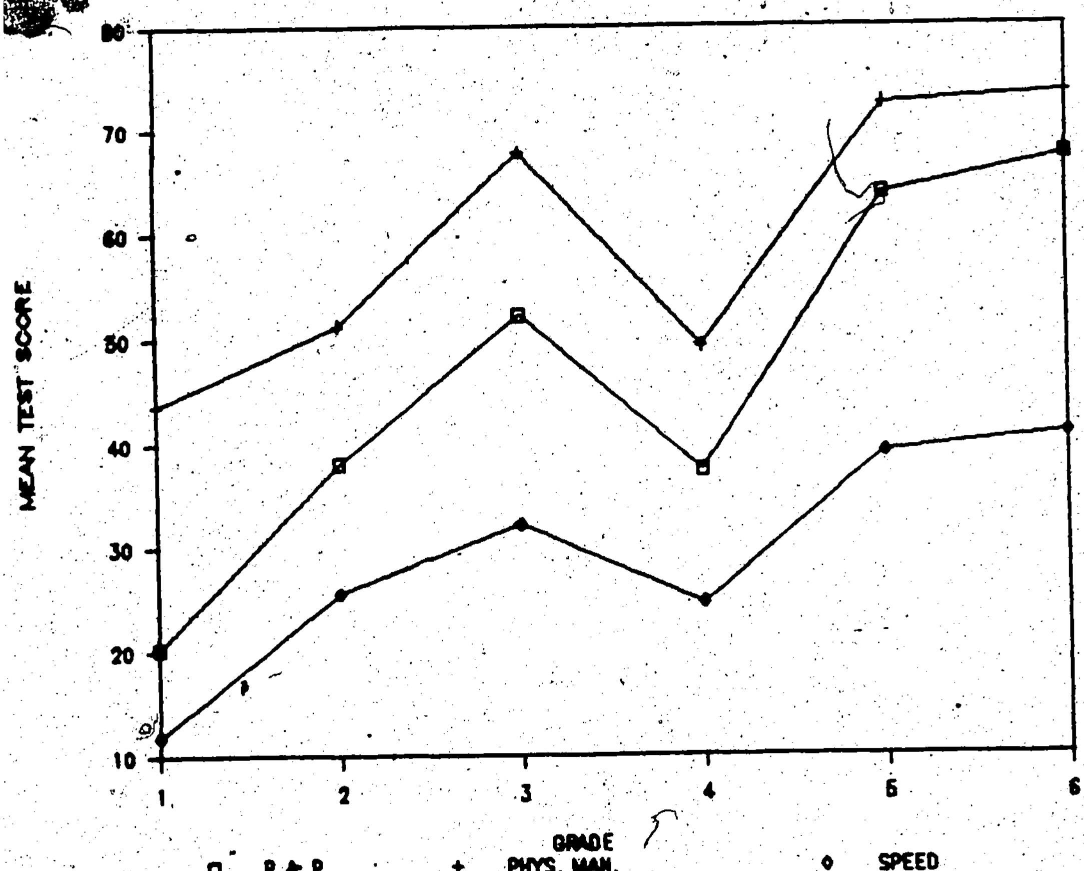

Figure 1 Mean predicting ability scores by grade (Pilot Study).

The Research Program

The research program was carried out between March 10 and May 30, 1986. The program was initiated after review and acceptance of the proposal by the ethics committee of the Elementary Education Department, University of Alberta, and by the Central Office personnel of each school district involved in the study.

Each principal of the eight schools chosen to participate in this study was contacted approximately one month before I hoped to enter the school. The support of school staff for the study was requested and granted by each school. Principals were then requested to deliver the information letter and permission slip to students selected for the study at least one week prior to my appointed arrival.

I travelled to each of the eight schools involved and administered the two predicting tests and conducted the interview with each child chosen for the sample. This took approximately one week per school. A flexible schedule was established during the first day in each school and teachers were consulted regularly throughout the week to ensure minimal disruption to regular classes.

Chapter Four

Results of the Investigation

The results of the statistical analyses which yielded data on each of the hypotheses are presented in this chapter along with the results of the interview. The calculations for the statistical analysis were carried out by means of the analysis of variance and 'Pearson Product Moment' computer programs. Members of the Division of Educational Research Services of the University of Alberta have documented and tested these programs.

Statistical Analysis of the Hypotheses

<u>Hypothesis #1</u>: There is no significant relationship between predicting ability score on the paper and pencil test, predicting ability score on the physical manipulation test, and predicting ability speed score.

This hypothesis was analyzed by means of the 'Pearson Product Moment' correlation technique which was calculated by utilizing the DEST 02 computer program (Division of Educational Research, University of Alberta). The correlations between the three predicting scores are presented in Table 2. A significance level of 0.05 was chosen for accepting or rejecting the hypothesis. The score obtained from the physical manipulation test and those obtained from the paper and pencil test were found to correlate significantly. Therefore, Hypothesis #1 is rejected.

Table 2

Correlations Between Predicting Scores

Predicting ability	2.	3.
1. PPT	.581 *	.739 *
2. PMT	--	.554 *
3. Speed		--

Note. PPT = Paper & Pencil Test; PMT = Physical Manipulation Test
* $p < .01$.

Hypothesis #2: There is no significant difference between grade levels in predicting ability scores on (a) the paper and pencil test or (b) the physical manipulation test, nor is there a significant difference in (c) the predicting ability speed scores.

Scores relating to this hypothesis were analyzed by the Scheffe multiple comparison of means as calculated by the use of the ANOV 16 computer program (Division of Educational Research, University of Alberta). The 0.10 level of significance was used as a basis for rejecting or failing to reject this hypothesis. Figure 2 shows the mean predicting scores by grade and Table 3 gives the Scheffe probability matrices for the multiple comparison of each of the predicting score means for grades one through six.

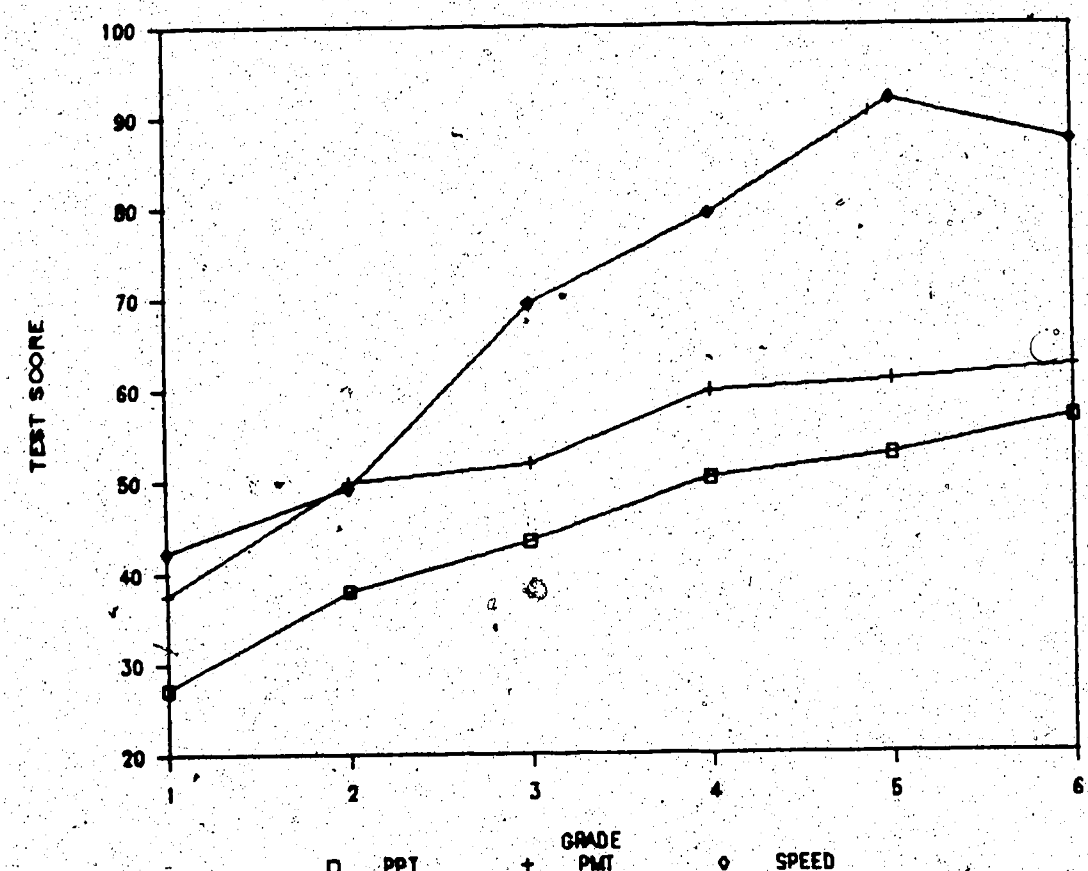

Figure 2 Mean predicting ability scores by grade.

Table 3

Sheffe Probability Matrices for each Predicting Score by Grade

Predicting Ability Paper & Pencil Test		Grade: Two	Three	Four	Five	Six
Grade:	One	.148	.003 *	.000	.000	.000 *
	Two	--	.826	.063	.010	.001 *
	Three		--	.639	.227	.048 *
	Four			--	.994	.763
	Five				--	.962
	Six					--

Predicting Ability Physical Manipulation Test		Grade: Two	Three	Four	Five	Six
Grade:	One	.043	.002	.000	.000	.000 *
	Two	--	.996	.102	.044	.024 *
	Three		--	.303	.162	.096 *
	Four			--	1.000	.990
	Five				--	.999
	Six					--

Predicting Ability Speed		Grade: Two	Three	Four	Five	Six
Grade:	One	.912	.001	.000	.000	.000 *
	Two	--	.003	.000	.000	.000 *
	Three		--	.707	.011	.138
	Four			--	.466	.900
	Five				--	.988
	Six					--

* $p < .10$.

(a) <u>Results Relating to Scores on the Paper and Pencil Test:</u> In eight of fifteen cases, the predicting ability score is significantly different for the pairs of grades compared. The grade one mean score is significantly lower than the grades three, four, five, and six mean scores but is not significantly different from the grade two mean score. The grade two mean score is significantly lower than the mean scores for grades four, five, and six. The grade three mean score is significantly lower than the grade six mean score. There are no significant differences among the grade four, five, and six mean scores. Table 3 summarizes this information.

(b) <u>Results Relating to Scores on the Physical Manipulation Test:</u> There is a gradual increase in the mean predicting ability scores from grades one through six. The grade one mean score is significantly lower than the mean scores of grades two, three, four, five, and six. The Grade two mean score is significantly lower than the grade five and six mean scores, and the grade three mean score is significantly lower than the grade six mean score. See Table 3 for this information.

(c) <u>Results Relating to Predicting Ability Speed Score:</u> The mean predicting speed scores increased from grade one through grade five and showed a slight drop in grade six. Eight of the fifteen possible comparisons between grade levels were significantly different. The grade one mean score is not significantly different from the grade two mean score but it is significantly lower than the mean scores of each of the grades three, four, five, and six. The grade three mean score is significantly lower than the grade five mean score but is not significantly different from the grades two, four, or six mean scores. There are no significant differences among the grades four, five, and six mean scores.

Summary of Results Relating to Hypothesis #2:

Significant differences in the predicting ability scores were found in many though not all grade pairings. Enough significant differences exist, however, to suggest a pattern of growth in predicting ability with respect to the paper and pencil predicting test. This growth pattern was most marked between grades one and two. (See table 3.) Hypothesis #2, therefore, may be rejected with respect to paper and pencil predicting ability scores for comparisons between grade one and each of grades three, four, five, and six; between grade two and each of grades four, five and six, and between grades three and six.

Significant differences for the physical manipulation predicting ability mean scores are found among many but not all grade pairings. Those significant differences that do exist, however, indicate a pattern of growth in children's predicting ability. (See Table 3). Therefore, hypothesis #2 may be rejected with respect to physical manipulation predicting ability scores for comparisons between grade one and each of grades two, three, four, five, and six. It may also be rejected for comparisons between grade two and grades five and six, and for the comparison between grades three and six. As with the other two predicting ability scores, significant differences in predicting speed scores were found among many but not every grade pairing. Enough significant differences do exist, however, to suggest a pattern of growth with respect to the rate of completion of the paper and pencil predicting test. The growth pattern was most marked between the grades one and two, and seemed to peak at grade five (See table 3). Hypothesis #2, therefore, may be rejected with respect to predicting ability speed scores for comparisons between grade one and each of grades three, four, five, and six; between grade two and each of grades four, five, and six and between grades three and five.

Children's Knowledge and Understanding of Predicting

Three Types of Responses.

