EVALUATING THE EFFECTIVENESS OF A HANDS-ON APPROACH TO PRIMARY SCIENCE INSTRUCTION EMPHASIZING SCIENTIFIC PROCESSES

by

JENNIFER E. LAWSON

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ABSTRACT

This study identified the effects of teaching a hands-on process approach to science at the primary level of schooling (grades one to three). This approach was used in developing an instructional program for grades one to three entitled "Hands On Science". A pre/post research design was used to examine the effects of the hands-on process approach. Experienced primary school teachers taught units from the instructional program in their classrooms. There were a total of nine participating classrooms and three students from each of those classrooms took part in the evaluation procedures. Evaluation measures included a performance test and a computer-based test, both evaluating science process skills. In addition, a teacher survey was used to evaluate the appropriateness of the instructional program for primary school teachers.

The major purposes of the study were to determine if the instructional program which emphasized a hands-on process approach to primary science instruction, would increase the development of children's scientific process skills, and also to determine if the instructional program was deemed useful to primary school science teachers. The findings of this study identified that students' scientific process skills increased significantly when treated with a hands-on process approach to science instruction. This was true for both the performance test results and the computer-based test results. In addition, the teacher survey results displayed that teachers implementing the "Hands On Science" instructional program found it appropriate and useful for the primary level of science instruction. The overall conclusion of this study was that the use of a hands-on process approach for science instruction at the primary level is an effective means of developing students' scientific process skills, and also an appropriate instructional approach for primary teachers.

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This thesis is dedicated to my father, Norman Earl Lawson, who has always been my inspiration and guide to achievement.

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EVALUATING THE EFFECTIVENESS OF A HANDS-ON APPROACH TO PRIMARY SCIENCE INSTRUCTION EMPHASIZING SCIENTIFIC PROCESSES

CHAPTER ONE

Introduction

> Learning science helps children develop ways of understanding the world around them. For this they have to build up concepts which help them link their experiences together; they must learn ways of gaining and organizing information and of applying and testing ideas. This contributes not only to children's ability to make better sense of things around them, but prepares them to deal more effectively with wider decision-making and problem-solving in their lives. Science is as basic a part of education as numeracy and literacy; it daily becomes more important as the complexity of technology increases and touches every part of our lives (Harlen, 1985, p. 5).

The major purpose of our educational system is to help prepare students for participation and survival in society. This not only means that they must learn to fulfill their physical needs, but also that they become aware of the people around them and the environment of which they are a part. In order to achieve such a goal, children must acquire skills in the many subject areas of the school curriculum. Science education is a necessary ingredient of the school experience, as our world is surrounded by scientific issues and factors to be contended with in everyday life.

Instruction in science, as in other subject areas, must have a strong foundation. "The primary school years should be used for the deliberate and sustained fostering of those 'finding out' activities ... which are the common core and first roots of all our sciences" (Isaacs, 1983, p. 111). Primary science education (grades one to three) will provide the foundation for all further acquisition of knowledge and skills in this field. Hence, the programs designed for the early years must set clear goals for the understanding of scientific concepts and principles. These goals must be supported by instructional activities and teacher guidelines in order that programs can be successfully implemented.

"Learning science can bring a double benefit because science is both a method and a set of ideas; both a process and a product" (Harlen, 1985, p. 5). It involves both the scientific processes for the gaining of knowledge, and products which are the resulting ideas and concepts grasped. In essence, using these processes leads to the acquisition of understandings (products). Educational programs must take both aspects of scientific inquiry into consideration. The processes and products of scientific inquiry are so interrelated that neither one can be ignored. To do so would be to disregard a most significant and essential aspect of science education.

When one deals with evaluation in science education, both process and product must again be emphasized. Science programs are not complete without the added creation of evaluation instruments, and these measures must evaluate what is being learned. Therefore, instructional programs, whether for primary, intermediate, or secondary use, must include workable procedures for evaluating all types of scientific learning.

Recent studies conducted by the Science Council of Canada (1984) support the need for further improvement of all elementary school science programs and the assurance of quality in science education. At present, science is still not receiving the attention it requires. This is especially true at the primary and intermediate levels where teachers tend to stress language arts and mathematics as the essentials of education (p. 33). Teachers' attitudes must therefore be changed, and this may well happen through the further development of exemplary science programs for use in elementary schools.

The Science Council Report also stressed the need for change in the area of student evaluation (p. 43). To date, too much emphasis has been placed on merely testing content rather than scientific processes, creativity and problem-solving. What is needed, therefore, are more measures for evaluating the progress of students in all aspects of science instruction.

Science is a basic subject worthy of further attention throughout all levels of the educational system. Such attention must, in part, focus on the development of new and exciting programs and evaluation measures for classroom use. If such resources are created and made available, interest in the teaching of science may increase and attitudes may become more positive. This study took one further step toward improving science education for children at the primary level by developing an innovative instructional program and evaluation instruments focusing on the development of students' skills in using the scientific processes.

Purpose of the Study

There were two major purposes to this study. The first of these was to identify the effects of teaching a hands-on process approach in science to students at the primary level. This identification focused on the development of primary students' skills with scientific processes. Students participated in a program using the hands-on process approach, and pre/post tests were administered in order to identify change in students' scientific process skills.

The second purpose of this study was to identify the value of this instructional program using the hands-on process approach for teachers of science in primary level classrooms. After using the program developed as part of this study (one that incorporates the hands-on process approach) with the primary students in their classrooms, the participating teachers evaluated the effectiveness of the program by means of a teacher survey.

Rationale

For young children, concrete experiences are of utmost importance. Students in the primary grades, according to Piaget (as in Dyrli, 1970), are generally at the pre-operational stage and entering the concrete operations stages of cognitive development. Piaget and learning theorists such as Bruner (1966) emphasized the significance of developing activities that directly relate to the child's level of cognitive development. For such primary students, therefore, it is necessary to provide learning experiences that are concrete and allow for the manipulation of materials.

A process approach to science instruction has the child actually becoming a young scientist, using the same processes as a scientist does in order to gain new understandings. These basic processes include observing, using space/time relationships, using numbers, measuring (metric), classifying, communicating, predicting and inferring. The integrated processes which may be considered more complex include defining operationally, controlling variables, interpreting data, formulating data and experimenting (Science - A Process Approach, 1964). In essence, a process approach to science instruction encourages the development of skills with these processes. With this approach, active involvement and concrete experiences are again of significance. (This is quite unlike the traditional textbook approach where the transfer of scientific facts may be a major focus.)

An influential figure in the development of process teaching is Robert Gagné. He believed that "the prerequisite knowledge of concepts and principles can be obtained only if the students have certain underlying capabilities - the science processes - which are needed to practice and understand science" (as in Finley, 1970, p. 62). Hence, in order to teach the concepts and understandings that are outlined in science curricula, the skills involved in the processes of science must be taught as well.

Gagné's influence in science education has indeed been significant. The elementary science program Science - A Process Approach (1964, S-APA hereafter) was designed using many of his views on the development of scientific understandings. This was a very popular funded program in the United States during the 1960's and early 1970's. However, S-APA lost much of its status as an exemplary program as teachers realized that the content and topics studied were not clearly defined (Symington & Osborne, 1983, p. 13). Although S-APA itself has not survived to any extent in schools, many of the major issues at the foundation of the program have remained popular. K-6 Science (the Manitoba Curriculum Guide for Science), for example, places great emphasis on the development of scientific process skills. At the present time, a large majority of science curricula focuses attention on the process skills of science.

Numerous efforts have also been made to design evaluation instruments for use with the process approach. More specifically, tests have been designed for elementary science programs. A major problem is, however, that very little significant research has been done that deals specifically with evaluating primary students' scientific processes skills. Furthermore, few tests have been designed with any practical (hands-on) evaluative measures. (Vide Chapter Two for a thorough review of evaluative measures and other related research.)

One recent process skills test has been developed at the University of Manitoba (Leith, 1986). Testing involved written experiences, group practical experiences, and individual practical experiences. This was a significant study because if one teaches with a hands-on process approach, it is definitely not sufficient to merely give students written tests. If hands-on activities are stressed, then educators must also use practical tests. A great deal of information can be acquired by observing children as they attempt to investigate scientific problems. This information can then provide the framework for further instruction and planning of science activities.

Although hands-on evaluation instruments are necessary, it is also important to evaluate students' skills in transferring knowledge into written form. For the process of communication, for example, information is relayed through graphs, charts and written descriptions. Therefore, children must be able to use all of these forms of communication. Limiting evaluation to only practical modes is insufficient. Written and computer-based tests can evaluate the student's ability to transfer understanding from laboratory experiences to other forms of communication.

Using the computer as an evaluation tool has definite advantages. Programmed tests can correct responses immediately and categorize areas of strength and weakness. The computer then becomes a management tool that can provide teachers with information regarding student achievement, without the teacher having to correct the tests manually. A computer-based test for scientific process skills may therefore be deemed as an alternative to paper and pencil tests.

The need for the further development of primary science programs that focus on hands-on activities and scientific processes is indeed apparent. It is also apparent that a variety of evaluation instruments are required in order to determine the development of students' scientific process skills.

Definition of Terms

The following definitions have been used for the purposes of this research study:

1.) Primary School - Grades one, two and three were considered as primary school levels in the public school system used for this study.

2.) Hands-On Approach - This approach stresses that children be actively involved in the learning process. Manipulating materials, conducting investigations and discussing findings are all included in the approach.

3.) Scientific Processes - These are the processes used by scientists for the gaining of new information. The basic processes include observation, classification, communication, measuring, using space/time relationships, inferring and predicting. The integrated processes include defining operationally, controlling variables, formulating hypotheses, interpreting data and experimenting. For this research study, the following processes were focused upon:

a) Observation: One must be able to perceive characteristics and changes through the use of the senses and scientific tools. Observation may be qualitative or quantitative. The categories recognized as observation for this study are:

   i.) information through the senses
   ii.) similarities and differences - used to specify a set of properties to describe an object or conditions that help to solve a problem
   iii.) sequencing - used to order events or objects to show relationships

b) Classification: This skill is used to show the grouping of objects and interrelationships among these objects. Classification is based on observable properties.

c) Interpreting Observations: This process involves the more complex integrated processes. Interpretation depends upon the use of information gained through observations. After observing an event or object, the next step is to be able to make inferences or predictions based upon the observations made.

d) Communication: In science, one communicates by means of graphs, charts, maps, symbols, written language and spoken language. The categories considered as forms of communication for this study are:

   i.) readings from tables
   ii.) readings from graphs
   iii.) making tables
   iv.) making graphs
   v.) recording results in forms other than graphs and tables, such as commentaries and diagrams

e) Measurement: This is a process of finding dimensions or quantity of an object or event. It usually involves comparisons of size, mass, temperature and time as accepted standards.

4.) "Hands On Science" Instructional Program - This instructional program was designed for grades one, two and three science using the hands-on process approach. The program was based on K-6 Science (the Manitoba Curriculum Guide Science, 1979) by using the main concepts and objectives from that curriculum guide in the lessons developed. Units in the program contained guidelines for teachers, lesson plans and student activity sheets.

5.) Performance Test - During this test, students were presented with five problems to solve. They were also presented with materials to assist them in planning and conducting the investigation to solve the given problems. All problems focused on the scientific processes taught and used during the classroom science lessons. Evaluation of these experiments was conducted by having the researcher observe the child and evaluate procedures used during the experiments.

6.) Computer-Based Test - This test included 30 questions that evaluated scientific process skills. Grade one students completed the first 10 questions, grade two students completed 20 questions and grade three students completed the entire test. The test was to be computer-based, meaning that all testing of the student was done at the terminal. The test was self-correcting and provided summaries of student results.

7.) Teacher Survey - This survey was completed by all teachers participating in the study. It asked specific questions regarding the value of the lesson plans and activity sheets, as well as the general appropriateness of the program.

Hypotheses

In accordance with the two major purposes of this study, there were two directional hypotheses focused upon:

1.) The teaching of a hands-on process approach in science to primary students will significantly increase those students skills with scientific processes. For statistical purposes, this hypothesis was tested using four null hypotheses:

H1: There is no significant difference between the means of the pre-test and post-test results of the performance test when participating students are treated with a hands-on process approach to science instruction.

