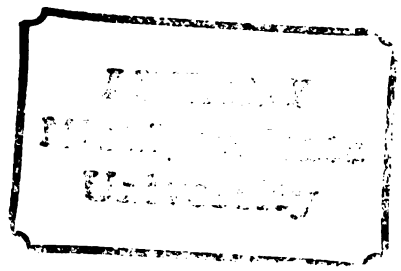
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A STUDY OF THE APPLICATION OF THE INQUIRY-SCRIPT TEACHING MODEL TO THE MODIFICATION OF AN ELEMENTARY SCIENCE STUDY UNIT

presented by

John B. Beaver

has been accepted towards fulfillment
of the requirements for

Ph. D. degree in Education

Bruce D Cheney
Major professor

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A STUDY OF THE APPLICATION OF THE INQUIRY-SCRIPT TEACHING MODEL TO THE MODIFICATION OF AN ELEMENTARY SCIENCE STUDY UNIT

By

John B. Beaver

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Administration and Curriculum

1982

ABSTRACT

A STUDY OF THE APPLICATION OF THE INQUIRY-SCRIPT TEACHING MODEL TO THE MODIFICATION OF AN ELEMENTARY SCIENCE STUDY UNIT

By

John B. Beaver

The purposes of this study were to: (1) revise an ESS unit according to the inquiry-script plan; (2) determine the goals and objectives for a single ESS unit, and develop student tests for this unit; and (3) apply the revised unit in an instructional setting and evaluate student and teacher perceptions, behaviors, student achievement, and student-teacher interactions.

Methodology

An inquiry-script was written for the ESS unit Peas & Particles. Ten unit activities were structured according to three instructional phases, launching, exploring and summarizing. A teacher training packet describing the inquiry plan was also developed. The populations included 12 teachers and their students in one school district (n=293).

Data concerning student and teacher interactions and perceptions were collected using an observation instrument (Activity Categories Index), perception forms, teacher logs, and end of the unit evaluation forms. In addition, three teachers were video-taped, interviewed, and their questioning practices were analyzed.

Results

1. Student measures showed significant achievement of unit objectives as a result of exposure to the scripted method of teaching. Students at three mathematics achievement levels demonstrated their ability to orally describe counting methods. These results indicated that student cognitive levels should be considered in developing student tests.

2. Observational data showed that ESS and inquiry-scripted ESS lessons were essentially equivalent in providing for student laboratory activity and teacher questioning. The inquiry-script model may be one way to structure ESS units without limiting the ESS emphasis on hands-on laboratory activities.

3. The presence of a script did not affect teachers' perceptions of their amount of talk or student perceptions of their activity levels.

4. Teachers needed more guidance from the script in terms of initiating inquiry activities, managing materials, and in allocating time to phases of inquiry lessons.

Recommendations

1. The inquiry-script model could be used to modify other math and science units and in identifying common elements of inquiry instruction for developing new interdisciplinary units.

2. Additional research can and should be conducted to compare: (1) specific teaching units (scripted vs. unscripted); (2) student, teacher and observer perceptions; and (3) oral interview and pen and pencil evaluation instruments.

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DEDICATION

To the memory of my beloved father, Charles Warren Beaver and father-in-law, Otto B. Candidus.

ACKNOWLEDGMENTS

The footnoting procedure found in the dissertation provides a method for formally acknowledging the aid received from books. It is far more difficult to adequately express appreciation to the fulfillment of a dream.

I am most grateful to Dr. Bruce D. Cheney, advisor and chairman of my Doctoral Committee, for his support, patience and direction.

I am indebted to Drs. Glenn D. Berkheimer and Shirley A. Brehm for serving as members of my Doctoral Committee, for their encouragement, and for sharing their knowledge in the areas of science supervision and environmental education. I am especially indebted to Dr. William M. Fitzgerald for serving as a member of my Doctoral Committee and for the introduction to the inquiry teaching model which became the basis for this dissertation. My thanks to Dr. Janet Shroyer who also contributed to the teaching model employed in the study.

I am indebted to Dr. Michael G. Jacobson, "New York committee member," editor, counselor, "Brother," and friend. Without Mike's constant encouragement, support and time this dissertation would not have materialized. I thank

Mike's wife Carol and his daughters Beth and Jennifer for sharing their husband and father with me.

I thank Dr. Francis Crowley, Fordham University, for his guidance and assistance with the statistical analysis and for editing sections of the dissertation.