Children's knowledge and understanding of predicting, as expressed during interviews, seemed to fall into three groups. ~~The~~ first group of responses came from children who said they did not know what predicting is, and who did not offer examples or explanations that suggested any conscious knowledge or understanding of predicting. The second group of responses came from the children who seemed unclear and who had only very generalized ideas about what predicting is. The examples and explanations these children offered did not clearly differentiate predicting from other tasks. The third group of responses suggested a better knowledge of predicting and an understanding that is sharper and more conventional. Children with this better knowledge and understanding were able to give explanations and examples to support their descriptions of predicting.

Figure 3 shows the distribution by grade of the number of children responding in each of the three groups identified. The number of children who said they do not know what predicting is declines steadily from grade one through grade four. There are no children in grade five or six who did not give some description of predicting. The number of responses indicating a better, more conventional knowledge and understanding of predicting shows a steady upward trend from grade two through grade six.

The physical manipulation test scores of children responding within each of the three groups were subjected to a one-way analysis of variance in order to determine what, if any, significant differences in predicting ability are present. The computer program used carries out a Scheffe

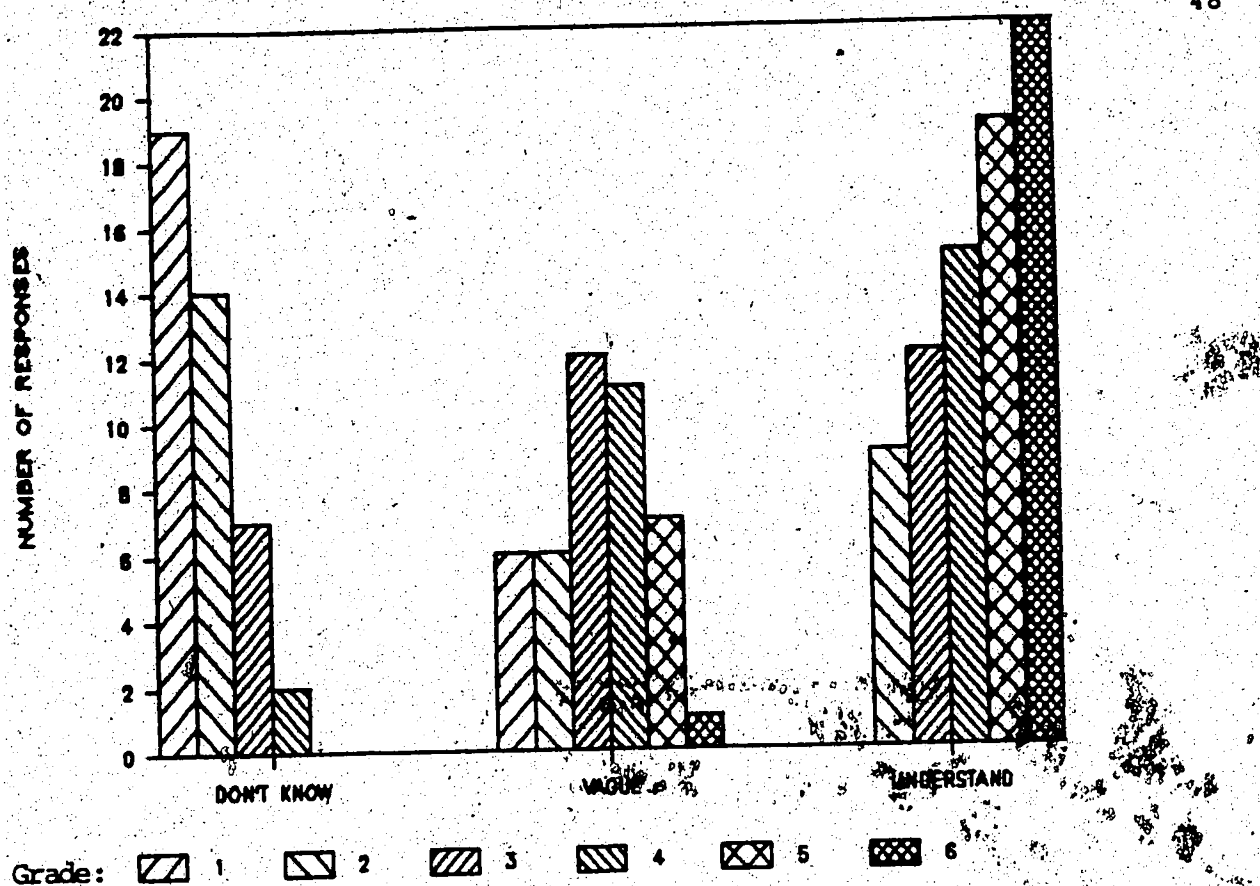

Figure 3 Children's understanding of prediction: Grade level distribution of responses by type of response.

multiple comparison of means, and identifies pairings that are significantly different at the 0.05 level.

A significant difference is noted in all cases. This shows that there is a relationship between children's level of understanding of the process of predicting and their predicting ability. It should be noted that a causal relationship between understanding and ability is not being suggested, only that they seem to be significantly related in some way.

Description of Responses by Grade Level.

The variety of responses given by children during the interviews highlighted the unique nature of each child while revealing some common patterns or themes in their knowledge and understanding of the process of predicting. Figure 4 shows the distribution within grades of children responding with each level of understanding outlined above. The individual responses of children, grouped by grade level and general themes, are presented in the following section.

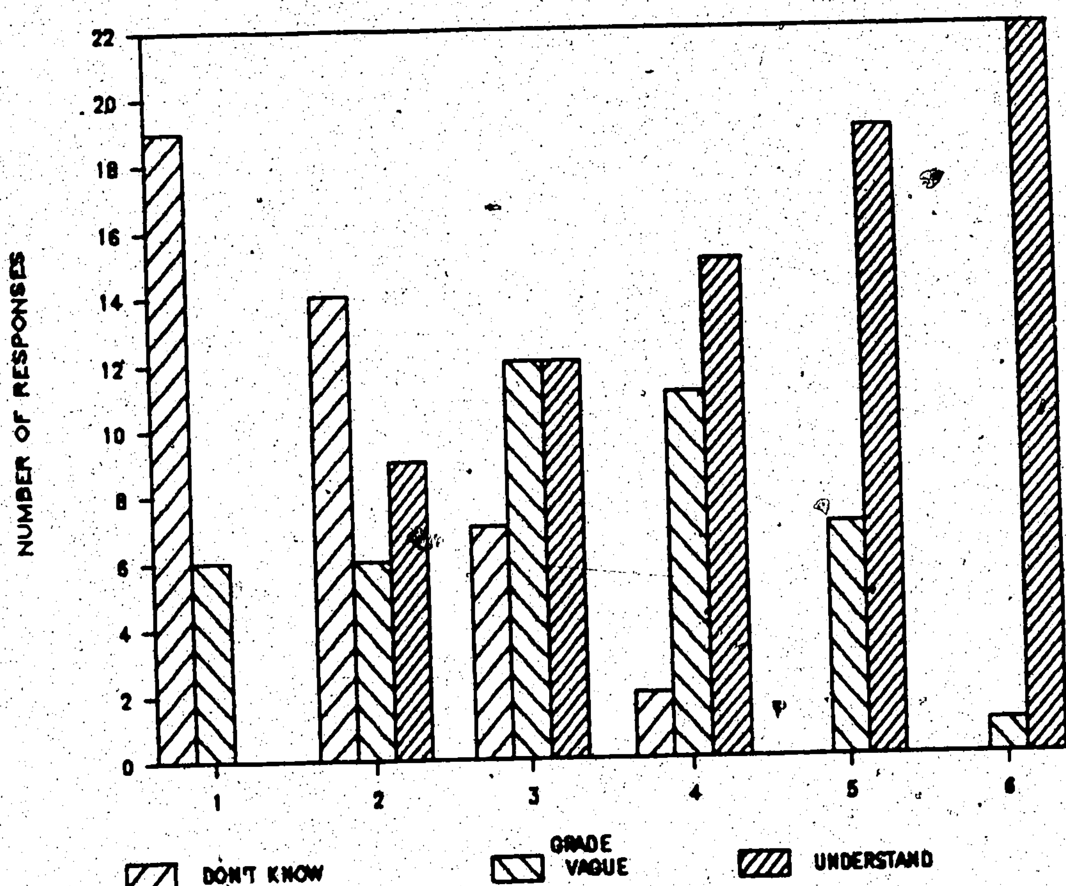

Figure 4 Children's understanding of prediction: Number and type of response by grade.

Grade One.

Most children in grade one answered, "I don't know." when asked what predicting was but some did describe predicting as

"Doing all kinds of things."

"Finding out and stuff."

"Doing a project."

"Trying experiments."

One child said, with a rising inflection,

"To tell the future?"

None of the children elaborated on how this is done, nor did many believe they do predicting in school. None of the children thought they did predicting at home.

Grade Two.

When asked to explain what predicting is, half the grade two children answered, "I don't know."

Six of those who did offer an answer were rather vague and overly general, saying that predicting is

"Doing stuff."

"Answering questions."

"Telling you answers."

These children didn't seem to separate predicting from any other request made of them. Their examples of doing predicting included

"Doing board questions."

"Reading questions."

"Showing your work [when doing math problems]."

"When Dad or Mom asks me something."

Nine of the children answered the question, "What is predicting?" with responses that suggested they have a better understanding of the process of predicting. Their answers included

> "Saying something that you don't really know if it's true or not."
>
> "Think about what the answer is then you get it right or wrong."
>
> "To guess what is going to happen."

Most of these children felt that you use your brain to predict but they were divided on whether or not you had to know anything to help make a prediction. Not all the children thought they "did predicting," but those who did offered examples from reading, math, social studies, and science in school. They had difficulty thinking of examples from home. Some of their examples were as follows:

> "In measuring you predict how long it is, then measure it to see how close your guess was."
>
> "In Social Studies we did a mosquito problem. They had a lot of things they could stop it with--we tried to find the best way."
>
> "Do I have to clean my room? [She predicts what will happen if she does not clean the room.]
>
> "In science, we put a little hole and water in a glass and see how long for the water to pour into the bottle. With a bigger hole we predicted less time."

The children who described predicting with a better, more conventional understanding in grade two were not clear about how predictions are formed but suggested it was something that happened "in your brain".

Grade Three

Only seven of the 31 grade three children interviewed said they did not know what predicting is. Twelve others gave vague answers such as

> "Finding out."
>
> "Asking questions."
>
> "Guessing the answer."
>
> "Making something work and guessing."
>
> "Explaining stuff."

These answers were not elaborated on even though children were encouraged to explain what they meant. Most of the examples they offered did not relate closely to predicting.

A further 12 children gave answers that suggested they had a better understanding of predicting. Their answers included

> "Thinking in your head, not knowing the answers."
>
> "Say that something in the future is going to happen."
>
> "Thinking of something that might happen."

These answers were explained and supported with examples. All but four of these children felt that one had to use or know something in order to make predictions. They said that you had to "think" or "use your brain," and you also had to

"Know what they (the materials you are making a prediction about) are and how many things you are using."

"Know about what you're going to predict and think about."

"Know about the things that are happening."

Four of the children felt they did not do predicting in school but the rest gave examples from a variety of situations in school and home. Some of these are as follows:

"What my Mommy needed to buy for supper."

"In jellybean contests."

"What I need to make something (a model), the cost of models."

"What kind of clothes do the Hutterite people wear? Decide, then teacher says what was right."

"We think what's going to be next when Miss Woods starts writing on the board."

"In a science experiment with marbles. When one marble hit one marble, then one ~~marble hit~~ two marbles, then one hit three . . . . . Then you do your own, you predict what will happen and find out."

"In reading, you guess what happens next in the sentence."

Grade three children with a better knowledge and understanding of predicting are the youngest in this study to address the importance of being able to predict. All but two of the 12 children believed it was important to be able to predict, although only a few offered a reason why. They gave reasons such as

"When you know what kind of weather, you could predict what to wear or what to do."

"If you predict somebody is going to get hurt you should tell that person."

"Cause then you can guess what's happening really fast."

"If you don't know what's going to happen, it might be a big surprise, like World War Three or something like that."

Grade Four

Only two of the 27 grade four children interviewed said they did not know what predicting is. Eleven offered vague answers, and 15 expressed a better, more conventional understanding of predicting.

Those children who answered vaguely remained vague even when encouraged to explain their answer and give examples. These children felt predicting was either "guessing" or "answering questions".

Children whose answers indicated they had a better understanding of what predicting is, elaborated on their answers with explanations and examples from school and home. These children described predicting as

"Saying what you think is going to happen."

"Telling things about what could happen in the future."

"Not really true answering but making an answer that you don't really know if it's true, just trying to see if it's true."

"Reading the future. You say what will most likely be. You're not exactly sure [but] close to."

"Scientific guess."

"Estimating or trying to guess what's going to happen in the future."

These children generally agreed that you have to "think" or "use your brain" to make predictions. In addition, they felt you needed to

"Know what you're trying to predict. Have a little sample to look at."