H2: There is no significant difference between the means of the pre-test and post-test results of the computer-based test when grade one students are treated with a hands-on process approach to science instruction.

H3: There is no significant difference between the means of the pre-test and post-test results of the computer-based test when grade two students are treated with a hands-on process approach to science instruction.

H4: There is no significant difference between the means of the pre-test and post-test results of the computer-based test when grade three students are treated with a hands-on process approach to science instruction.

2.) The second directional hypothesis tested in this research study was that teachers at the primary level will find the science program that emphasizes a hands-on process approach to be useful and appropriate for the classroom setting (H5).

Summary of the Research Method

One of the initial procedures for this study was the development of an instructional program which included science activities for grades one, two and three. This program emphasized the development of skills with the scientific processes using a hands-on approach.

Experienced primary school teachers taught units from this instructional program for a period of eight weeks.

In order to test the first directional hypothesis and the four null hypotheses, an individualized performance test (hands-on) and a computer-based test were developed, which were both used to evaluate the students' skills with scientific processes. Selected students were pre-tested and post-tested using these evaluation instruments.

Data on the performance test were collected across all grade levels. While some more conservative statistical test might be preferred for this hypothesis, it was felt sufficient in this exploratory study to test it again using a t-test for correlated data.

Data on the computer-based test were collected by grade level. Since the hypotheses that there are no significant differences between the means of the pre-tests and post-tests comprised three orthogonal planned comparisons, it was appropriate to test each of these hypotheses using a t-test for correlated data.

The research design for this study involved a pre-test (performance and computer-based), a treatment (participation in the "Hands On Science" program), and a post-test identical to the pre-test:

Research design: 01 X 02

X = treatment

0 = observation (01 = pre-test, 02 = post-test)

A teacher survey was designed in order to provide information on the effectiveness of the program for primary classroom use and to test the second directional hypothesis. Teachers completed this survey after the treatment period. For the purposes of data collection and analysis, teachers scored items on a scale from 1 to 4, and the mean for each item was then determined. Anecdotal comments were also collected from the participating teachers.

Systematic Limitations

The study sample was confined to one urban school division within Manitoba. Therefore there may be some question as to the generalizability of the results of this research study. This generalizability must also be questioned with regard to the short treatment period (eight weeks), and the small sample size of both students and teachers involved in the study.

The students chosen for assessment were randomly selected from a list provided by teachers. On the list, students were categorized according to their ability and performance in science. All students from the nine classrooms still had equal opportunities for being selected since all student names appeared on the categorized lists.

A control group was not used for the purposes of this research study. Control groups are included in experimental designs usually to control threats of maturation. However, in this study, the experiment had such a short time duration (a teaching period of eight weeks) that there was little likelihood that the subjects would 'mature' greatly over the experimental period. It was therefore concluded that maturation would not be a significant factor. It was also recognized that since students and teachers were participating in a new program, Hawthorne effects (attention and novelty) would likely be apparent and could not be effectively controlled using a control group design.

Budget Considerations

Budget considerations included the hiring of a computer programmer to program the computer-based test, a graphic artist to complete activity sheets, and costs of copying the instructional program for participating teachers.

Time Lines

A review of literature, the designing of the instructional program and related assessment measures, and analysis of tests for validity purposes were all completed by December, 1985. Pre-testing was conducted from January 6 to January 17, 1986. Teaching of units took place from January 20 to March 14. Post-testing was conducted from March 17 to 27. The analysis of all results, conclusions and recommendations was completed by June of 1986.

Significance of the Study

This study resulted in an instructional program that will be available to primary teachers. In addition, related evaluation measures were developed. Science resources, especially those focusing on primary school, must become available if involved teachers are expected to plan and conduct successful science programs that emphasize hands-on activities and the development of skills with scientific processes.

The results of this research study may also be deemed significant in that they identified the effectiveness of using a hands-on process approach to primary science instruction, with regard to both the development of students skills with the scientific processes and teachers' perceptions of the value of such an approach.

Summary

This chapter has presented an introduction to the research study. This introduction included a brief discussion of the problem focused upon, a list of definitions, the related hypotheses, an outline of the rationale, research method, experimental design, systematic limitations, budget considerations, time lines, and the significance of the study.

The following chapter presents a review of literature relating to the study, focusing on specific questions posed in an attempt to evaluate the effectiveness of a hands-on process approach to primary school science instruction.

CHAPTER TWO

REVIEW OF THE RELATED LITERATURE

Introduction

A review of the literature related to this study will be divided into four areas. This review will examine previous research on the following questions:

1.) Why is a hands-on approach to primary science instruction necessary?

2.) What are the relevant advantages of a process approach to primary science instruction?

3.) What are the factors involved in evaluating such science activities?

4.) How can the use of a computerized test for process skills be advantageous?

An overview of the research done in these areas will be conducted in order to provide a strong theoretical framework for this study.

A Hands-On Approach to Teaching Primary Science

> How young children learn science, or anything else for that matter, is an interesting and provocative question. The course of a child's intellectual development during ages six to fourteen changes greatly. The child's thinking undergoes a transition from concrete to abstract. In order to help him achieve this, the elementary science program must provide the individual child with many concrete experiences in manipulating objects and systems in the environment. At the beginning of this period the child is achieving mastery of his muscles and gaining the ability to carry out physical manipulations; in his thinking he is dependent on direct experience (Karplus & Thier, p. 64-65).

Scientific knowledge is something that cannot simply be transmitted from teacher to student through lectures or textual material, although traditionally it has. The learning process must involve interaction between the students, the teacher, and the materials and objects being studied. Only by this method can knowledge be successfully gained and learning be meaningful.

Child development theories provide useful information to support the use of the hands-on approach. The more the young mind is understood, the more effectively teachers can plan instruction to aid in cognitive development.

Piagetian theory, for example, has important implications for science educators. Piaget (as in Dyrli, 1970) believed that children proceed through four intellectual stages from birth to adulthood. These stages may well be influential on the types of activities that children can participate in during specific childhood years. The sensorimotor stage is recognizable from birth to approximately eighteen months. Due to a lack of full vocabulary, these children think by means of actions. Since they have not yet fully acquired verbal language they cannot react merely to the spoken word. Therefore, symbols and actions must be used in order to communicate with the infant. Another characteristic of children at the sensorimotor stage is that objects only exist for the child when he/she is able to see them. Their fields of perception are thus limited significantly.

The pre-operational stage has a general range of eighteen months to seven or eight years of age according to Piaget. Children during this stage are beginning to use more verbal language and, as a result, thought develops at a higher level. These children, however, are still goal-directed and perceptually oriented and much of their learning takes place by trial and error. Of importance especially to science educators, Piaget stressed that children during these years have difficulty controlling variables and understanding that a specific object may have several properties. It will be necessary to keep these issues in mind when planning science activities that involve the identification and controlling of variables as well as classification.

At the concrete operations stage, beginning at age seven or eight through eleven or twelve, thinking is still concrete as opposed to abstract. Logical thinking is developing, and concepts of conservation and reversibility also develop. Children can now perform classification and sequencing tasks, but still have difficulty isolating variables. Again, the relationship of Piaget's theory to children's ability to use scientific processes are readily apparent.

In the fourth stage, formal operations (ages thirteen to fifteen), a child can think in more abstract ways. Hypothetical-deductive reasoning develops and the child can control experimentation because he/she is more able to understand combinations of variables.

Piaget's conclusions regarding child development are worthy of recognition when planning science activities. Although the age levels specified for each stage will vary from child to child, the acquisition of skills through childhood years is an important factor. Piaget stressed experiences with concrete materials and manipulative involvement, especially during the first three stages. Children in primary school will generally fit into the pre-operational and concrete operations stages. Hence, the necessity of a hands-on approach to primary education is supported. The classroom environment must be designed to facilitate such an approach if teachers are to present material in a form that fits the child's stage of cognitive development.

Learning theorists such as Gagné (1965) and Bruner (1966) also emphasized such experiences with concrete materials for the primary school child. They stressed that active participation of the learner is of utmost importance for the acquisition of knowledge. In agreement with Piaget, these theorists focused on presenting material that relates to the learner's stage of growth such that concepts be learned initially through concrete references.

A review of learning theories is essential to the development of educational materials, but one must also analyze pertinent research done in this field of study. A valuable meta-analysis study was conducted by science educators Shymansky, Kyle and Alport (1982) in an effort to survey the effectiveness of science curricula in the United States. The study analyzes elementary curriculum projects which emphasize a hands-on approach - S-APA, the Elementary Science Study (1966), and the Science Curriculum Improvement Study (1962). By analyzing thirty-four studies which compared students in these programs with students in traditional text-book based programs the researchers found that "students in new programs (hands-on) out-performed those in traditional text-book based classrooms on every criterion measured" (Shymansky, Kyle & Alport, 1982, p. 14). These criteria included achievement, attitudes, process skills, related skills, creativity, and Piagetian tasks. On achievement tests, for example, the students involved in hands-on programs did better than 62% of those in traditional programs. On process skills tests, students in the hands-on program performed at an average of 25% better than those students using the traditional programs.

These researchers also found that "students' attitudes were more positive toward new programs than toward the traditional ones, with a difference ranging from 3 to 20 percentile points" (Shymansky, Kyle & Alport, 1982, p. 14). The researchers analyzed 21 studies focusing on attitude toward the hands-on approach, attitude toward science, and attitude toward self. They believed that a positive attitude toward science is an essential ingredient for a successful instructional program. Hence, these researchers have provided significant results in showing that such attitudes may be developed if a hands-on approach to science education is implemented.

Cohen (1980) studied Piaget's theory on the importance of hands-on activities and agreed that a young individual should be provided with manipulative experiences in order to truly understand scientific concepts. Cohen investigated the problem of the effects of hands-on activities on the spatial abilities of elementary school children. His sample population consisted of fifth grade students. The experimental group received science instruction using manipulative materials (based on the Science Curriculum Improvement Study), while the control group's science program was based on a text-book approach. The instruments used to collect data included The Science Process Test (Ludeman, Fyffe, Robinson, McLeod & Berkheimer, 1974) and a battery of six Piagetian tasks. His results support Piaget's ideas on cognitive development of children:

> The findings of this study speak loudly to the notion that any science program used with elementary-age children, which has at its core of goals the development of thinking should rely much more heavily on first hand manipulative experiences as opposed to the reading of textual material. The resulting higher thinking abilities should increase students' ability to comprehend in meaningful ways (Cohen, 1980, p. 11).

Symington and Osborne (1983) cited some of the teacher concerns regarding hands-on science programs. Using S-APA and Science 5/13 (1972-1975) as examples of programs emphasizing scientific investigation through hands-on activities, the researchers identified some very significant issues regarding the use of such programs. Of utmost importance, they noted that "sometimes teachers and more frequently pupils lost sight of the purpose of such activities" (p. 4). This seemed to be a result of the lack of specific objectives, concepts and direction of such programs. In addition, teachers did not always have success with experimental lessons and often did not realize the need for experimentation. As a result, text-book-based science programs have become an alternative. Although the researchers stressed that science programs for the primary level need not focus completely on hands-on activities, they saw it as essential to develop teacher-guide materials that respond to the problems and concerns mentioned:

> If this can be done effectively then issues which were previously of concern will hopefully become less significant and the teacher will move on to issues of pupil learning. In this way primary teachers should develop professionally in terms of science teaching (Symington & Osborne, 1983, p. 13).

Research studies indicate that a hands-on approach to science education at the primary level is preferable because it supports theories on the intellectual stages of the children involved. In addition, performance and attitudes toward science may be improved, and it may result in higher level thinking abilities. It is therefore a valid procedure to design programs for use in primary schools that will focus on a highly active, concrete learning environment, but at the same time offer specific objectives, concepts and direction. The following section of this chapter will relate the hands-on approach to the process approach, in order to indicate the compatability and strength of these two approaches.