I wish to thank Mr. Robert Bell, Mr. John Burns, Mr. Irving Carlin, Mrs. Olga Lagano Carlin, Mr. E. Michael Helmintoller, and Mr. Warren Hochberg, all building principals in the Three Village Schools, whose cooperation made this dissertation possible. I am also grateful to Dr. Pierce Hoban and Mr. Barry McManus, superintendent and assistant superintendent of the Three Village School District, who were instrumental in facilitating the graduate work and this study.

A very special note of thanks is extended to my colleagues: Mary Lue Boudreau, Edward Carpenter, Adrienne Grant, Beth Heyn, Clara MacDougal, Barbara McCahill, Judith McCready, Henry Pine, Virginia Portanova, Michael Recchio, Mark Robinson and Carolyn Vreeland, who willingly participated in the research, giving unselfishly of their time, and offering numerous words of encouragement along the way.

I am most grateful to my colleagues in the elementary science department. To Ben Werner, exemplar, leader, supporter and friend... thank you. To Robert Adams, Ronald Daszenski, Barbara Riley, James Riley, and Charles

Triolo, my gratitude for the many hours you gave to this work, your support, encouragement and friendship.

I am grateful to Ellen MacCary, friend and typist, who under the pressure of deadlines and a busy personal schedule prepared the final manuscript.

To Dr. Robert Moraghan and Dr. Charles Kephart, for their words of encouragement and advice at critical times in the preparation of the dissertation.

To Mr. Kerry Van Name, artist and friend, thank you for contributing your talents to illustrations contained in the teaching unit.

And, finally, my feelings of deep appreciation and love go to those closest to me, my family. They have made the greatest sacrifice of all...time. to Marjorie Beaver Park who advised her son to become a teacher and who has also encouraged me in my education and career. To Virginia Sax Candidus who prepared the original typed manuscript, but more importantly contributed significantly to her son-in-law's confidence, through her many words of encouragement and support. To Mary, who shouldered many responsibilities, editor, typist and friend, but most of all model wife and mother. To my daughters Kate and Jeanne, I wish that someday that I will be able to support them, in love and caring in their career's work, as they have supported me through this dissertation.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The early sixties marked a milestone in elementary science with the development of several innovative curricula. Bredderman (1977) reported that 30% of the elementary school children are influenced by one of three of these programs. They are Science-A Process Approach (SAPA), Elementary Science Study (ESS), and Science Curriculum Improvement Study (SCIS).[1] The programs represent hands-on inquiry approaches which seek to develop and expand critical thinking abilities in several discipline areas of the sciences. The materials and guides associated with each of these programs provide for varying amounts of organization and structure regarding the teaching-learning situation.

A characteristic of these science programs is the emphasis upon investigation by the student rather than his acquisition of facts. They often lack evaluative tools for measuring student achievement, even though it is recognized that inquiry is experienced through content. Nicodemus

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[1]Ted Bredderman, "Adoption of Science Programs Another Look," The Elementary School Journal, LXXVII (May, 1977), 364.

(1970) emphasizes this point in the following passage:

> Until instruments are developed to provide some reliable measures and description of inquiry, it will remain difficult to communicate its strategies. One beginning point in resolving this problem concerns organizing the factual part of a lesson in science taught as inquiry.[2]

In recent years schools have faced financial problems which have placed increased pressure on curriculum budgets including funds allocated for elementary science. Another factor affecting the classroom directly is the curtailment of support programs in the schools including physical education, music and art. This effectively eliminates some of the planning time of classroom teachers. Therefore, it has been difficult maintaining science curricula which rely on large quantities of supplies and the necessary preparation time for operating them.

An element in the adoption of any curriculum program is the implementation plan. Biesenhertz (1972) expressing concern for the classroom teacher's role in the implementation process states:

> The success of a science program is dependent on the teacher. We must supply teachers with the experience of observing children interacting with the materials and offer viable models. Without classroom experiences that apply theory to practice one cannot expect prospective teachers to internalize and transfer a strategy of instruction to the classroom.[3]

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[2]Robert B. Nicodemus, "Content and Skill Heirarchies in Elementary Science: An Analysis of ESS Small Things," Journal of Research in Science Teaching, VII (1970), 173.

[3]Paul C. Beisenhertz, "Effective Change in Elementary School Science," Science and Children, X (1972), 26-27.

ESS is recognized as one of the major inquiry science programs used in the elementary schools today. The organization and structure of the ESS program emphasizes student investigation. However, ESS materials do not include clearly defined objectives for unit content, or a means for evaluating the inquiry included in the teaching units. The teacher is important to the success of science curriculum implementation.