"Know what the thing is and where it's going to happen, [also], how strong or weak it is."

"Know things like about water, metal and equations, also science."

"Know the facts."

One child mentioned that, "sometimes" you use "paper or computers and calculators."

A wide variety of examples of predicting were given by these children. Some of these are as follows:

"We use rulers to get vibrations. We predict the speed [frequency of different lengths]."

"How long it takes to micro-wave something?"

"In science we put a sponge in a glass in water. Will it come out dry or wet?"

"When the cat is out, we predict when the cat will be at the door by when she went out."

"Who is going to make supper? Mom or Dad?"

"In measuring, guess about how much this is and then walked it."

"When the cat would have her kittens."

"Watching Karate Kid, you predict he's probably going to get something."

> "Will I have homework or not, so I can play after school. I work hard to have no homework."

> "In science, predict what will happen to the egg. Sink or float?"

> "Estimating in math."

These children felt that being able to predict was important because

> "Then you know something."

> "If you don't try and predict things, you might never get anything done. Sometimes you just have to guess at it."

> "You could know ahead of time. Sometimes it can help."

> "If you didn't have predictions, not too many things could be real."

> "If you didn't predict things, life would be boring."

> "If a hurricane or World War Three is predicted, you could be prepared."

<u>Grade Five</u>

All grade five children interviewed gave an answer to the question, "What is predicting?" Seven gave answers that suggested they had a poor understanding of the process of predicting, while 19 gave answers that indicated they had a better, understanding.

The seven children who gave responses that were vague, generally believed predicting meant

> "Answering a question."

> "Guessing."

or,

"Making a choice."

They didn't feel that one needed to know or use anything to make a prediction, and they offered examples which did not necessarily involve predicting, such as

"Talking about stuff."

"Rounding off in math."

The 19 children who answered with reasonable accuracy gave answers that included

"Telling something before it happens."

"Saying what's going to happen in the future."

"Trying to tell what will happen and you don't know."

"Trying to figure out something without knowing the answer and by guessing."

These children indicated, "you use your brain" or, "have to think" to make predictions. In addition, they said you needed to

"Watch and listen."

"See something go ahead of it."

"See a sample."

"Know information."

"Know a little about it. You can use the information. If you don't know, try to resemble it to something you do know."

"Try a prediction to see what really is."

They offered examples from school and home that included

"Predicting answers for measurement."

"When Mom is reading a story we were predicting what would happen next."

"We burned a peanut under [a can of] water and predicted if water would heat."

"I feel confident it's not going to rain or snow today!" (Child then pointed at his light clothing.)

"Estimating in math."

"Predicting what's going to happen on the next series of a show [on television]."

"Guessing who is going to be the next "super-kid" next week."(Part of a school recognition program.)

"When me and my Dad were working on the trailer. Will the lights work when we hook them up?"

Children who gave a better description of what predicting is also felt that being able to make predictions was important. They felt predicting was important because

"Sometimes it can be fun, and so you can predict the answer and find out what it really is and see how close you were."

"If it's bad [the event you are predicting] you can try and stop it from happening."

"Sometimes you have to know things you don't know."

"If you predict something [that] is good you make them work better. If bad, you prevent it."

"If I can't predict, I might think things out the wrong way and make a serious mistake."

"If you don't try to predict there is no use in even doing it."

Grade Six

All but one of the 23 grade six children interviewed gave a description of predicting that suggested they had a better understanding of predicting. Their answers included

> "Trying to tell what something is going to do based on a study of what it's already done."

> "When you say something that you think will happen but you're not completely sure. Like the weatherman."

> "Guess what is going to happen in the future."

> "What you think will happen before you even try it out."

> "Educated guess. Take facts you know and try to guess what's going to happen with all the things that are going on."

These children agreed that you "think about it" or "use your brain" and suggested that you also have to

> "Study to see what it does and how it behaves under certain circumstances."

> "Use instruments and experience."

> "Think of all the facts you know about it."

> "Use common sense."

> "Know the facts, like, what's going on and what's in there that might make things different."

Grade six children gave a variety of examples to support their descriptions. They were able to think of examples from home and school. Some of their examples were

"When I asked to go to the water slides. I knew Mom would say yes because she got paid that day."

"Would I get in trouble or would I get home in time without [Mom] noticing?" (Should I go out and play when Mom isn't home?)

"In math--estimate answers."

"If a hockey game only starts one hour before the guide says a show will be on you can predict the show won't be on so you don't plan to watch it."

"When you study, you sort of predict what kind of questions will be on the test and study for them."

"When you make supper you guess how long it will take."

"In science we predicted what would happen to the predators if prey grew larger."

"You predict if you can do something before you try."

"In science we predicted which jar would have a balloon that would rise."

"The weather."

"Think of what will happen next in a story."

"At softball games I predict what time I'll be home, how long the innings will be and stuff like that."

These children thought that being able to predict was important and offered reasons to support this such as

"When you predict earthquakes or things like that there won't be as much damage."

"For a field trip you dress according to the weather."

"So you're safe."

"Cause it would be boring to wait to find out what would happen next."

"It can be fun when you try to guess first. You can learn from it if you guess wrong.""

That's mostly what your life is about."

"Then you would know what was going to happen. If there was danger or trouble, you could warn someone."

"If you couldn't predict, then you wouldn't be able to prepare for things."

The children's comments show a change across the grades and suggest a pattern of growth and development in their knowledge and understanding of predicting.

Chapter Five

Discussion of the Results of the Study

This study was undertaken to identify the course of development through the elementary grades of children's ability to make predictions. This was to be done by assessing their achievement on two separate tests--a paper and pencil test and a physical manipulation test. I hoped that comparisons of children's performance on the two tests would also provide useful information regarding how the process of predicting can be evaluated. Further, I expected that insights into children's understanding of the process of predicting might be gained through an interview with each child.

The study suggests the following conclusions, which will be discussed in detail in this chapter. Firstly, children's ability to make predictions shows a marked increase between grades one and two, and continues to show gradual, progressive growth throughout the elementary school grades. Secondly, comparisons of the results of the two tests show that both tests may serve as indicators of children's predicting ability, although the physical manipulation test would seem to be more useful than the paper and pencil test. Both tests would need some refinement before they could be useful to teachers. In particular, the physical manipulation test seems well suited to incorporating a content element specific to the class that could make this test sensitive within grades. Finally, the pattern of growth and development in children's knowledge and understanding of the process of predicting seems to parallel their growth in ability to make predictions. Children seem to understand predicting to be an internal process in which one uses knowledge to anticipate a future event, and to regard predicting as a way of being intellectually involved with the world.

Even though the original experimental design for this study did not call for the making of any observations of the children beyond their performance on the tests, the concurrent observations I made of the children as they performed the prediction tasks of the physical manipulation test revealed unexpected insight and a deeper understanding of the children's ability to predict. This could not have occurred through an examination of their test scores or a strict comparison of their performance on the tests alone. The common characteristics notable in the children's behavior and discussion about the tasks were imbedded in a rich variety of expressions that demanded a recognition of the individual nature of the children. This complexity made the results all the more meaningful when related to my past experiences with teaching science in the elementary school classroom. The discovery of the significance of these observations of behavior and of the importance of really listening to what children say comprises an important finding in itself, and contributes significantly, as will be seen in this chapter, to all aspects of the study.

Development of Predicting Ability

The test scores clearly show that the predicting abilities of elementary school children increase gradually from grades one through six. My concurrent observations of the children's performance on the physical manipulation test support this conclusion. In general, children in higher grades seem to work more confidently and to express their predictions and explanations in a more organized manner than do children in lower grades. The test results also show that grade one children are significantly poorer in predicting ability than children in other grades. My concurrent observations are consistent with these results as well, and not only show how they are poorer but, as will be discussed here, may help to provide some explanation about why.

Grade one children responded to the test and the testing situation quite differently than did children in other grades. Grade one children were more anxious when they entered the room and were more easily distracted during the test. They seemed unsure of what was expected of them, but at the same time were determined to do well.

At times I became quite uncomfortable with the stress that the testing appeared to cause them; nevertheless the children always expressed great satisfaction about completing the tasks "just like the big kids."

Grade one children made a considerably greater number of errors in making observations during the test activities than did older children. Observations of events that occurred quickly, for example, such as observing the height of the first bounce of the ball in the 'ball and chart' activity, were most likely to be inaccurate. Observations that required children to focus on one aspect of a system, such as was required in the 'viscosity of liquids' activity, also tended to be inaccurate. Grade one children tended to notice irrelevant details and to ignore the main events that had been so carefully set up to draw their attention. Another difference between grade one children and those of the higher grades was the tendency for grade one children to regard each observation as a discrete event. They would seem to forget or to ignore the first observation while making the second or third observation in an activity and, therefore, could not compare a sequence of observations to determine a pattern.

On the surface, it appears that these children are simply not "ready" to engage in prediction tasks. The characteristics they displayed suggest that their thinking is that of Piaget's preoperational period of development in which children attend to only one attribute of an object or event and ignore all other characteristics and, therefore, are unable to cope with changes in a sequence.

There may be other reasons for their behavior, however. Donaldson (1978) points out that how children encode a problem makes a considerable difference in their ability to solve it:

> If you want to solve a problem it is obviously desirable, to say the least, that you should be able to register those features which are relevant to the solution." (p. 103)

Perhaps the activities included in this test were too complicated for these children; perhaps they involved too many "relevant features," or perhaps they were presented in a manner that confused the children in their encoding of the problem. Reconsidering the tasks and how they were presented to the children may provide better reasons for their poor performance than claiming that these children were not "ready" to engage in predicting.

When trying to understand their behavior, we might also consider the concepts the grade one children brought with them to the tasks. Grade one children have really had very little, if any, formal instruction in science topics, and their understanding about the content and concepts involved in the prediction tasks would primarily have been developed through everyday experiences. These kinds of concepts are what Vygotsky calls "spontaneous concepts". Vygotsky (1962) maintains that

> It could be shown that all the peculiarities of thought described by Piaget stem from the absence of a <u>system</u> in the child's spontaneous concepts. . . " (p. 116, emphasis added)

He points out that a child using spontaneous concepts makes empirical statements that follow the logic of perceptions but that do not involve generalizations. Vygotsky cites the example of a child in Piaget's experiments who said that one object dissolved in water because it was small and another dissolved because it was big. The child is not disturbed by the contradiction, according to Vygotsky, because he does not have the generalization "smallness leads to dissolution" in his mind. "It is this lack of distance from the immediate experience . . . that accounts for the peculiarities of child thought" (p. 116). Perhaps, the behaviors of grade one children owe more to the spontaneous concepts they brought to the prediction tasks than to a lack of intellectual "readiness."

Grade one children also quite commonly made highly inaccurate predictions and when the two of us "tried them out" claimed, nevertheless, that their predictions were correct regardless of quite obvious results to the contrary. The 'sound' activity most commonly provided this situation. Here grade one children consistently claimed that the sound was getting lower as a fret was moved to make a shorter string. The sound was actually getting higher and the children could correctly identify the change of pitch in the next part of the activity just seconds later. This anomaly was clarified for me when one child demonstrated that if the tray was placed on its side the fret had to be moved downward to make the change in pitch. "You see," he said, "The wood is going down, so the sound is going down." The other children had seen the fret moving closer to them, and had apparently interpreted this as "down" and "lower". They displayed no discomfort with the inconsistency between their observations on the two parts of the test.

This too could be an example suggesting that the thinking of these children's is that of Piaget's preoperational period of development; or perhaps this is one more example of the peculiarities of behavior that Vygotsky describes as occurring when children rely on spontaneous concepts. The example also seems to show clearly that the children were <u>interpreting</u> the task quite differently than I had expected. When discussing whether children interpret differently than adults, Donaldson (1978) suggests that perhaps young children give more weight to cues of non-linguistic kinds because they are less knowledgeable or confident about the language than are older children. She suggests that they may not have learned to distinguish between situations where primacy is supposed to be given to language and situations where it is not. Also, the meaning of words is perhaps more flexible for young children than for older. Testing situations tend to rely on the primacy of language for communication, and assume that both child and the teacher understand in the same way. Perhaps the grade one children have brought an expectation with them to this task that predisposes them to notice the motion of the fret rather than to attend to a strict meaning of words.

Plester (1972) noted that children's ability to infer from visual input was superior to their ability to infer from auditory input. The children in the task under consideration seem to be relying on visual observations of the situation rather than auditory observations. Perhaps these children are trusting and using input that they have experienced most success with in previous activities. This is consistent with Donaldson's view of the situation.