A Process Approach to Teaching Primary Science

> A process approach to science teaching is based on the examination of what a scientist does ... In order to teach a child these process skills, it is necessary that he actually observe, measure, infer, manipulate variables, etc., in short, that he act like a scientist. Or, in other words, that he does science. Therefore this approach involves less reading about science and more involvement with concrete materials, i.e., more doing. The process approach gives children a valid understanding of the nature of science. The child can experience the excitement of science and can better understand its facts and concepts (Funk, Fie, Jaus & Sprague, 1977, p. xii).

The statement made by these science educators identified the close relationship between the process approach to science education and the hands-on approach. A child cannot use the scientific processes unless he/she becomes actively involved in the learning experience. The two approaches therefore compliment each other.

Research on the teaching of process skills has greatly expanded since the early 1960's. Robert Gagné was an influential educator in this area and described the scientific processes as having the following features:

1.) Each process is a specific intellectual skill used by all scientists and applicable to understand any phenomena.

2.) Each process is an identifiable behavior of scientists that can be learned by students.

3.) The processes are generalizable (transferable) across content domain and contributes to rationale thinking in everyday affairs (as in Finley, 1983, p. 48).

As a result of Gagné's position and influence in this field of science education, he shaped the development of Science - A Process Approach (S-APA). This program was the first of its kind to emphasize scientific processes. In the document entitled "The Psychological Bases of Science - A Process Approach" (1965), Gagné described the design of such a program. Students begin by participating in observational activities and gradually move toward tasks involving processes such as classifying, measuring, communicating, quantifying, organizing through space and time, and making inferences and predictions. These process skills are not, however, developed simultaneously, but rather build upon those that come before. As skill with these processes develop, the student can then begin making operational definitions, formulating and testing hypotheses, carrying out experiments, and interpreting data from experiments (p. 4). As noted previously, Gagné believed that scientific process skills are necessary in order to acquire knowledge of concepts and principles. He saw the processes as the foundation for scientific inquiry and agreed that not only can students learn these behaviors, but that such skills will contribute to logical thinking.

The same document dealt in detail with issues concerning learning. Gagné focused on two conditions that are vital to the teaching of science through a process approach. First, the approach rejected teaching merely content and highly specific facts. "Learning will be most effective when relationships are 'discovered' rather than 'copied', when generalizations are attained rather than being imposed" (p. 12).

Secondly, it stressed that a wide variety of materials and learning situations be used, and that achievement be measured in terms of various kinds of performance, not just verbal and written responses. This second condition is based primarily on the fact that the needs and learning styles of each individual child vary.

The National Science Teachers Association supported Gagné and S-APA when publishing "Theory into Action - A Guide to Science Curriculum Development" (1964). This widely circulated document further emphasized a process approach to teaching science. As a result, the past two decades have seen a shift toward process teaching and now a large majority of science programs on this continent state goals and objectives that include the development of such skills.

The efforts of Gagné and his followers have made the process approach to science education an accepted practice. Developing skills with the scientific processes enables the learner to better understand concepts and acquire new information through scientific inquiry. These benefits indeed show the contributions that the process approach can offer the learner of science.

This section has presented the characteristics of the process approach and has shown how it relates to the hands-on approach described in the previous section. The following section presents a review of literature focusing on evaluating hands-on activities that emphasize the development of scientific process skills.

Evaluating Hands-On Science Activities that Focus on the Development of Scientific Process Skills

> The catch phrase in the development of new science programs over the past two decades has been "hands-on" ... However, one area that has not been improved significantly is the method by which science students are evaluated. Too frequently, the testing which occurs in science class is of the paper and pencil type even though the students have been "learning by doing" (Dyche, 1984, p. 31).

This science educator has suggested that hands-on examinations can be used to determine the students' ability to manipulate objects and gain knowledge through such experiences. A major benefit of such tests is that when used with primary school children, they do not rely heavily on reading and writing ability. The evaluator can therefore receive more actual information about a student's ability in science. Needless to say, transfer of knowledge to reading/writing situations is one acceptable aspect of evaluation, but it should supplement the more practical modes of hands-on evaluation.

As a result of the emphasis placed on the teaching of scientific processes, there have been several instruments designed to evaluate these skills. Tests developed specifically for primary students are not abundant, but there are a few tests for this age level that are worthy of review.

Beard (1971) developed a Group Achievement Test for Two Basic Processes. This test was designed to accompany S-APA. In an attempt to take into account the reading levels of primary children, the test items were projected 35 mm color slides with a tape recording on which were recorded questions and which was synchronized with the slides. Answers were given in written form. The skills of measuring and classifying were focused upon at the kindergarten to grade three levels. Six actual tests were developed to accompany different portions of the S-APA program. Two tests were used with each of Parts A, B and C of S-APA, one which evaluated classification skills and one which evaluated measurement skills. Evidence from the study indicated that the test format was effective as a group test for primary students. The data produced showed that only two sections of the test (those which accompanied Parts A of S-APA) were reliable, and that the remaining sections on classifying and measuring did not attain reliability standards.

Riley (1972) developed another group process test that was to be used with children involved in the Science Curriculum Improvement Study. Although the test was administered to grade five students only, it included the evaluation of skills from the grades three, four and five levels. Again, the test developed was of the paper and pencil type.

Science educators in the United Kingdom have used varying evaluative techniques in the Assessment of Performance Unit testing programs conducted from 1981 to 1985. The process skills tests designed for the elementary level were used with 10 and 11 year old students and included group practical, individual practical, and written tests. Practical tests were grouped into three categories including observation, use of apparatus and measuring instruments, and performance of investigations. Findings from this study indicated that all three techniques were valid at this age level, although it was noted that practical testing can impose difficulties in marking and interpreting results from tests:

> The experience of the APU is that it is possible to make valid and reliable measurements of the complex pupil activities involved in practical science.

> Generally, pupils of all abilities make a better showing at the investigatory processes than they do at the application of science concepts. If science for all is to include, and perhaps emphasise the ability to investigate, then more opportunities are needed to both practice and assess these skills (Welford, Harlen & Schofield, 1985).

Isaacs (1984) developed a test of process skills for grade three elementary school pupils. This instrument was designed to test processes taught in the first three years of schooling. Efforts were made to test the actual skills rather than content within the curriculum. In addition, the tests allowed for the low level of reading ability common in primary students. Practical tests were not included in the design, but rather, a pencil and paper approach was used to evaluate the skills of classifying, ordering, estimating and solving problems.

The previously mentioned study conducted by Leith at the University of Manitoba was an attempt to evaluate processes, and the scope of the study included both written and hands-on evaluation instruments.

The written portion of Leith's test was one of the few that focused partially on the evaluation of grade three students' scientific process skills. This written test involved multiple choice questions, short answer and long answer questions, as well as those requiring completion of tables and graphs.

Leith found that some information on process skills that was not available through written methods was acquired through the station-type and individual practical tests. For the individual test, the evaluating observer met with an individual student, discussed a scientific problem, watched the child's procedures in solving the problem, listened to the child's comments, observed expressions of excitement, frustration, and success, and discussed results. According to Leith, practical tests are definitely appropriate evaluative tools for the primary level, and the benefits of such hands-on tests are clearly recognizable. During practical tests, children also participated in station activities where they attempted to solve a problem using manipulatives and then answer questions in written form. Students moved from station to station performing different activities.

It is apparent that the development of process skills tests for primary level students is necessary but at this time rather limited. In addition, there seems to be even fewer that involve any form of hands-on evaluation. Hence, there is still a great need for evaluation instruments that provide for the students at this level of schooling and that focus on hands-on evaluative measures.

This section has presented a review of literature regarding the evaluation of hands-on activities that focus on the development of scientific process skills. The following section will present a review of literature that focuses on using the computer as an evaluative tool in science.

The Computer as an Evaluative Tool

Educational computer software that is developed for evaluative purposes has many advantages. "It enables the educator to collect information about whether the students' responses are right or wrong and to categorize students' errors" in a much quicker manner than if the teacher was responsible for designing and marking each child's written test (Walker & Hess, 1984, p. 1). Teachers often express the need for instructional or evaluative aids that will lessen tedious work and allow them more time for actual planning and implementation of programs. Hence, using a computerized test is a practical solution that will enable teachers to administer a test, have it immediately corrected, and have strengths and weaknesses in specific skill areas categorized promptly. In actuality, the computer becomes "a management aid ... since the teacher of a large class finds assistance in scoring tests, keeping records, checking on which students need what kind of work, and computing grades" (Zinn, 1979, p. 103).

When computerized tests are designed, ambiguities in items or responses must be specifically clarified. Although this is true for all tests, on a computer-based test, items must be programmed and the programmer is therefore virtually forced to create items that are clear and that control responses because all questions and answers must be precisely programmed on the computer. This results in unbiased evaluation that is valuable for analysis and diagnostic purposes. Programmed tests, therefore, measure with uniform precision:

> Urry points out that computerized testing is more standardized because the administrative procedures are programmed and, therefore, more uniform and controlled. This reduces differential effects of the testing environment (Kreitzberg, Stocking & Swanson, 1978, p. 231).

The computer-based test also controls accuracy in scoring, since mistakes cannot be made when marking the test. Human error is essentially eliminated.

Computerized testing has been shown to have significant effects on pupils. Current research has shown that such tests may increase the student's interest in and motivation for taking the test (Weiss, as in Kreitzberg, Stocking & Swanson, 1978). He observed that student attitudes toward taking computerized tests was more positive than those taking written tests. This conclusion was also cited by Waugh (as in Kreitzberg, Stocking & Swanson, 1978) who found that students were interested in computers and excited about computer use when involved in computer-based tests in science. One can therefore surmise that positive attitudes toward testing is another beneficial characteristic of computerized tests.

The development of computerized tests that focus upon evaluating students' scientific process skills is not abundant. Berger (1982) designed one program for evaluating estimation skills. He found that "the use of the microcomputer provided a powerful tool to gather time and strategy data, and to control the input data and to assist in the analysis process" (Berger, 1982, p. 258).

Science educators at the University of Georgia have developed a computer animated science process skills test for use with high school and college students. This test involved presenting students with animated situations and pertinent questions about the scene. Questions were formatted as multiple choice. The researchers believed that this test provided "a more stimulating and accurate portrayal of situations that rely less heavily than conventional assessment procedures on verbal understandings" (Hale, Shaw, Burns & Okey, 1984, p. 6). This conclusion was reached because of the computer's ability to display images rather than mere words or still pictures.

A computer-based diagnostic test may well be beneficial for both teachers and students. The test developed for this study enables teachers to evaluate process skills that they are emphasizing during instruction.

Summary

This review of related literature helped to generate the theoretical framework for this research study. It indicated that a hands-on process approach to science instruction at the primary level is both beneficial and essential. In addition, evaluation tools must be designed that will evaluate hands-on activities and the acquisition of scientific process skills. This can be accomplished by means of practical tests, and computer-based tests that will evaluate children's ability to transfer knowledge gained from laboratory experiences to reading/writing situations. This study acknowledged these conclusions and an instructional program was designed that emphasized hands-on activities and scientific processes. Evaluation instruments were also developed to focus on the skills acquired by students through such a program. The following chapter presents the details of the development of the "Hands On Science" instructional program and the administering of the evaluation instruments.

CHAPTER THREE

RESEARCH METHOD

Introduction

This chapter describes the procedures used in developing the "Hands On Science" instructional program, and for the collection and analysis of data. The program design, the research design, the sample, the treatment, and the instruments used are described in detail.

This study concerned itself with two major issues. First, it evaluated the effectiveness of the "Hands On Science" instructional program from the student's position, by evaluating scientific process skills developed during instruction with the program. Secondly, it identified the value of this instructional program for primary school teachers by having participating teachers complete surveys after implementing the program.

Designing the "Hands On Science" Instructional Program

The first step in designing this instructional program was to thoroughly review the major concepts and objectives outlined in the Manitoba Curriculum Guide for K-6 Science. This review focused more specifically on those concepts and objectives for grades one to three. Titles and general objectives of units were taken directly from the Curriculum Guide so that teachers could be assured that they were following provincial guidelines. At this point unit plans were designed by deciding on the sequence and combinations of concepts and objectives. In several cases, two or more objectives were covered using one activity. This happened when those objectives could be accomplished within one lesson.