Need

Among the three programs, SAPA, SCIS and ESS, the most diverse, in terms of unit offerings, is ESS which offers more than fifty-six units. The guides are written with many important cues and techniques for instruction, and are rich with examples from trial classrooms. They are marked by their infusion of open-ended questions and areas of exploration congruent with David Hawkins' "Messing About" paradigm. According to Hawkins' model,

> ...children are given materials and equipment things and are allowed to construct, test, probe and experiment without superimposed questions or instructions.[4]

Hawkins' instructional model represents one of the major changes brought about by the "new" science programs of the sixties. That was an attempt to change the way we teach. As noted in the 72nd Yearbook of the National Society

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[4]David Hawkins, "Messing About In Science," The ESS Reader (Newton, Ma.: Educational Development Center, 1970), pp.37-44.

for the Study of Education (NSSE, 1973),

> It is obvious that the science and mathematics projects had become involved in changes not merely within the system but of the system itself.[5]

The implications of these changes are that traditional modes of evaluation became inadequate.[6] Victor (1970) contends:

> One of the major criticisms of many of the projects is their failure to provide adequate evaluation. Too much consideration is being given to testimonials of classroom teachers who are using the exercises and units.[7]

The NSSE report goes on to characterize the ESS program as one of the most "open-ended and freewheeling" curriculums totally lacking in guidelines for the development of evaluation instruments.[8]

Maintaining these inquiry programs as a part of the regular classroom instruction may be difficult without a more careful outline for problem-solving activities. This problem is illustrated further by reference to studies

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[5]Wilma S. Longstreet, ed., "The Elementary School in the United States," "The School's Curriculum, Seventy-Second Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1973), p. 255.

[6]Longstreet, p. 255.

[7]Edward Victor, "Present Programs and Major Curriculum Developments in Elementary School Science--A Critique," Elementary Education in the Seventies: Implications for Theory and Practice, Ed. William W. Joyce, Robert G. Oana, and W. Robert Houston (New York: Holt Rinehart & Winston, 1970), p. 156.

[8]Longstreet, p. 255.

of curriculum developments which have attempted to alter the traditional relationship between teacher and student. Delamont (1976) outlines this problem in the following statement:

> The Nuffield approach to science teaching, which emphasized guided discovery rather than lecturing and demonstrating, was one such initiative. Hailed as revolutionary, Nuffield science was thought to be sweeping the schools. In fact, while the manifest curricula have changed as exam syllabuses incorporate Nuffield ideas, the hidden curriculum of classroom life has changed little. In a large scale, official evaluation of new science teaching, Galto and his co-workers observed over 100 teachers all over England in over 300 lessons. They found little evidence of the new techniques.[9]

The need for evaluation methods was noted by Nicodemus (1970) in his analysis of the ESS unit Small Things. In this study Nicodemus contrasted the carefully planned and outlined goals of Science--A Process Approach units, according to an heirarchy of component skills and processes, to any represented in the ESS unit Small Things. He noted difficulty, in his examination of the ESS unit, in ascertaining goals which were presented in a logical sequence according to preplanned skill and process outcomes.[10]

In a more detailed analysis, Appel and Stolte (1970)

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[9]Sara Delamont, Interaction in the Classroom (London: Metheun and Co. Ltd., 1976) pp. 47-48.

[10]Nicodemus, p. 173.

ranked seven elementary science programs according to a four category rating scale on three criteria: curriculum aspects, instructional aspects, and practical aspects.[11] ESS was found deficient in the following curriculum aspects:

> Goals of the program are behaviorally oriented. The structure of the materials is conceptually oriented.
>
> Concepts and processes are integrated and form a heirarchy.
>
> Concepts are organized around constructs which provide the possibility for going beyond the subject matter of science as opposed to being organized around conceptual schemes.
>
> Content from physical and biological sciences are introduced at all levels.[12]

Most often ESS unit development interpretation is left in the hands of the classroom teacher as an individual. Goals are established, lessons prepared and teacher-made tests are produced. The lack of materials and resources and the lack of time to utilize what materials and resources are available makes the classroom teacher's job difficult if not impossible.

It is essential to identify the goals and objectives for a unit of study prior to developing evaluative measures. Educators in California recognized this need in the ESS program and have defined the goals and objectives in an

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[11]Marilyn Appel and Joanne Stolte, Assessment of Existing Elementary Science Programs, U. S. Educational Resources Information Center, ERIC Document ED 062 163, June, 1970.