Beginning in grade two and continuing through grade six, children made references to previous experience with the equipment or to their previously acquired knowledge of the content associated with the activity. As testing progressed through the grades, comments such as "I know about this" or "I've seen that before" increased in number. Knowledge gained through prior experience with the stimulant materials seemed particularly important to a child's success in the physical manipulation test. With, for example, the 'candle and jars' activity, a child who had not been convinced by previous experience that candles eventually go out when placed under jars would always insist that, under the next larger jar, the candle might not go out until it burned away completely. One child was so sure that the candle would not eventually go out, that even after he had seen the candle go out under the largest jar, he was very amused to be asked how long it would take for the candle to go out under a smaller (the second largest) jar. He replied with knowing giggles, "I know a trick when I see one. It won't go out under this jar!"

Driver (1983) observed that when children undertake investigations with unfamiliar equipment they may explore what seem to be irrelevant aspects of a system while neglecting relevant features. This seems to have happened with children who were unfamiliar with the 'candle and jars' equipment. One child thought it was a trick, but others could often explain that the candle went out because there was not enough oxygen to keep it burning. They seldom, however focused on time as a variable even though during the activity I frequently asked, "How long did it take for the candle to go out?" Children who did not focus on the time it took for the candle to go out under each jar would not have the information necessary to discern the pattern that would help them make an accurate prediction. These children needed more opportunity for exploration of and messing about" with the phenomenon before they could be expected to change their beliefs about how long a candle would burn under a jar.

During the 'ball and chart' activity, children who predicted the ball would bounce considerably higher than suggested by evidence from the observational part of the activity, frequently explained their prediction by pointing out that "Its a golf ball and I know golf balls bounce high." Or, "The ball is hard and hard balls bounce quite high." When Driver (1983) considered how children's beliefs affect their classroom learning she concluded that

> These ideas [beliefs children have about the phenomena they study] influence the observations pupils make in their experiments, as well as affecting the explanations they give for them. They can also persist in a range of situations and be resistant to change." (p. 33)

It seems that these children brought their own ideas developed from previous experience with bouncing balls to the test activity, and used this as a basis for their predictions.

My observations of the performance of grade four children as they completed the 'magnets' activity on the physical manipulation test seems to reveal another aspect of the effects of the knowledge and understanding that children bring to a task. Children who spoke of playing or "doing stuff at home" with magnets frequently placed all the metals in the "things that the magnet will pick up" groups. This occurred even though the observational tasks they had been given in the first part of the activity provided evidence that only one of the three metals in the observational sample was actually picked up by the magnet. Children who spoke of learning about magnets in school, however, were far more likely to nod confidently during the observational part of the activity and make a correct prediction of the items in the test group. Perhaps the children who had played with magnets had not had enough opportunity to develop a full and accurate concept of what magnets will attract, while children who received instruction on magnets were expressly and explicitly introduced to this information. Vygotsky, however, would suggest that these two groups of children brought different kinds of conceptual knowledge with them to the predicting task, and that this difference explains their ability, or inability, to apply the knowledge successfully. Vygotsky (1962) identifies two types of concepts. The first, spontaneous concepts, are those concepts developed by the child in everyday experiences; the second, scientific concepts, are those introduced through formal instruction. He suggests that scientific concepts carry relationships of generality or rudiments of a system within them from their inception in the child's mind. The lack of a system in the spontaneous conc[illegible] of children, Vygotsky maintains, makes them difficult to generalize and to apply to problems.

Vygotsky notes that

> the child . . . lacks awareness of his concepts and therefore can not operate with them at will as the task demands. (p. 106)

The introduction of magnetism to some children through formal instruction seems to have developed a scientific concept which they could use to assist them in the predicting task. The observational part of the activity may or may not have changed their knowledge of what magnets will pick up, but the children with these scientific concepts seemed more able to use observations and to use their previous knowledge to make predictions than did the children who brought only spontaneous concepts of magnetism to the task.

Evaluation of Predicting Ability

The mean scores on both predicting ability tests showed a gradual increase through the grades, although, except in one case, change from one grade to the next was not significant. This raises the question of the usefulness of either test for classroom use by teachers. It seems that, in their present form, both tests are indicators of children's predicting ability over a broad range. Classroom teachers commonly want tests to measure fine changes over a short period of time and neither of these tests seems sensitive to smaller increments or changes in predicting ability. In addition, my concurrent observations of children's performance on the physical manipulation test suggest that the conceptual context within which children make predictions is critically important to their achievement. This factor must also be considered in designing and choosing test items.

Information supporting the predictive validity of the paper and pencil test was derived through correlations of the scores on the paper and pencil test with those of the physical manipulation test. Nevertheless, the experience of administering each test and analyzing the results demonstrated a great difference in their potential usefulness for teachers. Scores on the paper and pencil test actually tell very little about the child: these scores may indicate a child's position within a range of ability levels but offers no information regarding why the child is performing at that level and no information about the nature of the child's performance. Without the potential for providing this kind of information, the test is extremely limited in its usefulness to teachers.

Administering a physical manipulation test such as the one used in this study, on the other hand, allows not only an assessment of abilities but also allows a teacher to enter into dialogue with each child. Through this dialogue a teacher can learn a great deal about the nature of and reasons for a child's performance on the test. Learning about the knowledge and previous experience that the children bring to the test, the reasons why the children make the predictions they do, and finding out just what attitudes children have toward the activities, adds depth and meaning to the test scores. This deeper understanding can enable a teacher to respond in a helpful way to the individual needs of the children, and can also be useful in making general curricular decisions. Decisions regarding the effectiveness of previous lessons and potential usefulness of specific lessons in the future can be facilitated by a better understanding of each child. In contrast to the paper and pencil test, the physical manipulation test can be useful both as a source of information to assist with teaching decisions and as a way of evaluating the predicting abilities of pupils.

The close relationship of children's past experience and knowledge with their achievement in the physical manipulation test is evident in children's performance on the test. When completing the 'candle and jars' activity, the children's previous experience and knowledge affected what they focused on during the observational part of the activity and, consequently, affected their success in making an accurate prediction and in giving a clear explanation of that prediction. Similarly, the previous knowledge children brought to the 'magnets' activity, and perhaps how that knowledge was acquired, seemed to influence the accuracy of their predictions in this activity. When reviewing inference test items on a test of process skills, Molitor & George (1976) noted a similar effect and suggested that

> Apparently, when the [test] item has conceptual content of a high degree of familiarity, a student will rely on past experience rather than collecting data. (p. 411)

Efforts to develop a content free test of the process of predicting seems contrary to this close relationship between children's knowledge and their ability to predict. In common experience, the process of predicting is not practiced outside of a conceptual context, and would be most meaningfully evaluated <u>within</u> an appropriately selected conceptual context. This means, perhaps, in something other than formal testing situations. Jean Beard (1971) came to a similar conclusion after developing a group achievement test for the processes of measuring and classifying. She asked,

> If science teaching is moving toward more student involvement and representative natural phenomena, shouldn't science testing estimate achievement from more concrete testing situations? (p. 183)

Harlen (1985) suggests that

> Each [process] skill has an influence on performance in many activities but in no one activity to such an extent that one could say: if a child can do this then he knows how to interpret information, or how to hypothesize, or whatever. Process skills have to be built up by continued use in a wide range of activities. Similarly, <u>their development has to be assessed by gathering information about their use in this wide range of activities</u>." (p. 178, emphasis added)

Harlen emphasizes that the classroom assessment of children's abilities in process skills can not effectively be achieved through tests. Instead, she suggests, teachers should gather information about children's development from the skills, attitudes, and concepts they display in normal activities. Perhaps the physical manipulation test used in this study proved to be a more meaningful method of assessing children's ability to predict than did the paper and pencil test precisely because it is designed to be as close as possible to children's normal activities in school science. As such, it approaches what Harlen has identified as a practical way for teachers to assess the development of children in process skills.

The predicting ability speed score correlated significantly with the other two predicting ability scores, indicating that this too might be a valid measure of children's predicting ability. Concurrent observations of their performance during the physical manipulation test, however, suggest that the speed at which children make predictions is regulated by a variety of conditions and in fact may be an irrelevant variable to use when assessing children's predicting ability. Some children seemed to have difficulty understanding the activity and needed a long time to work through to a prediction; other children used an equally long time in order to do a thorough and careful job, even though they were having no apparent difficulty. On the other hand, some children worked very quickly, apparently because they understood little of the activity and were happy to choose arbitrary answers just to be finished, or to please the "teacher". Others worked at the same quick speed because they had (at least, seemed to have) such a clear understanding of the situation that they were able to make predictions immediately. Consider, for example, the grade two boy who, while completing the 'ball and chart' activity of the physical manipulation test, predicted without hesitation that the ball, when dropped from the designated height, would bounce to the letter M on the chart. He answered quickly and confidently, and M is not only a good prediction in this case but is also the "right answer". When I asked him why he chose M, though, he responded delightedly, "M is my favorite letter!" This can be contrasted with the performance of another grade two boy in this activity who made a prediction much more slowly but still accurately. When this child was asked to explain his prediction, he went into great detail about what he had noticed during the observational part of the activity and how that had helped him choose the letter M for the height of the bounce. It seems reasonable to assume that an equally wide range of conditions might affect the speed at which children completed the other activities, and even the paper and pencil test. If this is so, the predicting ability speed scores are, quite simply, meaningless.

Comparing the mean scores on the physical manipulation test with those of the paper and pencil test reveals that the children consistently achieved higher scores on the physical manipulation test. This fact along with further consideration of how much is actually learned about the child through the use of each test suggests that a fuller and in many ways more accurate measure of the predicting ability of children is gained through the physical manipulation test. This supports the conclusion of Walbesser and Carter (1970) who studied the effects that altering test administration from an individual to a group form has on test results. They concluded that, "By using the more convenient group format tasks, the teacher may be underestimating the attainment of students." Wynne Harlen (1985) would take this position even further. She points out that thoroughly adequate testing in elementary science would require very long tests that assess each skill, attitude, and concept across a range of situations. This she emphasizes would interfere with regular instruction, distress children, and still provide unsatisfactory and incomplete information.

Children's Knowledge and Understanding of Predicting

The move from making predictions based only on intuition, with no real understanding of the process, as happens with most grade ones, toward predicting with conscious understanding of the process, can be seen in the increasing number of children in each grade who have better and better notions of what predicting is. By grade three almost half the children express a conventional understanding of predicting, and this number continues to increase through grade six. Thus we see a pattern of growth and development in the knowledge and understanding of the process of predicting itself.

The growth and development in children's knowledge and understanding of the process seems to support a hypothesis which Vygotsky (1962) puts forth regarding the interrelatedness of "spontaneous" and "scientific" concepts. He stated that

> The formal discipline of scientific concepts gradually transforms the structure of the child's spontaneous concepts and helps organize them into a system; this furthers the child's ascent to higher development levels. (p. 116)

Vygotsky also expresses the view that

> School instruction induces the generalizing kind of perception and thus plays a decisive role in making the child conscious of his own mental processes. Scientific concepts [concepts taught in school], with their hierarchical system of interrelationships, seem to be the medium within which awareness and mastery first develop, to be transferred later to other concepts and other areas of thought. Reflective consciousness comes to the child through the portals of scientific concepts. (p. 92)

Early evidence of the influence of school instruction on the development of children's knowledge and understanding of predicting seems to be present in the responses of children who expressed a vague, overly generalized understanding of predicting. These children seemed to relate the process closely to school where they were formally requested to make predictions. They expressed a feeling that they do not predict at home and offered examples of predicting in school that included other tasks, such as brainstorming and answering questions. Even with the apparent difficulty these children had in articulating what predicting is, it seems clear that their awareness of the process is developing through school instruction. Children who express a better, more conventional understanding of the process gave explanations and examples from both school and home, and discussed the significance of predicting to their life. This suggests that their awareness of the process may actually have transferred to other areas of thought and perhaps to have deepened into the reflective consciousness that Vygotsky refers to.

Children who express a better, more conventional understanding of predicting seem to share several common themes in their understanding of the process: To make a prediction, one child suggested, one needs to

> Know a little about it [what you are making a prediction of]. You can use the information. If you don't know [the prediction immediately], try to resemble it [the information] to something you do know.

This child was expressing ideas about predicting that seem to be central to children's understanding of the process: Predicting is an internal process, something that happens "in your head"; and, predictions are based on information that comes through observations and from knowledge derived from previous experience. When describing the process, children also seemed to express a sense that predictions are about future events and thus are tentative in nature. The child who described predicting as "reading the future" expressed this quite clearly: "You say what will most likely be. You're not exactly sure [but] close . . . .".

The examples these children gave of predicting suggest that they regard predicting as a very personal process. Predictions, it seems, can be the basis of decisions and action. Choosing appropriate clothing or activities for the day based on a weather prediction, or pacing work in school based on a prediction of the consequences of having homework, are examples of this role of predicting that children seem to see as part of their life experiences.

Predicting seems, to be regarded by children as a stimulating way of being intellectually involved with their world. When one child said, "If you didn't predict things, life would be boring," and when another said, "Sometimes it [predicting] can be fun . . . .", they were referring to making predictions in everyday life as well as in formal settings. Children with this more conventional understanding of predicting drew many more examples from their personal experiences than they did from those times when they were formally requested to make predictions.