Once the sequence of objectives for a unit was specified, the researcher then developed activities to accomplish these objectives. These activities focused on hands-on experiences for students, and integrated the scientific processes used throughout the program (observation, classification, measurement, communication and interpreting observations). The teacher lesson plans for each activity included the following headings (Vide Appendix A for sample lesson plan):

1.) Main Concept - This statement was taken directly or modified from the Manitoba Curriculum Guide for K-6 Science under the heading "Theoretical Framework".

2.) Objectives - These statements also came from the Curriculum Guide, or were modified to suit the lesson.

3.) Scientific Processes - The processes used during the activity were stated briefly.

4.) Materials Required - A list of materials that were easily accessible to classroom teacher was given.

5.) Procedures - Step by step instructions and suggested questions were provided. In addition, all terms that identified the use of a scientific process were underlined so that teachers could readily see when and where students were using each process, i.e. "Have the students <u>classify</u> the objects according to the materials of which they are made."

6.) Evaluation - This statement described the specific skills and tasks that teachers should be observing in the students. The student activity sheets were also used as evaluative measures.

When all activities and lesson plans for a specific unit were completed, student activity sheets were then designed. (Vide Appendix B for sample student activity sheet.) These activity sheets focused directly on the objectives of each lesson, and reinforced the use of the scientific process skills emphasized in each lesson.

In addition to the lesson plans and student activity sheets, several pictures were included with the program that could be used during specific lessons. These pictures were designed for situations when resources may be limited, i.e. when an activity called for the use of pictures showing changes in the form of objects. These types of pictures are not often easily accessible to classroom teachers and were therefore provided.

The program began with an introduction for the teachers that explained the hands-on process approach, the scientific processes, the materials included in the program, and the scope and sequence of the program.

The Sample

Participants of this study were from one school division in the Winnipeg area. To obtain the sample, a letter was sent to the elementary school superintendent of that division, explaining the study and asking for permission to conduct the study. (Vide Appendix C for Request Letter and Letter of Permission.) Upon receiving permission, the researcher contacted individual schools randomly from a list of the schools in the division. Meetings were then arranged with the grades one, two and three teachers who taught science from three schools. These teachers received detailed information on the study and consented to be involved. In total, seven teachers participated in the study. Two of these seven teachers taught both grades one and two science, for a total of nine participating classrooms.

All students in the nine classrooms were involved in instruction using "Hands On Science". However, because student evaluation was on an individual basis, only three students from each of the nine classrooms were used for evaluative purposes. Teachers provided lists of their students categorized in general science ability as below average, average and above average. One student from each of these categories was randomly chosen for testing. In total, 27 students participated in the testing.

Experimental Design

A pre/post research design was used to examine the effectiveness of the "Hands On Science" instructional program in developing students' skills with scientific processes. Students were tested prior to receiving instruction with the program, and after eight weeks of instruction they were tested again. Subjects were divided by grade level and tested accordingly. Students in all three grade levels completed the same performance test. For the computer-based test of process skills, grade one students completed the first ten questions, grade two students completed the first twenty questions, and grade three students completed the total of thirty questions. For the four null hypotheses tested regarding the development of students' scientific process skills, the research design was as follows:

01 X 02

X = treatment

0 = observation (01 = pre-test, 02 = post-test)

The second component of the research design was the teacher survey (described later), completed by all participating teachers at the end of the eight week instructional period.

Treatment

The treatment given to all participating students consisted of eight weeks of instruction using the "Hands On Science" program. Science classes were conducted approximately three times per six day cycle for a period of thirty minutes each. Teachers taught various units from the program, so classroom students performed different activities. However, the same scientific process skills were emphasized in all units and hands-on activities were stressed.

Treatment of teachers consisted of three sessions conducted by the researcher prior to the instructional period. During these sessions teachers were given details on the hands-on approach, the scientific process skills, and the scope and sequence of the instructional program. The teachers' participation in instructing their science classes using "Hands On Science" was also considered part of their treatment.

Instrumentation

All evaluative instruments for this study were developed by the researcher. They included a performance test and a computer-based test for scientific process skills, and a teacher survey.

The performance test for scientific process skills involved five questions, one testing for each of the scientific processes emphasized in the study (observation, classification, measurement, communication and interpreting observations). The students were presented with a problem to solve and related materials required to solve that problem (Vide Appendix D). All questions were marked out of six points for a total of 30 points. Criteria for marking were stipulated and based on observations by the researcher as the children did the problems. The purpose of the test was to determine the students' understanding of science, not their abilities to read. Therefore, all questions were read to the students by the researcher and their answers were recorded by the researcher.

The computer-based test involved a total of thirty questions. As mentioned previously, grade one students completed the first ten questions, grade two students completed the first twenty questions, and grade three students completed the entire test. Within each group of ten questions, two questions were designed to evaluate each of the five scientific process skills (observation, classification, measurement, communication and interpreting observations) (Vide Appendix E). The test was multiple choice and students chose the best answer from a group of three to five possible answers. Questions and answers were read to the students to reduce the effects of reading ability. In the introduction to the test, students were asked their full names and grade levels. The computer was programmed to give the student the appropriate number of questions. The test was self-correcting and when completed, results were displayed on the screen. These results included a total mark as well as a detailed chart presenting the student's correct and incorrect responses. Results were then recorded by the researcher.

All test questions for the practical test and computer-based test were validated prior to testing by a panel of five validators including university-level science education professors and primary school teachers. These validators were not personally involved in the study, either at the university level or classroom level, and could therefore remain objective in their procedures. Panel members were given descriptions of the five scientific process skills, the test questions, and a form for validation (Vide Appendix F). On this form they were to mark which scientific process they believed each test question was attempting to evaluate. In all cases, if necessary, questions were changed or revised until 100% validation existed.

The teacher survey was completed by all participating teachers after the teaching period. This survey was designed to find out how appropriate the "Hands On Science" instructional program was for these teachers. It included questions regarding the program's introduction, lesson plans, activity sheets, and other graphics and stories; as well as its relationship to the Manitoba Curriculum Guide for K-6 Science and its general usefulness for primary school science teachers (Vide Appendix G). The majority of the items on the survey were scored from 1 to 4 (poor to excellent) with regard to the effectiveness of specific aspects of the instructional program. There were also several questions where the teachers were required to give a 'yes', 'no' or 'undecided' response. Teachers were also encouraged to provide comments to support their scoring.

The teacher survey was validated by a panel of five science educators from both the school and university level. Members of this panel were different from those involved in the validation of the computer-based test and performance test, since an effort was made to involve staff within the participating school division. This panel therefore included the elementary science consultant from the division, primary school teachers not involved in implementing the program, a science consultant from another urban school division, and university professors. Each member of the panel was required to review the survey in an effort to analyze the appropriateness of each item. The survey was revised until all members of the panel agreed that 100% of the items were appropriate.

Data Collection and Analysis

Data collected from the practical test were analyzed using a t-test for correlated data. Since all students at the three grade levels performed the identical test, data were analyzed in total. The hypothesis regarding students' development of process skills was tested with alpha at 0.1. Since this was an exploratory study, this alpha was chosen in an effort to detect any significance.

Data collected from the computer-based test were analyzed using a t-test for correlated data, but since students at the various grade levels performed different portions of 'the test, data from each grade level were analyzed separately'. The hypothesis regarding students' development of process skills was tested with alpha at 0.1, again in an effort to detect any significance.

The teacher survey was analyzed by finding the mean for each item on the survey. The items involving 'yes', 'no' and 'undecided' responses were tallied and presented on a percentage basis. In addition, in order to provide further details on the teachers' perceptions of the program, their comments were collected and presented verbatim.

Time Line

The following statement of time lines outlines the specific procedures used to collect data for this study.

September, 1985	- Recruit sample of schools, teachers and children
	- "Hands On Science" Instructional Program developed
October	- Meetings with teachers
	- Test validation
November	- "Hands On Science" Instructional Programs delivered to teachers
January 6 - 17, 1986	- Pre-testing of children
January 20 - March 14	- Teaching period
	- Survey validation
March 17 - 27	- Post-testing of children
	- Teacher survey
April - June, 1986	- Analyze data
	- Write report

Summary

The procedures used for the development of the "Hands On Science" instructional program, and for the collection and treatment of data have been presented in this chapter. The specific findings of the study and the analysis of these findings are presented in Chapter Four, and the conclusions of the study are presented in Chapter Five.

CHAPTER FOUR

RESULTS

Introduction

The results relating to the two directional hypotheses and four statistical hypotheses tested in this study are presented in this chapter. The presentation and analysis of data pertaining to the development of students' scientific process skills when using the "Hands On Science" instructional program is organized under the heading 'The Development of Students' Scientific Process Skills'. The presentation and analysis of data pertaining to the teacher survey is organized under the heading 'Teachers' Perceptions of the Effectiveness of the "Hands On Science" Instructional Program'. Conclusions and recommendations based on this data will be presented in the next chapter.

The Development of Students' Scientific Process Skills

The first directional hypothesis tested in this research study was that the teaching of a hands-on process approach in science to primary students will significantly increase those students' scientific process skills. In order to test this directional hypothesis, the four statistical null hypotheses stated previously were tested. These null hypotheses related to the results of the performance test and computer-based test. These evaluation instruments were administered to students participating in the "Hands On Science" Instructional Program. The overall pre-test and post-test results were then analyzed using t-tests for correlated data.

The data obtained from testing these hypotheses also provided interesting information regarding the increase of students' skills with specific scientific processes. Although many valuable conclusions may be derived from these data, such was not the purpose of this research study. The findings would have no bearing on the hypotheses as stated herein. However, such data may well promote future research studies relating to the development of primary students' scientific process skills when implementing a hands-on process approach to science instruction.

The results of the performance pre-test and post-test are presented in Table 1. Each test was scored out of 30 marks by totalling the scores for each of the five performance problems (Vide Appendix H for details on these scores).

When analyzing these data using a t-test for correlated data, the difference between the pre-test and post-test results were significant. With a resulting t of 39.43, the probability of making an error when detecting significance is less than .0005. Therefore, the null hypothesis that there is no significant difference between the means of the pre-test and post-test results of the performance test when participating students are treated with a hands-on process approach to science instruction (H1) may be rejected. These findings supported the statement that the teaching of a hands-on process approach in science to primary students would significantly increase those students' scientific process skills.

The results from the computer-based pre-test and post-test at the grade one level are presented in Table 2. Each test was scored out of 10 marks by adding the number of correct responses (Vide Appendix I for details on these scores).

TABLE 1. PERFORMANCE TEST RESULTS

	Student	Pre-Test	Post-Test
Grade 1	1	16	18
	2	23	27
	3	24	28
	4	27	26
	5	24	25
	6	26	28
	7	21	24
	8	24	25
	9	22	29
Grade 2	10	10	20
	11	8	22
	12	20	25
	13	13	23
	14	23	27
	15	20	30
	16	22	30
	17	21	29
	18	26	30
Grade 3	19	18	27
	20	14	29
	21	20	28
	22	23	21
	23	24	30
	24	25	27
	25	17	27
	26	22	24
	27	25	28

TABLE 2. GRADE ONE COMPUTER-BASED TEST RESULTS

Student	Pre-Test	Post-Test
1	4	8
2	5	6
3	10	9
4	3	7
5	5	8
6	7	8
7	5	9
8	7	9
9	9	10

When analyzing these data using a t-test for correlated data, the difference between the pre-test and post-test was significant. With a resulting t of 10.55, the probability of making an error when detecting significance was again less than .0005. Therefore, the null hypothesis that there is no significant difference between the means of the pre-test and post-test results of the computer-based test when grade one students are treated with a hands-on process approach to science instruction (H2) may be rejected.

The results from the computer-based pre-test and post-test at the grade two level are presented in Table 3. Each test was scored out of a total of 20 marks by adding the number of correct responses (Vide Appendix J for details on these scores).

TABLE 3. GRADE TWO COMPUTER-BASED TEST RESULTS

Student	Pre-Test	Post-Test
1	15	17
2	19	20
3	19	18
4	11	17
5	16	19
6	19	20
7	16	19
8	17	20
9	20	20

When analyzing these results using a t-test for correlated data, it was again apparent that the difference between the pre-test and post-tests scores was significant. The t resulting from these data was 8.33 and the probability of making an error by detecting significance was less than .0005. The third null hypothesis must therefore be rejected.