[12]Appel and Stolte, p. 4.

evaluation guide published by the California Test Bureau, McGraw-Hill (1974).[13] The California Test Bureau effort has provided some structure and a means for defining content along with providing baseline information to measure student outcomes for the ESS units.

In addition to a need for a more careful articulation of goals and objectives for ESS units and the subsequent evaluation instruments, there is a need for planning of inquiry activities. Victor (1974) outlines this need in the following statement:

> Learning by inquiry is centered around a series of problem-solving investigations that actively involve the children. This calls for careful planning on the part of the teacher. The teacher must plan problem situations that will initiate pupil curiosity, interest and questions.[14]

Planning for inquiry should also take into consideration the need for supplies and materials for the activities. It may be necessary to outline these needs carefully because of the problem of funding. Welch (1981) indicates, in a compilation of various surveys comparing the "desired" and "actual" status of inquiry in science classes. He reports that the desired state is for student

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[13]William Aho et al., The McGraw-Hill Evaluation Program for ESS (New York: McGraw-Hill Book Co., 1974).

[14]Edward Victor, "The Inquiry Approach to Teaching and Learning: A Primer for Teachers," Science and Children, XII (October, 1974), 23.

[15]Wayne W. Welch et al., "The Role of Inquiry in Science Education: Analysis and Recommendations," Science Education, LXV (January-March, 1981), 33-50.

exposure to process/inquiry activities in all science courses. Contrary to this expectation, Welch finds that the actual status in the elementary schools includes the following problems limiting inquiry instruction: low priority to science by superintendents, therefore low financing; and process and inquiry exist in the elementary schools but many teachers cannot teach science or do not try.[16]

Beam and Horvat (1975) identify an additional variable for consideration relative to the curriculum implementation process.[17] They outline the nature of this variable, which is concerned with the teacher's viewpoint in the following statement:

> In the new science curricula, classroom teachers should implement learning activities in a fashion consistent with the project's philosophy. But the implementing process may be short-circuited if teachers are unaware their classroom behaviors significantly differ from their own ideal behavior.[18]

Tyler (1968) is also supportive of research which includes teacher perceptions of their teaching behavior as noted in the following statement:

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[16]Welch et al., p. 48.

[17]Kathryn J. Beam and Robert E. Horvat, "Differences, Among Teachers' and Students' Perceptions of Science Classroom Behaviors, and Actual Behaviors," Science Education, LIX (July-September, 1975), 333.

[18]Beam and Horvat, p. 333.

> Investigations are needed of the conceptions teachers actually have of the objectives they are trying to attain in connection with particular units, what behavior they are trying to get students to carry on, how they try to stimulate and guide the behavior, and how successes are rewarded.[19]

In summary, there is a need for student evaluation instruments for "new science programs" including the ESS program. In addition there is a need to delineate goals and objectives for ESS units so that the focus of evaluation can be outlined. Researchers have determined that deficiencies in the ESS program involve process, content and conceptual aspects of the curriculum. There is also a need to apply inquiry plans in the revision of ESS science units which will provide a means to achieve the goals and objectives for the units and which take into consideration the viewpoints of teachers and students. This process should also assist teachers in their planning and in delimiting unit material requirements.

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[19]Ralph W. Tyler, "Resources, Models and Theory in the Improvement of Research in Science Education," Journal of Research in Science Teaching, V (1967-68), pp. 43-51.

Purpose

The major purposes of this study include: (1) the selection of an existing inquiry model through which a "script" providing structure to science units can be developed; (2) determination of the goals and objectives for a single ESS unit thereby establishing intended learning outcomes and material requirements for the unit; (3) the application of the revised unit in an instructional setting to evaluate student and teacher perceptions, behaviors, student achievement and student-teacher interaction.

It is expected that the revision process will suggest a model for revising other science and mathematics units. Furthermore, it is expected that the model will be of particular benefit to curriculum planners, local school districts, and classroom teachers who desire to foster the development of inquiry science programs in the elementary school.

Procedurally, this study will seek to achieve these goals. First, identify, through a review of the literature, common elements of inquiry science teaching methods which can be utilized in modifying ESS unit; second, demonstrate that the inquiry model is a useful means to represent the goals and objectives of an ESS science unit in an instructional setting; third, analyze teaching and learning variables which can be utilized in a unit revision plan.