Children also seem to be saying that predicting is important as a way of checking their understanding of the world around them. An accurate prediction is a confirmation that their understanding is correct, while an inaccurate one indicates they must reformulate that understanding in some way. Reality, it seems, is the confirmation of one's intellectual conception of the world.

The sense of personal involvement in determining what is real that some children expressed is remarkably similar to the epistemological theory known as "Constructive Alternativism" that was outlined by George Kelly (1955) and referred to above (p. 25). Kelly's belief is that people understand their surroundings and themselves, and that they anticipate the future, by building "constructs" about the world and testing the predictive efficiency of these constructs against experience. Kelly would say that reality itself is the confirmation, through the testing of predictions, of each person's constructs. This sense of intellectual involvement in determining reality for the individual was perhaps most clearly and touchingly articulated by the gr[illegible]ur child who said, "If you didn't have predictions, not too many things could be real."

Making predictions, though, is not without risk. As one child pointed out, "It [predicting] is scary. I feel terrible when I'm wrong." Whether for better or for worse, children seem to feel that predicting is an integral part of their life. This was most strongly expressed by the girl who said, "Predicting is mostly what your life is all about."

Chapter Six

Conclusions and Implications of the Study

A number of conclusions and implications follow upon this study.

Conclusion 1: Children in grade one are able to make predictions but have little or no conscious understanding of how they came to the prediction. This is probably because they interpret the situation with less attention to word meanings than older children, and bring fewer "scientific", or formally taught, concepts with them to the predicting task.

Implications: Teachers can and probably should give grade one children activities that involve predicting. Vygotsky (1962) stresses that

> The only good kind of instruction is that which marches ahead of development and leads it; it must be aimed not so much at the ripe as the ripening functions. (p. 104)

Teachers must be sensitive, though, to the potential that grade one children have for interpreting the situations presented to them in a different way than is intended. This sensitivity means being careful to present the activity as clearly as possible, and then both allowing for and listening carefully to the questions and comments the children will make about the activity. Those concerns must be discussed fully with them in order to give helpful assistance both to their understanding of the concepts and to their efforts to make predictions.

Conclusion 2: Children's ability to predict shows continued, gradual, progressive growth from grade one through grade six. This growth seems to be related to the concepts they bring with them to the predicting task, and to their level of knowledge and understanding of the process itself.

Implications: Children should be given opportunities to practice the process of predicting throughout elementary school. At least some of this practice should be intentional, within a more or less familiar conceptual context; if it is the process itself which is to be practiced, it should be related to knowledge that the children have acquired either from past experience or from instruction, so that they are familiar enough with the context to be able to attend to the relevant features. In addition to providing practice in predicting, teachers should explicitly identify the process for children and encourage discussion of how they arrived at their predictions and of what predicting is. Vygotsky (1962) stresses that

> Scientific concepts [concepts developed through formal instruction] supply structures for the upward development of the child's spontaneous concepts toward consciousness and deliberate use. (p. 109)

Explicit instruction regarding the process would encourage the growth and development of children's understanding of the process as such.

Conclusion 3: The predictive validity of the paper and pencil test is supported by correlations of the scores on this test with the scores on the physical manipulation test. Nevertheless, the experience of administering the tests leads to the conclusion that the physical manipulation test is a more meaningful test of predicting ability because of the potential for dialogue with children and the knowledge of the children that is gained thereby.

Implications: The paper and pencil test may serve as an indicator of predicting ability but doesn't tell enough to be practical for use in the classroom. Harlen (1985) emphasizes that teacher's need information about children's thinking and abilities, information that will help in

> planning activities at the level likely to provide a challenge that children can meet, for deciding how to help individual children's ideas and skills to develop, and for keeping records of progress to use in future planning. (p. 175)

The physical manipulation test offers better opportunities for teachers to gather the wide range of information they need to serve the purposes Harlen identifies.

Conclusion 4: Engaging in dialogue with children when assessing their abilities to make predictions is an important and valuable part of the evaluation procedure.

Conclusion 5: Children's ability to predict is closely related to the conceptual context of the task and should be evaluated within a suitable conceptual context. The physical manipulation test provides a model for procedures teachers could use to assess the predicting abilities of their pupils during regular classroom activities.

Implications: The predicting ability of pupils could be evaluated through focused interaction with the children while they are participating in an activity that engages them in that process. The procedures used during the physical manipulation test are actually similar to the usual activities of a teacher when children are involved in a science activity and the teacher is interacting with individual pupils or small groups. The physical manipulation test activities engage children in the process of predicting, and the questions used in the test focus the evaluation specifically on the children's use of the process. Teachers who wish to assess the predicting abilities of their pupils could involve their pupils in activities similar in design to those on the physical manipulation test, but within a conceptual contexts which the teacher has determined are familiar to the children. Teachers could pattern their interaction with the children along the lines of the procedures used in the physical manipulation test, thereby focusing evaluative attention on the process of predicting.

<u>Conclusion 6</u>: There is a wide range of reasons for the speed at which children make predictions; knowing only the speed at which children complete a predicting task is essentially meaningless.

Implications: Teachers should not use time as a criterion of achievement in predicting. Time is probably not a good criterion for measuring achievement of other process skills either.

<u>Conclusion 7</u>: Children with a vague understanding of predicting seem to relate the process closely to what they do in school.

Implications: Children begin to develop an understanding of the process through instruction by teachers. This supports the earlier suggestion that teachers should identify the process of predicting for children and should explicitly try to enhance their understanding of predicting.

<u>Conclusion 8</u>: Children with a more conventional understanding of the process of predicting emphasize that predicting is an internal process, whereby knowledge is used to anticipate a future event. They seem to regard predicting as a way of being intellectually involved with the world in a manner that allows them to check their conceptions of it.

Implications: Accepting the personal and important nature of predicting that these children seem to express implies that each child's response on a predicting task should be treated with respect and each "mistake" handled with sensitive concern.

Reflections on the Study and Suggestions for Further Research

This study was undertaken to identify the course of development of children's ability to predict by assessing their achievement on two separate tests, a paper and pencil test and a physical manipulation test. Another intent of the study was to establish some validity for the paper and pencil test in terms of the physical manipulation test. Both of these intents have been to some degree fulfilled through statistical analysis of the test results. Concurrent observations of each child's performance on the physical manipulation test supported and added depth of understanding to these analyses.

The concurrent observations of children's performance, and the interviews included in the study, in which children's knowledge and understanding of the process of predicting was explored, were initially intended to be a small part of the study. Nevertheless, as the research program progressed, the nature and amount of information gained through these two procedures went beyond providing simple support for the analysis of test scores. Instead, they drew attention to comparing the tests from a different perspective, making apparent the importance not only of a test's sensitivity to achievement levels in predicting, but also of a test's ability to provide different kinds of information about children. Observing and interviewing provided unexpectedly deep insight concerning the tests and the development of children's ability to predict. It became obvious, for example, that one test is vastly more informative than the other, and that the numerical scores which the tests provide are of limited value. It also became obvious that children's development in ability to predict is accompanied by a development in their knowledge and understanding of the process. Although the concurrent observations and the interviews in some ways remained the lesser part in the overall design of this study, it is clear now that the insights they provided about the tests, and about the children's understanding of predicting and of its role in their lives, is the greater contribution to the study.

The findings of this study suggest some specific questions that would be worthwhile pursuing.

(1) The conclusion that there is a relationship between children's previous experience and knowledge, their level of understanding of the process, and their ability to predict, suggests that research designed to explore this relationship more fully could provide information helpful in program development.

(2) Further research is needed to develop our knowledge of how to better understand and be more sensitive to the way grade one children think.

(3) Grade one children showed a definite preference for visual input when trying to make sense of the "sound" activity in the physical manipulation test. Research comparing how children of this age use auditory and visual input and what their preferences are when choosing between input from both sources could enhance our understanding of how children process observational information.

(4) During the physical manipulation test children were asked to explain their predictions. Their responses tended to fall into four broad categories. Students would: (a) reiterate the prediction; (b) give a statement of the observations they used for the prediction; (c) give a statement of the observations and inferences used and describe how they led to the prediction; or (d) give a rule that leads to the prediction, such as, "The smaller the jar, the shorter the time." No effort was made during this study to determine what significance, if any, there may be to this variation. Further research is required to deepen our understanding of exactly how children make predictions.

(5) Further study is needed to provide a more precise description of how the ability to predict actually develops. Such research could provide valuable

information for program decisions and evaluation procedures, and could in general help to clarify our understanding of the intellectual development of children.

(6) Findings of this study highlighted the importance of the conceptual context of the prediction tasks that children undertake. Research is needed to determine which concepts are best suited for predicting activities at specific grade levels.

(7) Children in all grade levels overwhelmingly chose to time events by counting. Only four of all the students tested used a clock, even though there was always a wall clock with a sweep second hand and a digital watch readily available throughout the test. Not only did children choose to count, but very few seemed to be aware of the pace at which they counted. The younger children would frequently increase or decrease the pace of their count in order to finish on the number of seconds they had predicted the event would take. Even grade six children varied their pace, although not so obviously as the younger children. Research to explore children's conce[illegible] time, their measurement of time, and their <u>expe[illegible]</u> of time may provide some insights to this phenomenon.

The results of this study have provided some insight concerning the gradual, progressive growth and development of the predicting abilities of elementary school children across the grades. The study also confirms the possibility of the development of a practical and useful procedure to assess children's ability in the process of predicting. Perhaps more importantly though, the study has demonstrated a need for research that attends to children's experiences. Studies designed to better understand how children make predictions, why they make the predictions they do, and how they explain their predictions seem crucial. Research to deepen our understanding of how children experience predicting, how they feel about it, and how they value this and other science processes, would provide important insights into the child's world. Such studies would require extensive use of naturalistic, qualitative research procedures. This research would be of interest not only to science educators but to all who hope to understand children's thinking and the child's world.

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APPENDIX 1

RANDOM NUMBER GENERATION PROGRAM

RANDOM NUMBER GENERATION PROGRAM
MARCH 31,1986

```
10 CLEAR
20 CLS
30 OPTION BASE 1
40 DIM TSAM%(4)
50 DIM SAMPLE%(7,6,4)
60 FOR S = 1 TO 7
70  FOR G = 1 TO 6
80   RANDOMIZE TIMER
90     FOR C = 1 TO 4
100     TSAM%(C) = 1+(INT(RND*36))
110      FOR T = 1 TO 4
120       IF TSAM%(C) = SAMPLE%(S,G,T) THEN GOTO 100
130      NEXT T
140     SAMPLE%(S,G,C)=TSAM%(C)
150    NEXT C
160   ERASE TSAM%
170  NEXT G
180 NEXT S
190 REM PRINTING NEXT
200 REM
210 REM
220 FOR S = 1 TO 7
222  LPRINT
223  LPRINT
224  LPRINT       "School Random Sample Listing"
225  LPRINT
230   FOR G= 1 TO 6
240     FOR T = 1 TO 4
250      LPRINT SAMPLE%(S,G,T)
260     NEXT T
270    LPRINT
280    LPRINT
290   NEXT G
300  LPRINT "---------------------------------------------"
305  LPRINT CHR$(12)
310  NEXT S
320 PRINT "END OF LISTING"
330 END
```

APPENDIX 2

LETTER TO PARENTS

Dear Parents,

As a graduate student in the Department of Elementary Education at the University of Alberta, I am currently conducting a research project in the field of science education in elementary schools.

Your child has been selected to participate in this project. The purpose of the study is to determine the ability of elementary school students to predict, based upon their response to observations of familiar things and events. The study is intended to compare two methods of measuring the predicting abilities of the students and will help in bringing about improvements in educational methods and procedures.

Your child's participation in the study will require involvement in approximately three half-hour sessions. A general abilities test and two separate tests of predicting ability will be given to students from each of grades one through six. Your child is one of those chosen. The first pair of tests are of a paper and pencil type and will be given to the chosen students as a group. The third test involves activities similar to those during science class, and will be given on an individual basis.

No individual student who takes part in this study will be identifiable in the final report and the full privacy of each person and their responses to all tests is completely assured. Upon completion of the study, a summary of the results will be available for your information from the school.

Involvement of your child in this study is entirely voluntary and will be based upon your personal feelings about this matter. Should you wish to allow your child to participate your assistance through written consent (as set out below) for your child's pioneering contribution to this potentially important study would be greatly appreciated.

If you wish further information, please feel free to contact me (office: 432-2286; home: 458-6725). Thank you for your consideration of this matter.

Sincerely,

K. W. Melville

Kathleen W. Melville

A STUDY OF THE PREDICTING ABILITIES OF
ELEMENTARY SCHOOL STUDENTS

by

Kathleen W. Melville
Department of Elementary Education
University of Alberta

- **Parent Consent Form:**

I give permission for my child, ______________________,
to participate in the study indicated above.