The results from the grade three computer-based testing are presented in Table 4. Both the pre-test and post-test were marked out of a total of 30 marks (Vide Appendix K for details on these scores).

TABLE 4. GRADE THREE COMPUTER-BASED TEST RESULTS

Student	Pre-Test	Post-Test
1	24	25
2	27	29
3	27	30
4	27	30
5	27	30
6	28	29
7	21	27
8	28	30
9	30	30

When analyzing these results using a t-test for correlated data, a t of 13.71 was present. As a result, the probability of making an error when detecting significance was again less than .0005. The fourth null hypothesis must therefore be rejected since there was significant difference between the pre-test and post-test results of the computer-based test when grade three students were treated with a hands-on process approach to science instruction.

As a result of the data analysis presented herein, it was apparent that the teaching of a hands-on process approach at the primary level significantly increased primary students' skills with the scientific processes as measured by the instruments described herein. The first directional hypothesis was therefore supported by the four statistical tests conducted. Further conclusions and recommendations relating to these findings will be presented in the following chapter.

Teachers' Perceptions of the Effectiveness of the "Hands On Science" Instructional Program

The second directional hypothesis tested in this study was that teachers at the primary level will find the science program that emphasizes the hands-on process approach to be useful and practical for the classroom setting. In essence, teachers were evaluating the effectiveness of the "Hands On Science" Instructional Program. This hypothesis was tested using a teacher survey. Since teachers scored each item on a scale from 1 to 4, these scores were analyzed to find the mean for each item on the survey. In addition, on items where a 'yes', 'no' or 'undecided' answer was indicated, these were presented using percentages of teachers that responded in each of the three manners. The comments received from teachers were also reviewed to determine a global viewpoint.

The results from Parts One to Four of the teacher survey are presented in Table 5 (Vide Appendix L for details regarding each item).

Data analysis for Parts One to Four of the teacher survey clearly indicated that the "Hands On Science" Instructional Program was very highly thought of by the participating teachers. A detailed review of each part follows.

Part One of this survey dealt with the introductory explanation of the program, giving teachers an opportunity to reflect on the description of the hands-on approach, the explanation of the scientific processes, and the guidelines for implementation. All teachers believed that these aspects were very good to excellent, since the means of all survey items were between 3 and 4. Although some teachers did not complete the section for comments, one teacher did reply that the

TABLE 5. RESULTS FROM PARTS ONE TO FOUR OF THE TEACHER SURVEY

Part	Item Number	Mean Score
1	1	3.89
	2	3.89
	3	3.89
2	1	3.67
	2	3.78
	3	3.56
	4	3.50
	5	3.11
	6	3.28
	7	3.28
	8	3.11
3	1	3.78
	2	3.33
	3	3.39
	4	3.44
	5	3.56
	6	3.67
4	1	3.67
	2	3.57

Scoring key:

1 = poor
2 = satisfactory
3 = very good
4 = excellent

introduction was "very well done and easy to follow".

In Part Two, teachers were to evaluate the lesson plans in the program. They were to score items focusing on main concepts, objectives, scientific processes, materials required, activity, follow-up, optional activities and evaluation. The mean scores show that these teachers found all aspects of the lesson plans to be very good to excellent. It was interesting to note that item 5 (activity) and item 8 (evaluation) indicated the lowest means of the items in this portion of the survey. From the teachers' comments it was derived that some teachers felt that the activities took a great deal of time and that unit tests should be included in such a program. This may explain why these two items received lower mean scores. Generally, however, teachers commented that the lesson plans were "well suited", "helped the teacher in presenting meaningful lessons" and "provided reinforcement that the teacher was providing science instruction according to objectives".

In Part Three of the survey teachers were to comment on the activity sheets included in the "Hands On Science" Instructional Program. They were to evaluate activity sheets according to their relationship to the lessons, format, reading level, instructions, graphics and print. The mean scores for this portion of the survey showed that teachers found the activity sheets to be very good to excellent. Above all, the teachers scored the activity sheets high with regard to their relationship to the lessons. One teacher, for example, commented that the activity sheets "were a good reinforcement", while another stated that "evaluation by the activity sheets was helpful" since they related so well to the lessons. With regard to items 2, 3 and 4 (format, reading level and instructions), teachers found that the activity sheets were "clearly laid out - children could understand instructions with minimal help". One teacher, however, found that at the grade one level, the print and line spaces were too small. Another grade one teacher commented that she often had to guide children through the activity sheet to assist them with reading and instruction. However, the overall concensus was that the activity sheets were appropriate for use in primary classrooms.

In Part Four of the survey teachers were asked to evaluate the large pictures and stories that were included in the program. (In some units, teachers did not have the opportunity to use these materials, so they were unable to respond to these questions.) The mean scores for this part of the survey show that again teachers found these materials to be very good to excellent. For example, one teacher commented that she "loved stories and pictures that reinforce" and that she wished she had access to more of these materials. Another found that the stories related very well to lessons and reinforced concepts learned during science activities. Generally, the comments from all teachers were very positive.

The results from Part Five of the teacher survey are presented in Table 6. From the nine surveys completed by participating teachers, a percentage was determined from the number of teachers who responded in each of the three ways (Vide Appendix M for details regarding these items).

TABLE 6. RESULTS FROM PART FIVE OF THE TEACHER SURVEY

Item Number	Yes %	No %	Undecided %
1	100%	-	-
2	67%	22%	11%
3	67%	22%	11%
4	78%	22%	-
5	100%	-	-
6	100%	-	-
7	100%	-	-

It was apparent in this part of the survey, that teachers' perceptions of the "Hands On Science" Instructional Program were very positive.

According to the results from item 1, all teachers felt that the "Hands On Science" Instructional Program coincided with the Manitoba Curriculum Guide for K-6 Science. In this section, one teacher also stated that the program "correlates nicely with other subjects".

The majority of teachers found that the program enhanced their awareness of the concepts and objectives of their grade's science program although some teachers felt that they were already very aware of these (item 2).

With regard to item 3, teachers generally felt that the instructional program enhanced their awareness of the scientific processes. One teacher commented that she "found that [she] had a better grasp of childrens' ability to reason. Watching them helped [her] evaluation." Again, a few of the participating teachers felt they already understood these processes well.

Teachers also agreed that the "Hands On Science" Instructional

Program assisted them in becoming more aware of the hands-on approach to science instruction and how to implement such an approach. One teacher, for example, made the following very encouraging comment with regard to the hands-on approach:

> The term "hands-on" has always scared me, as I visualize "hands on everything" (chaos). I now can cope with the concept and realize hands-on is not always everyone on their own!

The majority of comments provided in this section reinforced this viewpoint, although again, some teachers believed that they already had an adequate understanding of this approach and how to implement it in their science teaching.

Item number 5 on the survey dealt with the elementary science goals for the school division where the sample was situated (Vide Teacher Survey in Appendix G). Teachers were asked if they felt that the "Hands On Science" Instructional Program assisted them in accomplishing these goals and all participants agreed that it did. Teachers believed that the use of such a program helped them emphasize laboratory safety as well as organize adequate laboratory equipment for use with specific activities.

In items 6 and 7, teachers were to comment on whether they would use the "Hands On Science" Instructional Program in the future and whether this program should be made available to primary school teachers throughout the province. On both items, all teachers supported the extended use of this program to supplement their science programs. One teacher commented that she "found the program helpful, useful and practical. The children enjoyed being involved in the many concrete experiences."

At the end of the survey, teachers were given the opportunity to make general comments on the "Hands On Science" Instructional Program. Again, these comments were very positive and teachers generally seemed enthusiastic about the implementation of the hands-on process approach to science instruction at the primary school level. These general comments reinforced the teachers' views on many of the survey items discussed previously. All teachers found that the "Hands On Science" Instructional Program was useful, organized, and well thought out. They were supportive of the hands-on process approach to science instruction and saw the first-hand benefits of such an approach for their students. Some teachers believed that the program should be extended to include more evaluative measures and ideas for activities, and also that it be extended for use at the intermediate level as well (grades four to six) (Vide Appendix N for a list of these comments).

Summary

This chapter has presented the results of this research study. In as much as the results of the performance test and the computer-based test indicated significant improvement of students' scientific process skills and the results of the teacher survey supported the use of the "Hands On Science" Instructional Program, it is suggested that this format of a hands-on process approach to science instruction at the primary school level is beneficial for both students and teachers alike. The next chapter will summarize these results and, in turn, present conclusions and recommendations following from this research study.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The purpose of this study was to determine the effectiveness of a hands-on process approach in science at the primary level (grades one to three). To achieve this purpose, primary school students' scientific process skills were evaluated before and after these students participated in the "Hands On Science" Instructional Program. In addition, participating teachers completed a survey to indicate the effectiveness of the "Hands On Science" Instructional Program for the primary classroom setting. This chapter will summarize the results of these investigations and provide some recommendations related to the hands-on process approach to science instruction. In addition, some suggestions for future research in this area will be made.

Summary of Results

In previous chapters, a review of literature relating to the hands-on process approach provided the basis for a theoretical framework and supported the idea that children's scientific process skills may be significantly improved if this approach is used. In order to further test this concept, the "Hands On Science" Instructional Program was developed for grades one to three science. This program focused on the hands-on approach and the development of students' scientific process skills. Furthermore, a performance test and a computer-based test were developed to evaluate these process skills.

Students involved in this research study received science instruction from their regular teachers, who implemented the "Hands On Science" Instructional Program for a period of eight weeks. Prior to this treatment period, nine students from each of grades one, two and three participated in pre-testing using both the performance test and the computer-based test. After the treatment period, these same students were post-tested using the same evaluation measures.

The results of this aspect of the study showed that students' skills with the scientific processes significantly increased after participating in the hands-on process approach to science instruction. Data analysis indicated significance on both the performance test and the computer-based test at .0005 using t-tests for correlated data.

The second aspect of this research study focused on teachers' perceptions of the effectiveness of the "Hands On Science" Instructional Program. This problem was investigated by having the teachers involved in this research study complete a survey to provide information regarding the effectiveness of the "Hands On Science" Instructional Program. The results of this survey indicate that teachers involved in this study expressed very positive opinions regarding the program. The structure of the program itself was highly thought of, and teachers believed that the program heightened their awareness of the concepts and objectives for their grade level science program. In addition, teachers believed that they became more confident with the hands-on approach and the development of students' scientific processes.

Conclusions

The original rationale for this study was based on several critical issues in science education. The need for concrete learning experiences for the young child, as described by Piaget, provided support for the use of the hands-on approach to science instruction. The process approach, which encourages active involvement and concrete experiences, was also supported. Science educators such as Gagne stated that students must have skills with the scientific processes in order to practice and understand the concepts and principles of science.

This research study found that a hands-on process approach to science at the primary school level was effective for both students and teachers alike. The implementation of this approach significantly increased students' scientific process skills, and at the same time the participating teachers found it useful and practical for the primary classroom setting.

In that it has been realized that the development of programs such as "Hands On Science" was effective in the manner stated above, it would be reasonable to conclude that such programs can be successfully designed. In addition, it may be concluded that such programs can be effectively correlated with existing curricula in an effort to meet local needs. The hands-on process approach was found to be effective as a means of learning content, since the concepts presented in the Manitoba Curriculum Guide for K-6 Science were focused upon throughout the program.

The development and use of process tests such as those designed for this research study have indicated that these instruments can be effectively used at the primary school level. The rationale described in chapter one and the review of literature presented in chapter two indicated that very few evaluation measures focusing on primary school students' scientific process skills have been developed to date. Many of the process tests that have been developed were for use with students in higher grades, and most were of the written type. Past performance tests have been used only with students in grades three and higher. Since this study has indicated that the performance test has been used successfully and provided pertinent information regarding the development of students' scientific process skills, it may be concluded that such evaluation measures are both appropriate and effective for evaluating such skills at the primary level. Due to the lack of existing performance tests for evaluating primary students' scientific process skills, the development of the performance instrument for this research study may be deemed of value to science education.

The lack of computer-based tests for evaluating primary students' scientific process skills was also identified in the rationale and review of literature. It was stated that such tests are of value because of their managerial advantages and their positive effects on student motivation. Since the computer-based test designed for this research study was effectively administered and provided significant findings as to the development of primary students' scientific process skills, it may be concluded that the development and use of this test was a valuable endeavour.

In as much as the original rationale for this research study stated that the hands-on process approach to science instruction at the primary level is effective, and that there is a need for the development of more process tests for students at this level, this rationale has been substantiated by the findings of this research study.

Practical Applications

The following recommendations have been determined as a result of this study:

1.) Further efforts are required to develop and implement instructional programs that emphasize a hands-on approach to science instruction while focusing on the development of students' scientific process skills, especially in the early formal schooling years, most particularly at the primary (grades one to three) levels.

2.) Efforts must also be made to design such programs to meet the needs of local students and teachers. In essence, this means that such programs be correlated to existing science curricula; eg., provincial guidelines.

3.) It is recommended that performance tests to evaluate students' scientific process skills be developed and used in order to allow students opportunities to express their skills in a hands-on manner.

4.) It is also suggested that educators consider designing computer-based tests to evaluate students' scientific process skills, in an effort to add variety to the process of evaluation while at the same time acquiring instant feedback regarding students' skills with the scientific processes.

Research Implications

The following suggestions for future research are presented as a result of this research study:

1.) Further efforts should be made to attempt to identify the effectiveness of the hands-on process approach. Such research is required at the primary level, but should also extend to the upper elementary and secondary levels.

2.) Further efforts should be made to identify the effectiveness of instructional programs that have been developed with the hands-on process approach in mind. Such research should take into consideration the local needs and provincial guidelines of specific user groups. Again, research is still required at the primary level, but involvement at the intermediate and secondary levels would be pertinent.

3.) It may also be worthwhile to conduct a research study that attempts to identify the effectiveness of the hands-on process approach to science instructions to the primary level over a longer treatment period such as one entire school year. Such a study could then include a control group since maturation and history may be more significant over a longer period of time.

4.) Replication of this study on other populations and with larger samples would add to the generalizability of the benefits of the hands-on process approach to science instruction.

5.) Research on the development of further evaluation measures for the purposes of identifying primary students' scientific process skills would be most beneficial to educators.

6.) Further research is required in the area of evaluating the effectiveness of the process approach as a means of learning content in science. This research would be valuable not only at the primary level, but also at the intermediate and secondary levels of schooling.

Summary

This final chapter has presented a summary of results, conclusions, practical applications, and research implications regarding this study of the effectiveness of the hands-on process approach to science instruction at the primary school level. These findings have been presented in an effort to further enhance educators' understanding of science education and the beneficial implications of implementing a hands-on process approach. This research study has provided pertinent information regarding the needs and abilities of primary school children as they experience and participate in science.

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APPENDIX A

SAMPLE LESSON PLAN FROM THE "HANDS ON SCIENCE" INSTRUCTIONAL PROGRAM

(Grade One)

ACTIVITY #3

Main Concept

The characteristics of non-living objects are:

1.) They do not need food or water.

2.) They do not grow.

3.) They do not die.

4.) They do not reproduce.

Objectives

- Define a non-living object.

- In order to establish properties of the non-living objects, compare living things to non-living objects on the basis of growth, need for food and water, and reproduction.

Scientific Processes

Observation, classification, communication

Materials Required

- Various living and non-living objects. Students can be asked to bring a non-living object to school for this activity.

- Chart paper for listing characteristics of non-living things.

Activity

- Again display all the objects for the students to examine and observe.

- Discuss the characteristics of all the objects and as a review of the previous lesson, have the students classify the objects into living and non-living sets.

- Have the students remove all the living things from the display area.

- Students observe and examine the non-living objects. Using the list of characteristics of living things, compare living and non-living objects, i.e. "Does a rock need food and water?", "Does a toy car grow and die?", "Does a wooden block reproduce?".

- As a result of this discussion, a list of definitive characteristics of non-living objects can be made.

Optional Activity

- Have the students look through magazines and make two murals for the classroom, one with pictures of living things and one with pictures of non-living things.

Follow-Up

- Student activity sheet

Evaluation

Observe students as they participate in the activity and as they use the scientific processes involved in the lesson. Check to see which students fully understand the differences between living and non-living things. Also use the student activity sheet as an evaluative measure.

APPENDIX B

SAMPLE STUDENT ACTIVITY SHEET FROM THE "HANDS ON SCIENCE" INSTRUCTIONAL PROGRAM

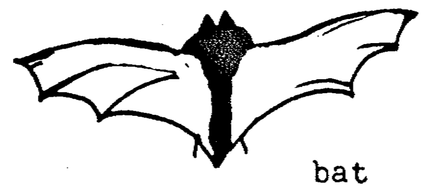
(Grade One)

NAME________________

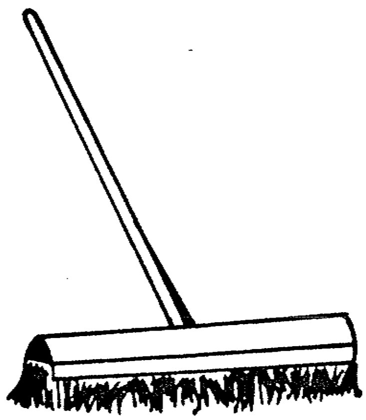
ACTIVITY 3

1. Look at the pictures of living and non-living things.
2. Draw a circle around the things that are not living.
3. Color the pictures of the things that are not living.

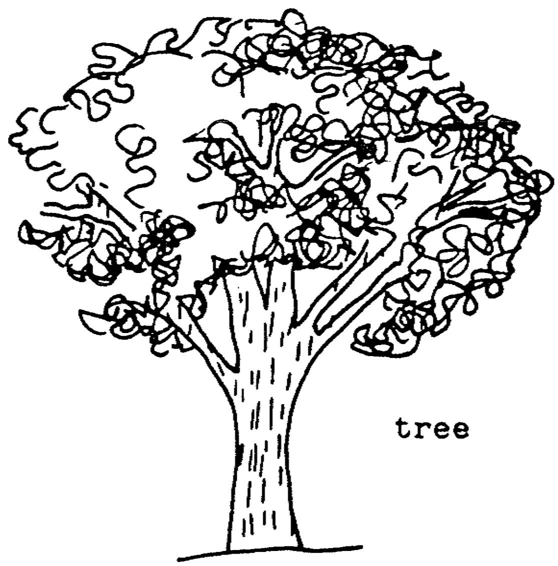
kettle



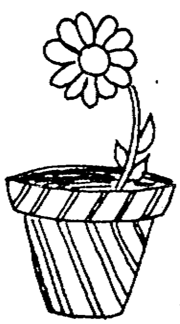
bat



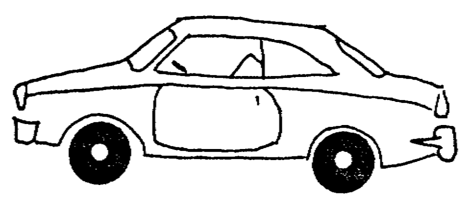
broom



tree

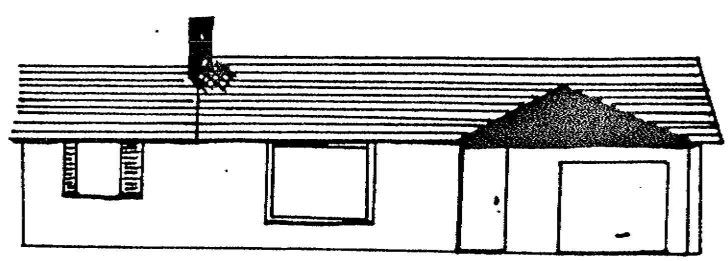


flower



car

girl



house

APPENDIX C

REQUEST LETTER AND LETTER OF PERMISSION

September 3, 1985

Dear ___________:

I am currently studying in the Faculty of Education at the University of Manitoba, where I am completing my Masters in Elementary Science and Computer Studies. At this time I am working on my thesis research and would very much like to conduct my study in your School Division.

I have spoken to your Elementary Science and Mathematics Consultant, who is in full support of my plans. She communicated to me the goals of the Elementary Science Program for your Division, and I believe that my study supports your directions. Your goals are as follows:

- To develop effective laboratory facilities in all elementary schools.

- To develop science research (hands-on) teaching techniques and classroom management to maximize the effectiveness of laboratory activities.

The purpose of my study is to develop an instructional program for primary school children (grades one to three). The activities emphasize the development of scientific process skills using a hands-on approach.

The program is divided into sections for grades one, two and three. Each grade level package is again divided into units of study coinciding with those in the Manitoba Curriculum Guide for K-6 Science. Hence, the program will be used to teach the same concepts and topics that these children would normally be taught, the only difference being that hands-on activities will be focused on more so. All activities in the program are complete with teacher guidelines; lesson plans including main concepts, objectives, scientific processes, materials required, procedures and evaluation techniques; as well as student activity sheets.

I am hoping to have nine experienced primary school teachers from your Division participating in the study, three of which each teach the specified grade levels (1, 2, 3). Each teacher will be responsible for teaching one unit from the program at their grade level.

Prior to the teaching of all units, randomly selected students (three from each classroom) will be asked to conduct a performance test and a computer-based test for scientific process skills. Following the teaching of each unit, the students will again meet with this researcher for a post-test. The results of the pre-test and post-test will be used to identify the potential of the hands-on approach for both students and teachers alike. Teachers will also be asked to complete a survey outlining the effectiveness of the program for classroom use.

I would like to emphasize that complete discretion will be used regarding all schools and students. Names will not be presented in the final thesis publication. All results will be made available to the Division for your own purposes. In addition, there will be no costs involved for the schools or teachers participating in the study. If any materials required are not available in the schools they will be provided by the researcher.

I sincerely hope that your School Division will consider allowing me to conduct my thesis study in your schools. I am very willing to meet with the School Board or other involved members to explain the study in more detail and discuss dates. I would greatly appreciate your attention to this matter in the near future. I may be contacted at the University address or the home address stated below. Thank you for your time and consideration, and I look forward to your reply.

Sincerely,

Office 417
Dept. C.: M.N.S.
Faculty of Education
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

Phone: 474-9745

or:

388 Sackville Street
Winnipeg, Manitoba
R3J 1Z8

Phone: 888-4601

September 11, 1985

Ms Jennifer E. Lawson
388 Sackville Street
Winnipeg, Man.
R3J 1Z8

Dear Ms Lawson:

I have approved, in principle, your request to conduct a study on science activities for primary school children (Grades 1-3).

Please contact me at your earliest convenience to establish procedures for contacting classrooms in which to conduct your in-depth study.

I will look forward to hearing from you.

Yours truly,

Superintendent of Elementary Schools

APPENDIX D

PERFORMANCE TEST

OBSERVER INSTRUCTIONS AND ITEMS

OBSERVATION

Materials

- Rabbit in cage
- Gerbil in cage
- Answer sheet

Directions

1.) The student is presented with a rabbit and a gerbil to examine.

2.) The student is asked to give three similarities and three differences regarding the way the two animals look.

3.) The evaluator will record the student's answers.

Marking Procedure

- One mark is given for each similarity and difference noted by the student.
- There will be a total of six possible marks allowed for this question.

OBSERVATION

Look carefully at the two animals. Tell three things that are the same about the way the animals look and three things that are different about the way the animals look.

THINGS THAT ARE THE SAME ABOUT THE WAY THE TWO ANIMALS LOOK:

1.) ____

2.) ____

3.) ____

THINGS THAT ARE DIFFERENT ABOUT THE WAY THE TWO ANIMALS LOOK:

1.) ______________________________
____

2.) ______________________________
____

3.) ______________________________
____

CLASSIFICATION

Materials

- three pie plates
- small metal objects
- small plastic objects
- small wooden objects

Directions

1.) The student is presented with three pie plates filled with objects classified according to the material of which they are made.

2.) Three additional objects, one made of each of the three materials, will be placed on the table.

3.) The student is asked to place the three extra objects into the plate where he/she thinks it belongs.

4.) The student will also be asked to tell what is the same about the objects in each plate.