____
Signature of Parent or Guardian

____
Date

- **Student Consent Form:**

I also wish to take part in this study.

____
Signature of Student

____
Date

- **Completed Form Received:**

____
School Principal or Designate

____
Researcher

____
Date

APPENDIX 3

DIRECTIONS FOR PAPER AND PENCIL TEST OF PREDICTING ABILITY

DIRECTIONS FOR PAPER AND PENCIL TEST OF PREDICTING ABILITY

In this test you will see rows of figures or designs like <u>these</u>.

(Investigator shows class an example--prepared ahead of testing and mounted for easy handling.)

Each row shows you a different problem. In each of the problems, the first four pictures show you something happening in order. You are to choose the picture that will come next from the five pictures that follow.

Let me show you what I mean:

(Investigator displays one problem, has students choose what they think is the correct answer, and discusses the result. Investigator then does the same with a second problem.)

Mark the picture which you think is the best answer by putting a circle around the letter below the picture. Remember, you are to choose the one picture from the answer pictures which belongs <u>next</u> in the question or set.

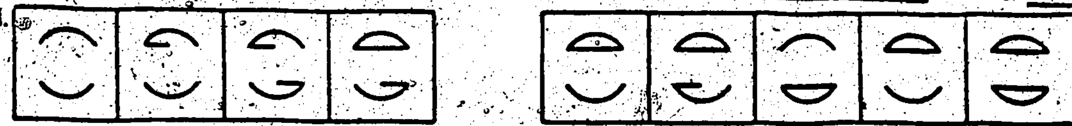
APPENDIX 4

PAPER AND PENCIL TEST
OF PREDICTING ABILITY
WITH CORRECT ANSWERS
CIRCLED

Key

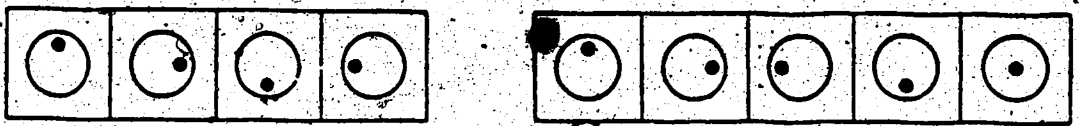
Name ____________ Grade _____ School ____________ Time _____

1.



A B C D E

2.

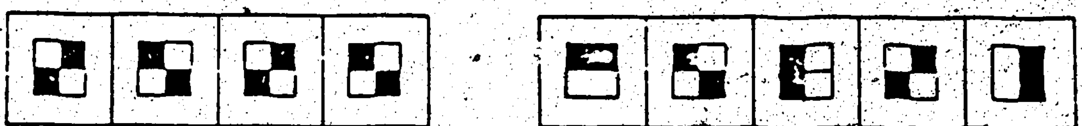


A B C D E

3.

A B C D E

4.



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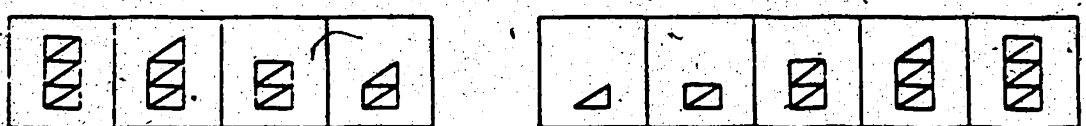
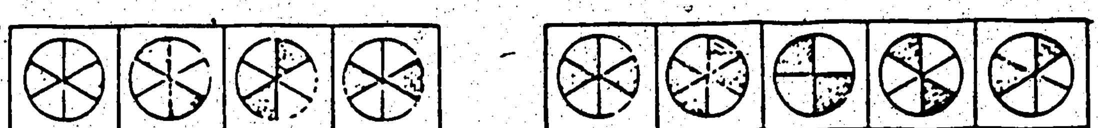


A B C D E

6.

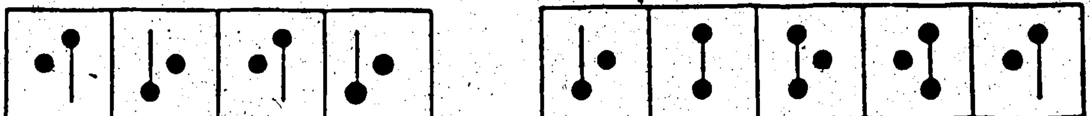
A B C D E

7.



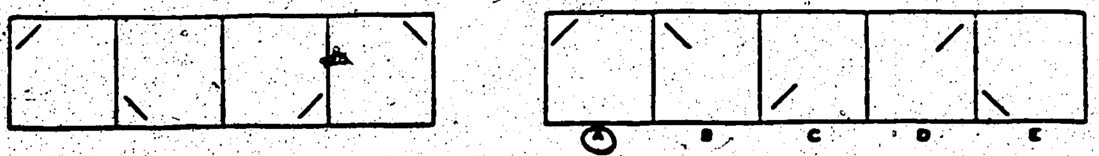
A B C D E

8



A B C D E

9.



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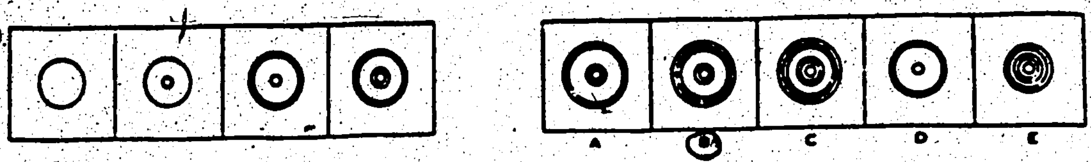

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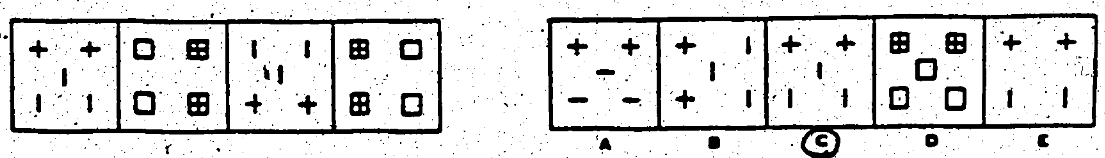

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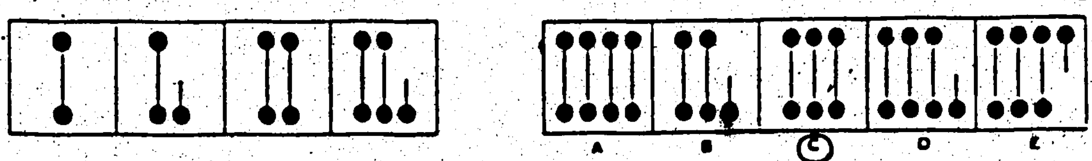

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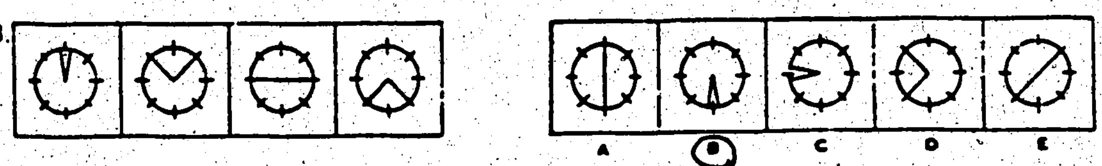
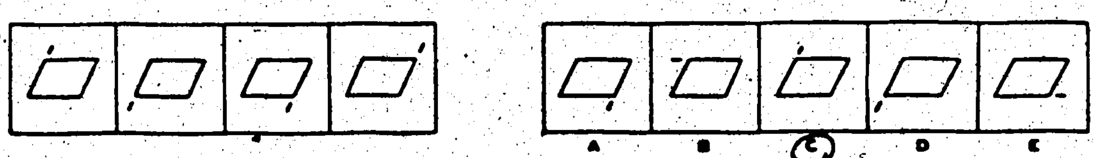


14.

15.



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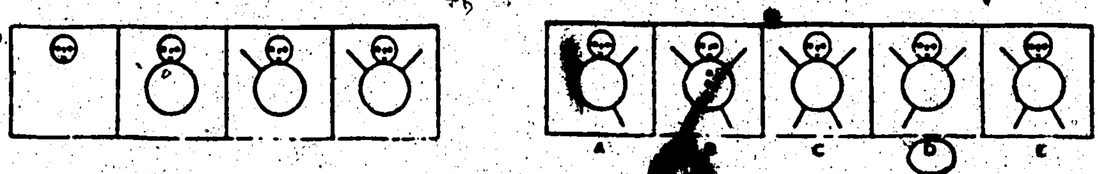
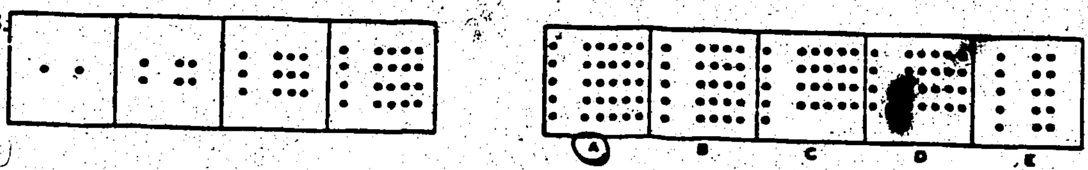


17.


18.


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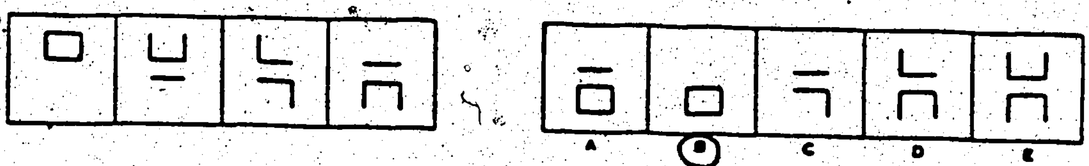
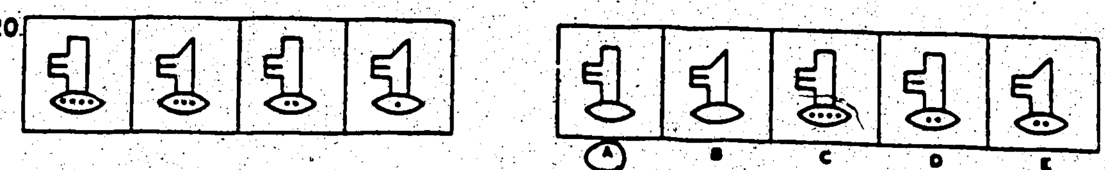
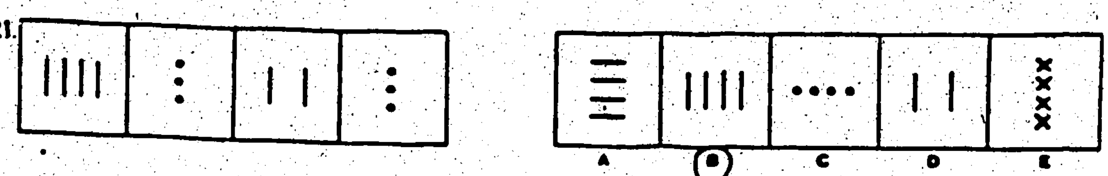
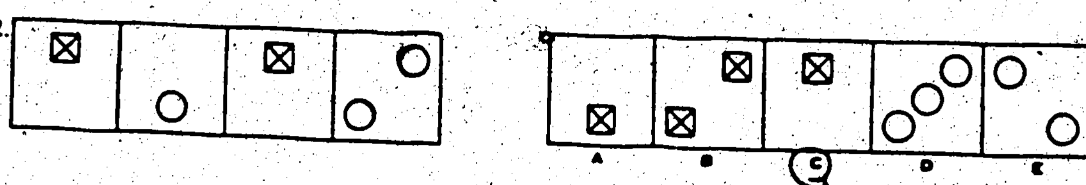


20.


21.


22.