Marking Procedure

- The student will be given three marks for correctly classifying the objects, plus three additional marks for naming the materials of which each group of objects are made.
- There are six possible marks for this question.

CLASSIFICATION

1.) Look carefully at the objects in the three plates.

2.) Now look at the three objects on the table.

3.) Decide in which group each object belongs.

4.) Put each of the three objects into the plate where you think it belongs.

Evaluator's Observations

5.) How are all the objects in plate A the same? ____________________

6.) How are all the objects in plate B the same? ____________________

7.) How are all the objects in plate C the same? ____________________

MEASUREMENT

Materials

- 30 centimetre ruler
- three straws of various lengths

Directions

1.) The student will be asked to measure the length of straw A and B. The evaluator will record the student's answers.

2.) The student will then be asked to estimate the length of the third straw. The evaluator will record this estimate.

Marking Procedure

- Two marks will be given for correctly measuring the length of each of the two straws (4 marks).
- Two additional marks will be given for correctly estimating the length of the third straw. The student's estimate must be within two centimetres of the actual length of this straw.
- There will be six possible marks for this question.

MEASUREMENT

1.) Use the ruler to find the length of straw A.

_______________ centimetres

2.) Use the ruler to find the length of straw B.

_______________ centimetres

3.) Now without using the ruler, what do you think the length is of straw C?

_______________ centimetres

COMMUNICATION

Materials

- six green circles
- six yellow squares
- six green squares
- six red squares
- six yellow triangles
- six red triangles
- large chart
- answer sheet

Directions

1.) The student will be asked to examine the chart.

2.) The student will be asked to use the various colored shapes in the container to replicate the information given on the chart.

Marking Procedure

- One mark will be given for providing the correct number of each colored shape according to the information on the chart.
- A total of six possible marks will be given for this question.

COMMUNICATION

1.) Look at the chart.

2.) Look at the colored shapes in the box.

3.) Place the right number of each colored shape on the large chart.

4.) Make sure to look at the shape, the color, and the number of each.

Shape	Color	Number
Circle	Green	5
Square	Yellow	2
Square	Green	4
Square	Red	1
Triangle	Red	3
Triangle	Yellow	6

INTERPRETING OBSERVATIONS

Materials

- small box containing a ticking clock
- small box containing some rice
- small box containing one marble
- answer sheet

Directions

1.) The student will be asked to infer what is inside each box without opening the box. The evaluator will record the student's answer.

2.) The student will also be asked to infer the number of objects in each box. The evaluator will again record the student's answer.

Marking Procedures

- One mark will be given for providing a reasonable answer for what is inside each box (3 marks).
- One mark will be given for correctly stating the number of objects (one or more than one) in each box (3 marks).
- There will be a total of six possible marks for this question.

INTERPRETING OBSERVATIONS

Try to guess what is inside the each box without opening the box.

1.) What do you think is inside box A? ______________________________

2.) Do you think there is one object or more than one object inside box A? __________

3.) What do you think is inside box B? ______________________________

4.) Do you think there is one object or more than one object inside box B? __________

5.) What do you think is inside box C? ______________________________

6.) Do you think there is one object or more than one object inside box C? ___________

APPENDIX E

SCIENTIFIC PROCESSES TESTED

IN EACH ITEM OF THE COMPUTER-BASED TEST

AND

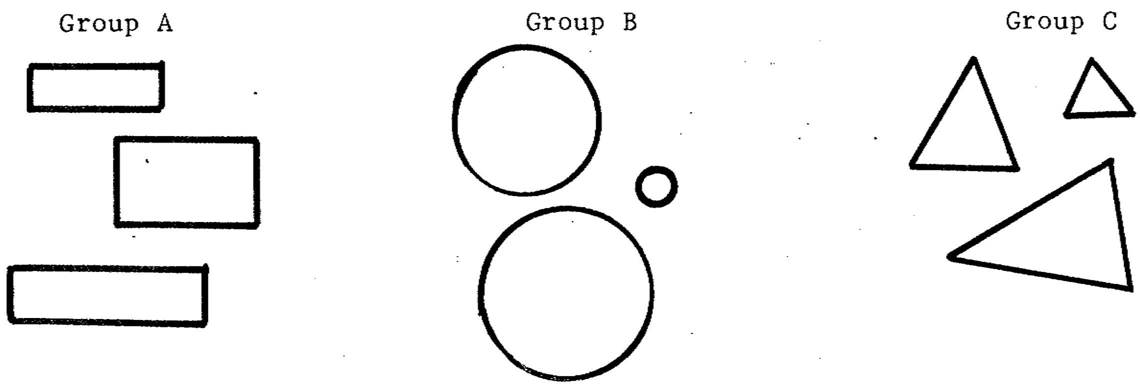
SAMPLE TEST ITEM FROM THE GRADE ONE COMPUTER-BASED TEST

(PROCESS SKILL TESTED: CLASSIFICATION)

SCIENTIFIC PROCESSES TESTED
IN EACH ITEM OF THE COMPUTER-BASED TEST

Item	Scientific Process
1	Observation
2	Observation
3	Classification
4	Classification
5	Measurement
6	Measurement
7	Communication
8	Communication
9	Interpreting Observations
10	Interpreting Observations
11	Observation
12	Observation
13	Classification
14	Classification
15	Measurement
16	Measurement
17	Communication
18	Communication
19	Interpreting Observations
20	Interpreting Observations
21	Observation
22	Observation
23	Classification
24	Classification
25	Measurement
26	Measurement
27	Communication
28	Communication
29	Interpreting Observations
30	Interpreting Observations

2.) Look at the shapes.



Now look at this shape.

Which group does this shape go in?

(choose A, B or C)

APPENDIX F

VALIDATION FORM FOR THE COMPUTER-BASED TEST AND PERFORMANCE TEST

INSTRUCTIONS FOR VALIDATING THE SCIENTIFIC PROCESS SKILLS TEST

1.) The purpose of validation is to assure the test developer that the skill that he/she is attempting to evaluate in a particular test question is actually being focused upon, i.e. Is it a valid question to test that particular skill.

2.) There are five (5) skills that are being evaluated with this test. They are:
Observation
Classification
Measurement
Communication
Interpreting Observations

3.) Each test question is focusing on one (1) of these skills.

4.) Please read the definitions of each scientific process skill carefully.

5.) Read each test question carefully and decide which one of these five skills is being evaluated.

6.) Check your answer on the accompanying validation form.

7.) Finally, if you notice any discrepancies or weaknesses in any of the test questions, please make comments to that effect on the accompanying sheet.

THANK YOU FOR YOUR ASSISTANCE. IT IS GREATLY APPRECIATED!

AN EXPLANATION OF SCIENTIFIC PROCESSES

A process approach to science instruction has the child actually becoming a young scientist, using the same processes that a scientist uses in order to gain new understandings. The basic processes include observation, classification, communication, measuring, using space/time relationships, inferring, and predicting. The integrated processes, which may be considered more complex, include defining operationally, controlling variables, formulating hypotheses, interpreting data, and experimenting. It is necessary to keep in mind, however, that at the primary level, students are not ready to use all of these scientific processes. This instructional program therefore focuses on developing skills with five basic processes - observation, classification, measurement, communication and interpreting observations:

Observation

The students should be able to perceive characteristics and changes through the use of their sense and scientific tools. Observation may be qualitative or quantitative. Categories recognized as observation include:

a.) information through the senses

b.) similarities and differences

c.) sequencing events or objects

Classification

This skill is used to show grouping of objects and events. Classification is based on observable properties.

Measurement

This is a process of finding dimensions or quantity of an object or event. It usually involves comparison of size, mass, temperature and time as accepted standards. Measurement also includes the ability to choose appropriate measuring devices in order to measure a particular object or event, estimate and use proper directional and positional terminology.

NOTE - Throughout the program, the term 'mass' will be used since it is scientifically appropriate. Students should be introduced to the term. It is not necessary that they know the scientific explanation behind the difference between mass and weight. To the young child, they will mean the same thing and can be explained as such. However, it is still suggested that both teachers and students use the term 'mass' instead of 'weight' as much as possible.

Communication

In science, one communicates by means of graphs, charts, maps, symbols, written language and spoken language. The categories recognized as forms of communication for this program are:

a.) reading from tables and charts

b.) making tables and charts

c.) reading from graphs

d.) making graphs

e.) recording results in forms other than tables, charts and graphs, such as commentaries and diagrams

f.) diagrams

Interpreting Observation

Interpretation depends on information gained through observation. It is a more complex skill and often involves being able to infer, generalize, explain, predict, relate and state conclusions based upon information gained. As a result, trends and patterns may be realized.

NOTE - The young child's inferences and predictions will likely be very elementary. This is to be expected since they do not have a great deal of past experience and information to base their inferences and predictions on. However, they should still be encouraged to make predictions and inferences as much as possible.

COMPUTER-BASED TEST VALIDATION

Question	Observation	Class.	Comm.	Meas.	Interp. Obs.
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					

PERFORMANCE TEST VALIDATION

Read each test item carefully and check the scientific process skill that you believe is being focused upon. There are a total of five items.

Item	Obs.	Class.	Comm.	Meas.	Int. Obs.
1					
2					
3					
4					
5					

Legend:

Obs. = Observation
Class. = Classification
Comm. = Communication
Meas. = Measurement
Int. Obs. = Interpreting Observations

APPENDIX G

TEACHER SURVEY

TEACHER SURVEY FOR THE "HANDS ON SCIENCE" INSTRUCTIONAL PROGRAM

Grade Level: __________

Unit(s) taught from the "Hands On Science" Instructional Program:

____

Approximate number of minutes of instruction per six day cycle:

____

Instructions

Please answer <u>all</u> questions in Parts One, Two, Three and Four by circling the appropriate number according to the following scale.

1 - poor
2 - satisfactory
3 - very good
4 - excellent

Part One

How worthwhile were the following aspects of the introduction to the "Hands On Science" Instructional Program?

1.)	Description of the hands-on approach	1	2	3	4
2.)	Explanation of scientific processes	1	2	3	4
3.)	Guidelines for implementation	1	2	3	4

Comments: ____

____

____

____

____

____

Part Two

How useful did you find the following aspects of the lesson plans in the "Hands on Science" Instructional Program?

1.)	Main concepts	1	2	3	4
2.)	Objectives	1	2	3	4
3.)	Scientific processes	1	2	3	4
4.)	Materials required	1	2	3	4

5.)	Activity	1	2	3	4
6.)	Follow-up	1	2	3	4
7.)	Optional activities	1	2	3	4
8.)	Evaluation	1	2	3	4

Comments: ____
____
____
____
____
____

Part Three

How appropriate were the following aspects of the activity sheets in the "Hands On Science" Instructional Program?

1.)	Relationship to the lessons	1	2	3	4
2.)	Format	1	2	3	4
3.)	Reading level	1	2	3	4
4.)	Instructions	1	2	3	4
5.)	Graphics	1	2	3	4
6.)	Print	1	2	3	4

Comments: ____
____
____
____
____
____

Part Four

1.) How appropriate were the large pictures in the "Hands On Science" Instructional Program? 1 2 3 4
(not applicable ___)

2.) How appropriate were the stories in the "Hands On Science" Instructional Program? 1 2 3 4
(not applicable ___)

Comments: ____
____
____
____
____
____

Part Five

Please answer "yes", "no" or "undecided" to the following questions. Please comment where appropriate.

1.) Did you find that the "Hands On Science" Instructional Program coincided with the Manitoba Curriculum Guide for K-6 Science?

Yes ______
No ______
Undecided ______

Comments: ____
____

2.) Did you find that the program enhanced your awareness of the concepts and objectives for your grade's science program?

Yes ______
No ______
Undecided ______

Comments: ____
____

3.) Did you find that the program assisted you in becoming more aware of the scientific processes and how to focus on them in your teaching?

Yes ______
No ______
Undecided ______

Comments: ____
____

4.) Did you find that the program assisted you in becoming more aware of the hands-on approach to science instruction and how to implement such an approach?

Yes ______
No ______
Undecided ______

Comments: ____
____

5.) The goals for elementary science in your School Division are stated as follows:

i. To develop effective laboratory facilities in all elementary schools.

ii. To develop science research (hands-on) teaching techniques and classroom management to maximize the effectiveness of laboratory activities.