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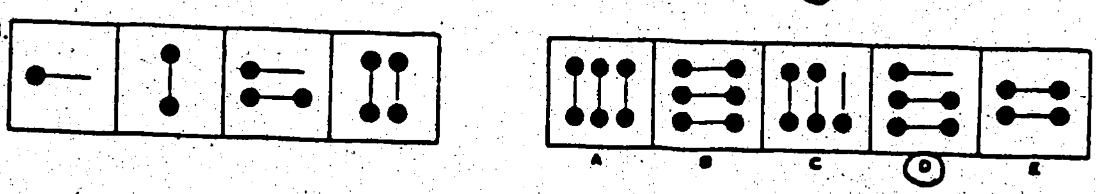

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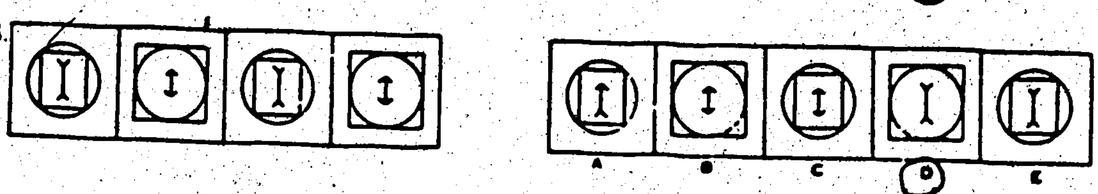

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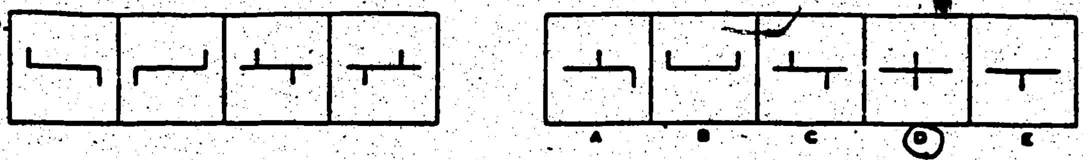

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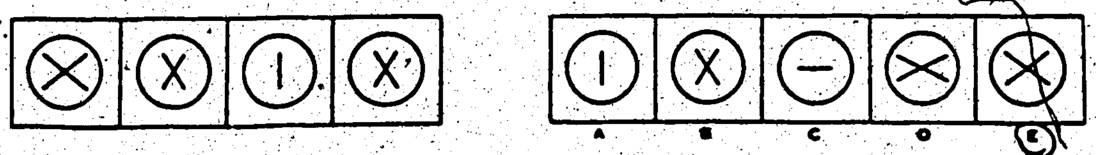

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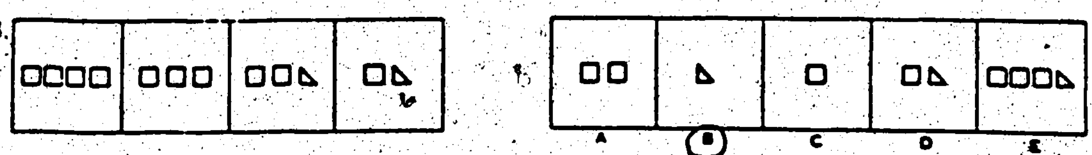

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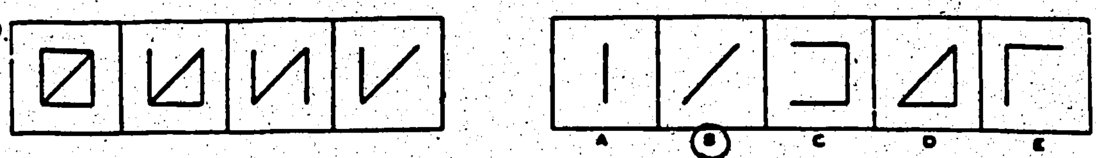

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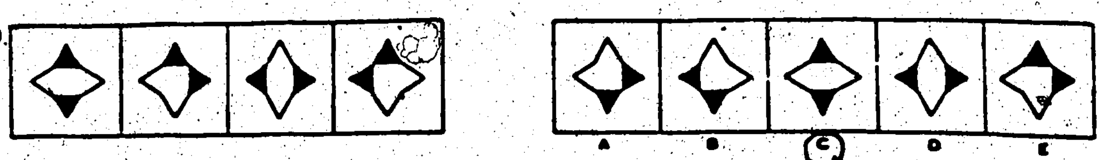

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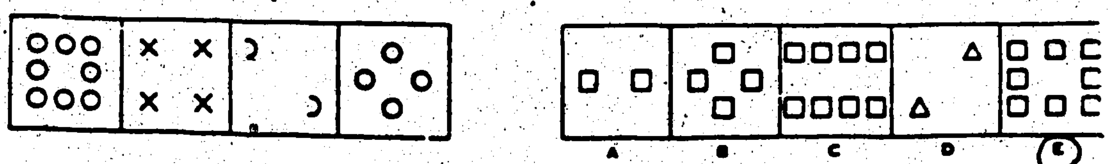

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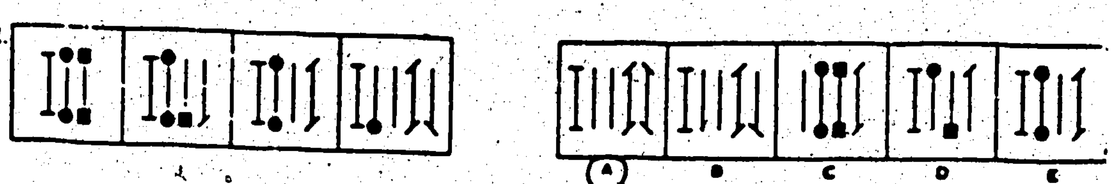

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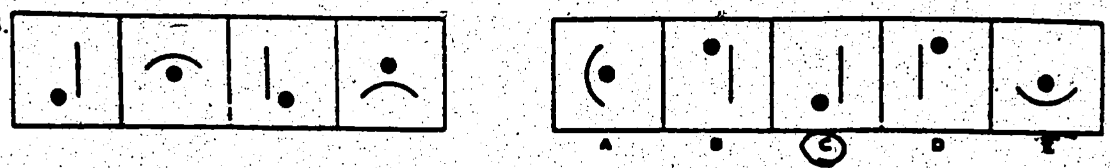

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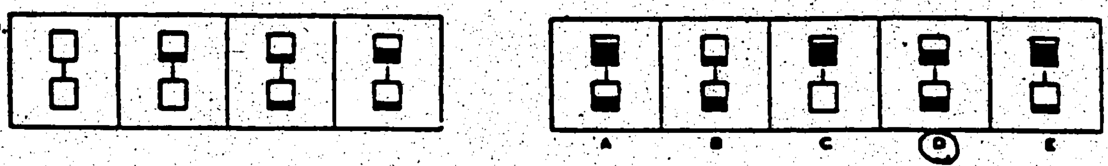

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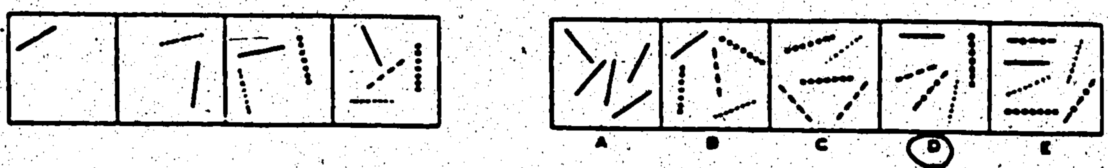

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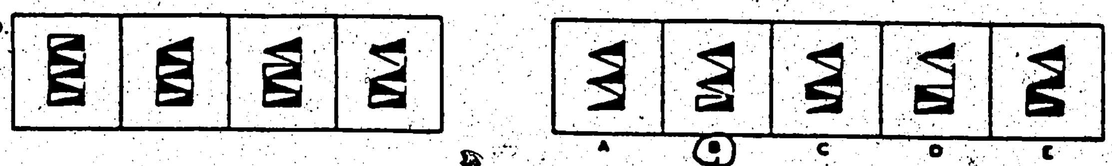

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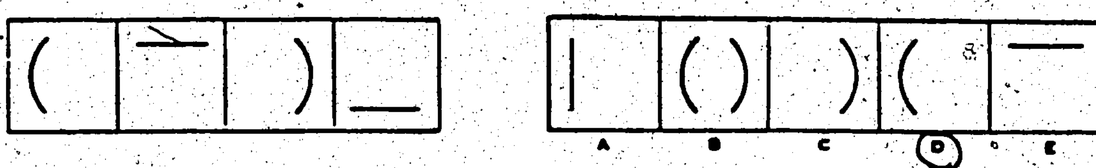

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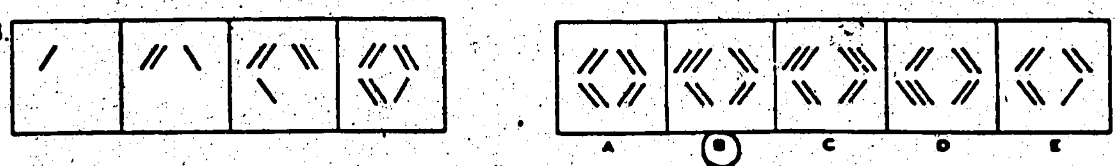

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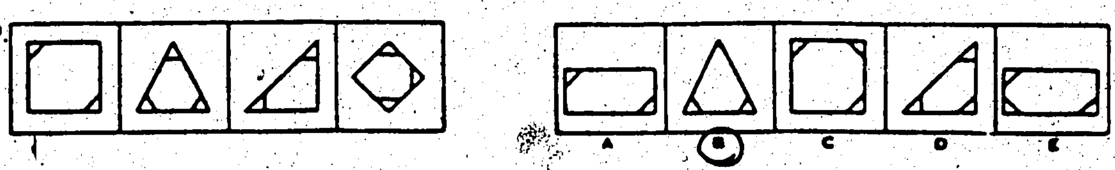

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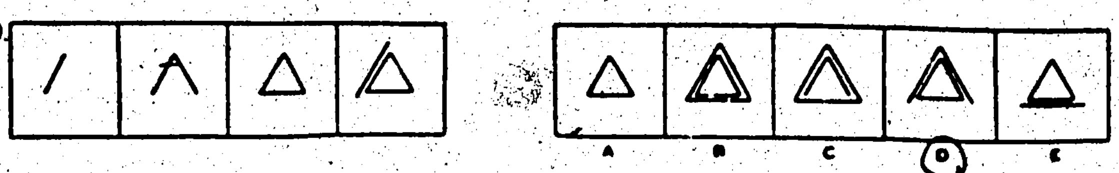

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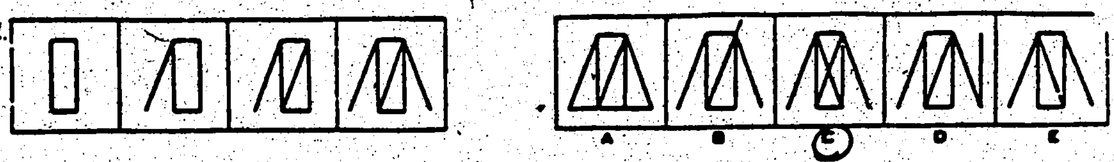

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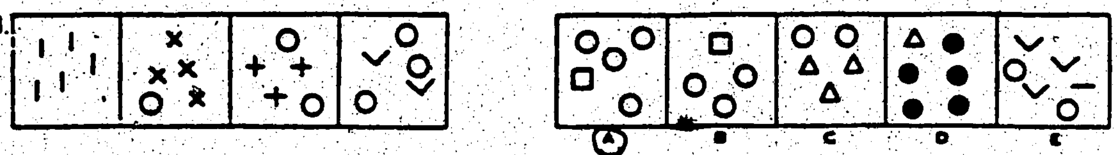

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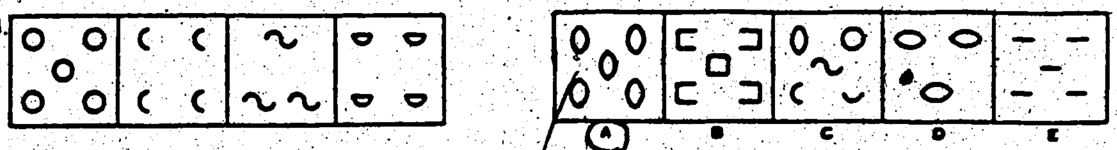

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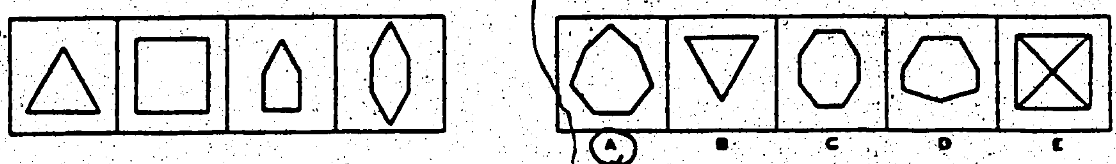

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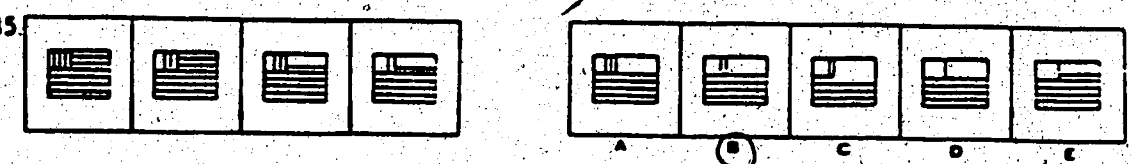