Do you feel that the use of the "Hands On Science" Instructional Program assisted you in accomplishing these goals?

Yes _____
No _____
Undecided _____

Comments: ____

6.) Will you use the "Hands On Science" Instructional Program in the future?

Yes _____
No _____
Undecided _____

Comments: ____

7.) Do you think that the "Hands On Science" Instructional Program should be made available to primary school science teachers?

Yes _____
No _____
Undecided _____

Comments: ____

GENERAL COMMENTS: ____

Any additional comments or suggestions you may have regarding specific lessons or the program in general are most welcome. These may be added on separate paper if you desire.

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS SURVEY AND ESPECIALLY FOR TAKING PART IN THIS RESEARCH STUDY!

APPENDIX H

PERFORMANCE TEST SCORES

PERFORMANCE PRE-TEST RESULTS

Student	Class.	Meas.	Comm.	Int.	Obs.	Total
1	6	0	2	3	5	16
2	6	6	5	3	3	23
3	6	4	5	5	4	24
4	6	6	6	3	6	27
5	5	6	6	3	4	24
6	6	6	6	3	5	26
7	5	4	3	4	5	21
8	4	4	4	6	6	24
9	6	0	5	6	5	22
10	5	0	2	1	2	10
11	3	0	0	1	4	8
12	5	2	6	3	4	20
13	3	4	0	3	3	13
14	6	4	3	5	5	23
15	6	4	0	4	6	20
16	6	4	4	3	5	22
17	6	4	4	5	2	21
18	6	6	5	4	5	26
19	6	4	0	2	6	18
20	2	0	4	3	5	14
21	6	6	0	4	4	20
22	3	4	6	4	6	23
23	6	4	4	5	5	24
24	5	4	6	4	6	25
25	2	4	3	4	4	17
26	5	4	5	4	3	22
27	6	6	6	4	3	25

*All test items were marked out of a total of six marks.

Legend:

Class. = Classification item
Meas. = Measurement item
Comm. = Communication item
Int. = Interpreting Observations item
Obs. = Observation item

PERFORMANCE POST-TEST RESULTS

Student	Class.	Meas.	Comm.	Int.	Obs.	Total
1	6	2	0	4	6	18
2	6	4	6	5	6	27
3	6	6	5	6	5	28
4	6	2	6	6	6	26
5	6	2	6	5	6	25
6	6	6	6	4	6	28
7	4	4	6	4	6	24
8	5	6	3	6	5	25
9	6	6	6	5	6	29
10	5	0	6	6	3	20
11	0	4	6	6	6	22
12	5	4	6	6	4	25
13	5	4	6	4	4	23
14	6	4	6	5	6	27
15	6	6	6	6	6	30
16	6	6	6	6	6	30
17	6	6	6	5	6	29
18	6	6	6	6	6	30
19	6	4	6	5	6	27
20	6	6	6	5	6	29
21	6	6	6	4	6	28
22	5	0	5	5	6	21
23	6	6	6	6	6	30
24	6	4	6	5	6	27
25	6	4	6	5	6	27
26	6	0	6	6	6	24
27	6	4	6	6	6	28

*All test items were marked out of a total of six marks.

Legend:

Class. = Classification item
Meas. = Measurement item
Comm. = Communication item
Int. = Interpreting Observations item
Obs. = Observation item

APPENDIX I

COMPUTER-BASED TEST SCORES FOR GRADE ONE

COMPUTER-BASED TEST SCORES FOR GRADE ONE

Pre-Test

Student	1	2	3	4	5	6	7	8	9	10	Total
1			X	X	X	X					4
2	X		X	X	X	X					5
3	X	X	X	X	X	X	X	X	X	X	10
4	X		X	X							3
5	X		X	X	X				X		5
6	X	X	X	X	X				X	X	7
7	X		X	X	X					X	5
8	X	X	X	X	X	X			X		7
9	X	X	X	X	X	X	X	X	X		9

Post-Test

Student	1	2	3	4	5	6	7	8	9	10	Total
1	X	X	X	X	X	X	X	X			8
2	X	X	X	X				X	X		6
3	X		X	X	X	X	X	X	X	X	9
4	X	X	X	X	X		X	X			7
5	X		X	X	X	X	X		X	X	8
6	X		X	X	X	X		X	X	X	8
7	X	X	X	X	X	X	X	X	X		9
8	X	X		X	X	X	X	X	X	X	9
9	X	X	X	X	X	X	X	X	X	X	10

X = correct response

APPENDIX J

COMPUTER-BASED TEST SCORES FOR GRADE TWO

COMPUTER-BASED TEST SCORES FOR GRADE TWO

Pre-Test

Student	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1	X	X	X	X	X		X	X	X	X	X	X		X	X	X		X			15
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	19
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		19
4	X	X	X	X	X	X		X	X	X	X			X							11
5	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X				16
6	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	19
7	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	16
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X		X	17
9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20

Post-Test

Student	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X			17
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			20
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	18
4	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X	X		17
5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	19
6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20
7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	19
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20
9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	20

X = correct response

APPENDIX K

COMPUTER-BASED TEST SCORES FOR GRADE THREE

COMPUTER-BASED TEST SCORES FOR GRADE THREE

Pre-Test

Student	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X						X	24
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	27
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				27
4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X		27
5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X			27
6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X	28
7	X	X	X	X	X	X			X	X	X	X	X	X	X	X		X	X	X	X	X		X	X						21
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	28
9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	30

Post-Test

Student	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X				X	X	25
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	29
3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	30
4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	30
5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	30
6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	29
7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	27
8	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	30
9	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	30

X = correct response

APPENDIX L

TEACHER SURVEY RESULTS: PARTS ONE TO FOUR

TEACHER SURVEY RESULTS: PARTS ONE TO FOUR

Part	Item	Teacher's Score* A1	B1	C1	A2	B2	C2	A3	B3	C3	Mean
One	1	4	4	4	4	4	4	4	4	3	3.89
	2	4	4	4	4	4	4	4	4	3	3.89
	3	4	4	4	4	4	4	4	4	3	3.89
Two	1	4	4	3	4	4	4	4	3	3	3.67
	2	4	4	3	4	4	4	4	4	3	3.78
	3	4	4	3	4	4	3	4	3	3	3.56
	4	4	3.5	3	4	4	3	4	3	3	3.50
	5	4	3	2	4	2.5	3	4	2.5	3	3.11
	6	4	3	3	4	2.5	3	4	3	3	3.28
	7	4	3	3	4	2.5	3	4	3	3	3.28
	8	4	3	2	4	2	3	4	3	3	3.11
Three	1	4	3.5	4	4	3.5	4	4	3	4	3.78
	2	4	3.5	2	4	3.5	4	3	3	3	3.33
	3	4	2.5	2	4	4	4	4	3	3	3.39
	4	4	3.5	2	4	3.5	4	4	3	3	3.44
	5	4	3	3	4	4	4	3	4	3	3.56
	6	4	4	2	4	4	4	4	4	3	3.67
Four**	1	NA	4	3	NA	4	4	NA	4	3	3.67
	2	NA	3	4	NA	4	4	3	4	3	3.57

*A1, B1, C1 = grade one teachers
A2, B2, C2 = grade two teachers
A3, B3, C3 = grade three teachers

**Part Four had two items where the teacher could respond as "not applicable.

APPENDIX M

TEACHER SURVEY RESULTS: PART FIVE

TEACHER SURVEY RESULTS: PART FIVE

Item	A1	B1	C1	A2	B2	C2	A3	B3	C3	Yes%	No%	Undecided%
					*Teacher's Response							
1	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%	-	-
2	Y	N	U	Y	N	Y	Y	Y	Y	67%	22%	11%
3	Y	N	U	Y	N	Y	Y	Y	Y	67%	22%	11%
4	Y	N	Y	Y	N	Y	Y	Y	Y	78%	22%	-
5	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%	-	-
6	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%	-	-
7	Y	Y	Y	Y	Y	Y	Y	Y	Y	100%	-	-

*Y = Yes response
N = No response
U = Undecided response

A1, B1, C1 = grade one teachers
A2, B2, C2 = grade two teachers
A3, B3, C3 = grade three teachers

APPENDIX N

GENERAL COMMENTS FROM TEACHER SURVEY

GENERAL COMMENTS FROM TEACHER SURVEY

1.) The unit I worked with has been both useful and practical. I observed growth and development of the scientific processes stressed throughout the activities. The unit covered the major concepts of the curriculum guide. The lesson plans were a tremendous help to me. I wish to express my thanks in allowing me to be part of the research study. It's been a very valuable experience.

2.) I noted a great deal of growth between a grade one class and a grade two. The children handled all activities well, including activity follow-up sheets which seem well suited to the grade level and developed very positively in the five basic processes that were used in order to gain new understandings of the unit.

3.) The "Hands On Science" Instructional Program is well thought out and very useful. It correlates well with the curriculum and other subjects. I found it beneficial and overall I was impressed with the format.

4.) Would like to see pre-test and post-test or end of unit test - perhaps more suggestions re: follow-up sheets. On the whole this is a very worthwhile program that I will use along with my other resources and curriculum guide.

5.) Properties of materials and change - could use or have a lot more ideas or activities included. I found the worksheets to be very useful and just changed them a bit if I found them to be too difficult or not appropriate for my kids. Would like a lot more of these idea worksheets and a unit test. Perhaps even a pre- and post-test for each unit. Appreciated that you let us field test this program.

6.) The program was well set up and could be easily used by myself. However I would not use it as the sole instructional tool but along with my program. Well done! I certainly would be interested in seeing units developed for grades 4-6. The students certainly like to become part of the lesson. They seem to retain the objectives more in hands-on lessons. It's not often teachers find such a useful tool.

7.) I have found it very useful. The children really enjoyed the activities. It is great to have everything set up so nicely. There is a lot of setting up to do and preparation and clean-up.

8.) Science in primary has and probably is still looked on as an "extra" subject. With guidelines like these packets, teacher prep is minimized as the organizational procedures are done for you. The importance of science and the relationship to overall "learning" is emphasized with the hands-on approach. I have enjoyed using the material and find myself "KEEN" (can you believe it) to tackle another year of science teaching.

APPENDIX O

THESIS PROPOSAL APPROVAL

UNIVERSITY OF MANITOBA

FACULTY OF EDUCATION

THESIS PROPOSAL APPROVAL

The undersigned have examined

(Mr., Mrs., Miss) Jennifer E. Lawson

and give their approval for the candidate to proceed with the research for the Major thesis.

The topic of the thesis is: A Hands-On Approach To Primary Science Teaching Emphasizing Scientific Processes

and approval is: unconditional / based on the reservations noted below:

Dated Friday, September 20 19 85

HEAD OF MAJOR DEPARTMENT

APPENDIX P

ETHICAL PERMISSION

AND

CORRESPONDING LETTER FROM PARTICIPATING SCHOOL DIVISION

THE UNIVERSITY OF MANITOBA

Inter-Departmental Correspondence

DATE November 4, 1985

TO Jennifer Lawson

FROM R. Carreiro, Chairman, Ethics Review Committee

SUBJECT: "A Hands-on Approach to Primary Science Instruction Emphasizing Scientific Processes"

The committee requires that parents be informed that your study is being undertaken, what is involved for the children, and that they have the right to decline to have their children participate at the beginning and at any point during the study. Points 1 through 6 in part B of the ethical approval form you completed for the committee should provide you with a satisfactory outline. Please submit this letter to us and we will try to review it quickly so that your study can get underway.

RC/mlg

October 16, 1985

Ms Jennifer Lawson
Office 417, Faculty of Education
University of Manitoba
Winnipeg, Man.
R3T 2N2

Jennifer Lawson:

Re: Science Project - Primary Grades

The process for developing and assessing this material in the schools contacted by you requires no specific parental permission. The school administrators and teachers are in support of your project and any public relations activities that would centre on it can be handled by the principal and the teachers involved.

Therefore, you may proceed with your project without the necessity of receiving permission from each of the parents of children who are going to be involved.

Yours truly,

Superintendent of Elementary Schools