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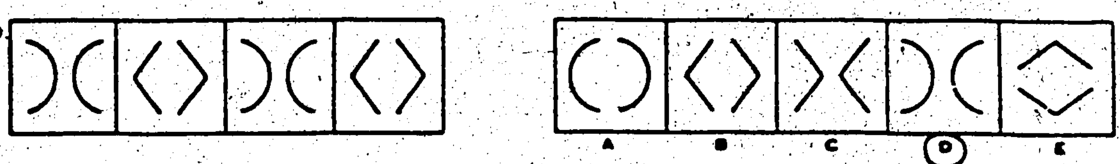

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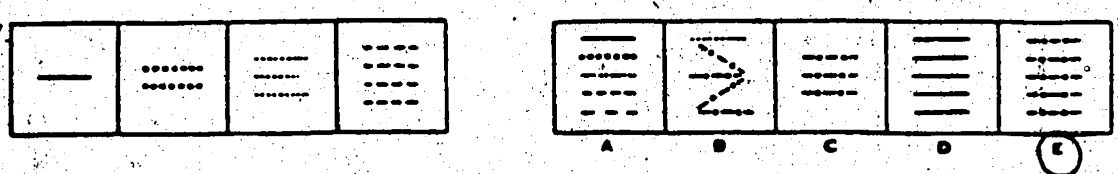

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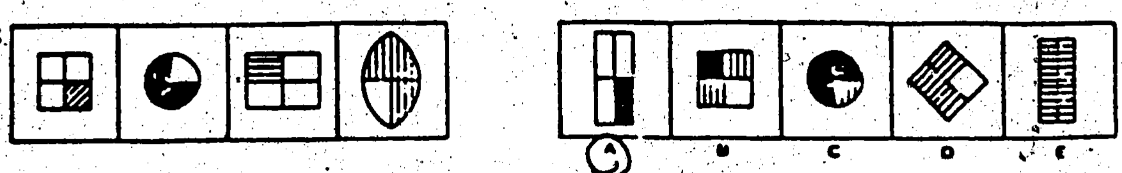

APPENDIX 5

DIRECTIONS FOR PHYSICAL MANIPULATION TEST OF PREDICTING ABILITY

DIRECTIONS FOR PHYSICAL MANIPULATION TEST OF PREDICTING ABILITY

Viscosity of Liquids

Apparatus

Two glass cylinders: one containing water and a marble, the other glycerine and an identical marble.

Investigator's Presentation

1. I'd like you to look at these two tubes. Each tube has a clear liquid and a marble inside it. I'm going to ask you to turn the tubes upside down but before you do, tell me what you think will happen to the marbles when you turn the tubes over.

   Good, you were right

   Try it or

   What happened? (to the marbles?)

   Did you notice anything different between them? What did you notice?

2. If we could pour the liquids out of the tubes, which liquid would pour faster--A or B? Why?

3. If you could touch them, which of the liquids would feel thicker--A or B? Why?

Weights and Spring

Apparatus

Four weights, spring, stand with scale.

Investigator's Presentation

The spring is hooked to the top of this scale. I have measured equal distances on this board and drawn lines, then written a letter by each line so we can name them.

1. Where is the bottom of the spring when I hook it to the top of the scale?

   Right, it's G.

   Try <u>or</u>

   The bottom is here (point), that is, at G.

2. What will happen to the spring when I hang the weights on?

3. (Hook one weight on). What happened?

   Down to F

   What happens when I put another on?

   Down to E

   And when I put two more one?

   Down to C

4. Now, what will happen if I take one weight off?

   Let's check your answer: Were you right?

Magnets

Apparatus

Six rectangular objects, 9 objects of cylindrical and sperical shape made of the same substances, one magnet.

Investigator's Presentation

This time we are going to look at magnets. Before we use the magnet, can you tell me what these things are made of?

1. Point to each one and tell me what it is made of if you know.

   Now, use the magnet to find out which ones can be picked up by the magnet (give magnet to student).

   Only one is picked up by the magnet. Let's put these up here (arrange above the tray with the one attracted separate from those not attracted).

2. (Place set of objects in the tray.) Without using the magnet, put these things in two groups: one group will be things which the magnet can pick up and the other will be things which the magnet cannot pick up.

3. Why will the magnet pick these things up?

   Why won't it pick these ones up?

4. Was there anything you learned from the first set we looked at with a magnet that could help you make the groups?

   Do you want to check your groups? Here is the magnet.

Ball and Chart

Apparatus

Golf ball and chart.

Investigator's Presentation

This is the chart we used with the spring. This time, I'm going to drop this ball and I want you to tell me how high it bounces. Do you have any questions? You might want to use the paper and pencil to help you remember what heppens.

1. First I will drop the ball from G (drop ball from G). How high did it bounce?

2. This time I will drop the ball from D (drop ball from D). How high did it bounce?

3. Now, if I drop it from I, how high will the ball bounce?

   Why do you think it will bounce to _______?

Sound

Apparatus

Musical instrument with four elastics and one length of wood.

Investigator's Presentation

Let's look at this musical instrument I made.

1. First, we will only use this elastic (the thickest elastic). Listen to this sound (pluck the elastic on long side of fret [wood]). Now, when I move the wood listen to this sound (pluck after placing fret in middle).

   Are the sounds different?

   How are they different?

   What will happen to the sound if I move the board here (move to shorten the elastic)?

   Why do you think the sound will get higher?

   Try it!

2. Now, let's look at these two elastics (pluck one, then the other).

   What's different between their sounds?

   Will the sound be higher or lower when we pluck this (third, thinner) elastic?

   Why?

   Try it!

3. I can place the board here (right side), here (middle), or here (left side), and I can pluck any elastic I want to make a sound. Where should I put the board and which elastic should I pluck to make the highest sound I can on this musical instrument?

   Where do I place the board?

   Which elastic do I pluck?

   Why?

   Let's try it. Were you right? (If not, pluck where it would be correct.)

Candle and Jars

Apparatus

Jars, clearly marked 4 units, 8 units, 16 units and 32 units; matches, candle, paper; pencil, timing device.

Investigator's Presentation

1. Here are four jars and a candle. I'm going to light the candle (light candle). What will happen to the flame when I place a jar over the candle like this (demonstrate beside the candle)?

   Let's try it with this jar (place smallest jar over the candle).

   You were right!

   Try or

   The flame goes out.

   Why did it go out?

   How long do you think the candle burned before it went out?

2. What will happen when I put this jar over the candle?

   How long will it take? (place 8-unit jar over)

   Were you right?

   How can you tell how long it takes?

3. Let's use this jar this time (32-unit jar). What will happen when I put the jar over the candle?

   How long do you think it will take?

   Let's try it (place jar over candle); were you right?

4. Now, let's look at this jar (16-unit). What will happen when I put this jar over the candle?

   Will it take more time, the same time, or less time for the candle to go out under this (16-unit) jar than it did under this jar (32-unit)?

   Why?

Will it take more time, the same time, or less time to go out under this jar (16-unit) than it did under this jar (8-unit)?

Why?

How long do you think it will take for the candle to go out?

Why?

Let's try it (place 16-unit jar over candle): were you right?

Proportion

Apparatus

"Grab bag" containing 200 pieces of colored pasta--140 blue, 60 green; paper, pencil.

Investigator's Presentation

For the last investigation we are doing, I have colored macaroni in this bag (take out a handful and show student). I have 200 pieces of macaroni in here, some is blue and some is green.

The first thing I want you to do is to reach into the bag and, without looking in, take ten pieces of macaroni out, one at a time, and place them on the table.

How many blue do you have?

How many green?

Remember, there are 200 pieces in the bag. I want you to tell me how many of them are blue and how many are green.

You may take ten more pieces out of the bag if you wish. You may use the pencil and paper to help you work out the answer if you want.

Do you want to give me the answer now? Or do you want to take some more pieces from the bag?

(2nd sample: repeat previous statement)

Prediction: __________blue; ____________green.

Why do you think there are ______blue and ______ green?

APPENDIX 6

PREDICTING ABILITY SCORE SHEET:

PHYSICAL MANIPULATION TEST

PREDICTING ABILITY SCORE SHEET

Name Scoring Key ____________ Date of Testing ____/____/____ (day / mo. / year)

School ____________ Date of Birth ____/____/____ (day / mo. / year)

Sex ________ Grade ____________

Total 62

A. VISCOSITY OF LIQUIDS

1. Marbles will fall to the other end — 1 ☐
   - Other — 1 or 0 ☐
   - Difference — 1 or 0 ☐
   - Sequential <————————> Simultaneous

2. A would pour faster — 0 ☐
   - B would pour faster — 1 ☐
   - Other — 0 ☐
   - Why — 2 / 0 ☐

3. A would feel thicker — 1 ☐
   - B would feel thicker — 0 ☐
   - Other — 0 ☐
   - Why — 2 ☐

   Comments:

B. WEIGHTS AND SPRING

1. Spring stretches — 1 ☐
   Other — 0 ☐

2. Spring will go up
   Spring will go down
   Other
   Spring will go to letter — ☐ (2 - correct; 1 - up but wrong space; 0 - incorrect)
   Why? — ☐ (2 - logical; 1 - weak reason; 0 - unrelated reason)
   Comments:

C. MAGNETS

1. ________ ________ ________ ________ ________ ________

2. Will ~~be~~ picked up ________ ________ ________ ________

   ________ ________ ________ ________ ________ ________

   Won't be picked up ________ ________ ________ ________

   ________ ________ ________ ________ ________ ________

   ☐ (3 all correct; 2 one wrong; 1 two wrong; 0 more than two wrong)

3. Why picked up — 2, 1 or 0 ☐
   Why not picked up — 2, 1, or 0 ☐

4. Use other set
   No — 0 ☐
   Yes — 1 ☐
   Other — 0 ☐
   Comments:

D. BALL AND CHART

1. Bounced to ______ (student) ______ (actual) 1 ☐
   Other response:

2. Bounced to ______ (student) ______ (actual) 1 ☐
   Other response:

3. Prediction: Will bounce to letter
   Other response:

   2 within one space
   1 just outside one space ☐
   0 further off

   Why? 2, 1, or 0 ☐

   Right ______ (student) ______ (actual)

   Comments:

E. SOUND

1. Sounds different? yes no

   Second sound higher
   Second sound lower
   Other response
   Why

   Prediction:
   - Sound will get higher 1 ☐
   - Sound will get lower 0 ☐

   Other response 1 or 0 ☐
   Why 2, 1, or 0 ☐

2. Sound of elastic 2 is higher
   Sound of elastic 2 is lower
   Other ______________________________
   Why
   Prediction:
   Sound gets higher — if consistent with observation 1 ☐
   Sound gets lower ☐
   Other — if consistent with observation 1 or 0 ☐
   Why — 2, 1 or 0 ☐

3. Board placed LEFT MIDDLE RIGHT — 1 ☐
   Why ☐
   Elastic 1(thinnest) 2 3 4(thickest) plucked — 1 ☐
   Why ☐ — 2, 1 or 0 together
   Right? __________(student)
   __________(actual)
   Comments:

F. CANDLE AND JARS

1. Flame will go out — 1 ☐
   Other — 0 ☐
   Why? — 1 or 0 ☐
   How long (4 unit)
   No response

2. How long (8 unit) — 2 related to previous observation, 1 poorly related, 0 not related ☐
   Right __________(student) __________(actual)
   No attempt to time — 0 ☐
   Time by counting — 1 ☐
   Time with watch — 2 ☐
   Other timing — 1 if logical 0 if not ☐

3. How long (32 unit) 2, 1, 0

Right ____________(student) __________(actual) ☐

4. (a) 16 unit jar compared to 32 unit jar

More 0 ☐

Less 1 ☐

Why? 2 ☐

(b) 16 unit jar compared to 8 unit jar

More 1 ☐

Less 0 ☐

Why? 2, 1, 0 ☐

Prediction:

Time 2, 1, 0 ☐

Right ____________(student) __________(actual)

Comments:

G. PROPORTION

1. Student sample

2 used more than one sample
1 recognized as sample but used only one
0 did not recognize as sample ☐

blue ________ ________ ________

green ________ ________ ________

Use of paper and pencil

Yes 1 ☐

No 0 ☐

Student prediction ____________

2 correct within 10 either way ☐
1 if more blue than green in prediction
0 illogical

Why? 2, 1 or 0 ☐

Comments:

APPENDIX 7

INTERVIEW QUESTIONS

AND

RECORD SHEET

INTERVIEW QUESTIONS

What is predicting?

Do you need to know or use anything to make predictions?

Do you do predicting in school?

No

Yes

E.g.

Do You do predicting at home?

No

Yes

E.g.

Is it important to be able to predict? Why or Why not?