Statement of Research Questions

The primary purpose of this study is to revise an Elementary Science Study Unit utilizing an existing inquiry plan, apply the revised unit in an instructional setting, and analyze student and teacher variables in that setting. It is expected that the unit modification process will suggest a model for revising other math and science units.

A major concern in any such research is the establishment of reliability and validity of instrumentation. Instrumentation should render consistent results and measure that which it purports to measure.

General research questions such as the following should be answered:

1. What effects will the application of a modified ESS unit (inquiry script) have on student's active participation in science lessons?

2. What will be the effect of this unit-modification on the amount of time students spend in laboratory activities?

3. What will be the effect of this unit-modification on the nature and frequency of teacher questioning?

4. What is the relationship between teachers' observed talk and their perceptions of teacher talk during use of the scripted materials?

5. What is the relationship between students' observed activity levels and their perceptions of activity levels during use of the scripted materials?

6. Have students demonstrated achievement of the goals and objectives of the modified ESS unit?

7. Is the student achievement test reliable and valid?

8. What deviations from the script were observed and what are the implications of these deviations to the script?

9. Using a classification of questions, how frequently are the various kinds of questions asked?

10. What information from end of the unit evaluations, teacher logs, and interviews with teachers indicates need for further revision of the unit?

Definition of Terms

The terms employed in this chapter and elsewhere in this study can be defined in a variety of ways. The following definitions have been selected for use in this study.

Activity

A lesson focusing on a particular science or math concept, skill and/or rule, characterized by launch, exploration, and summary phases. The activities of the

unit require children to engage in the manipulation of materials.[20]

ACI Observations

The set of observations utilizing the interaction analysis instrument Activity Categories Index (ACI). The observations conducted in the classrooms of all teachers participating in the study and focusing on student activity, laboratory time and teacher questioning aspects of science activities.[21]

Activity Ratio

A measure of the relative amount of time spent teaching with indirect activities. The amount of time students are actively involved in their learning. The activity ratio is derived from data collected using the ACI.[22] (see Appendix C).

$$\text{Activity Ratio} = \frac{\text{No. of intervals assigned to categories } 1,2,3,4,5, \text{ \& } 6}{\text{No. of intervals assigned to categories } 8,9, \text{ \& } 10}$$

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[20]William M. Fitzgerald and Janet Shroyer, "A Study of the Learning and Teaching of Growth Relationships in the Sixth Grade," (unpublished research study, Department of Mathematics, Michigan State University, 1979), pp. 3-4.

[21]Harrie E. Caldwell, "Activity Categories: A Model for Planning and Evaluating Science Lessons," School Science and Math, LXXXI (January, 1971), 55.

[22]Harrie E. Caldwell, Evaluation of In-Service Science Methods Course by Systematic Observation of Classroom Activities, Educational Resources Information Center, ERIC Document ED 024 615, September, 1967, pp. 10-12.

Challenge

Problem focus of a science or math activity intended to motivate and orient the problem-solver (child). The challenges are associated with each activity of the script.[23]

Deviation

Teachers were asked to record their digressions from the script on teacher logs. Deviations in the study are represented by observed or reported departures from the plans or content of the script.

ESS Unit

Refers to the "Peas & Particles" unit which was modified for use in this study and is one of the 56 science units produced by the Educational Development Center as part of the Elementary Science Study Program.

Exploration Phase

The time period in each activity when the students in small groups or individually pursue the problem solution through manipulation of materials. During this phase the teacher moves about the room maintaining on-task behavior by assisting, correcting, prodding and offering extra challenges to those students who are ready and interested to further their understanding and knowledge.[24]

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[23]Fitzgerald and Shroyer, p. 5.

[24]Fitzgerald and Shroyer, p. 7.

Laboratory Ratio

This represents the amount of time spent with laboratory activities in an elementary science class. The laboratory ratio is derived from data collected using the ACI.[25] (see Appendix C).

$$\text{Laboratory Ratio} = \frac{\text{No. of intervals assigned to categories 1 \& 2}}{\text{No. of intervals assigned to all ten categories}}$$

Launching Phase

The time period in each activity when the whole class meets and the teacher introduces the activity. This time is used to clarify new concepts and review old ones, to ensure that the task, information and directions are understood, and to issue the major challenge.[26]

Observation-Interview

The set of observations focusing on deviations from the script and teacher questioning categories and frequency during each of the three activity phases. These observations were video-taped, included three teachers, and covered the entire modified science unit.

Observer-Training

This pertains to training in the use of the ACI observation instrument. Five math-science consultants were

---

[25]Caldwell, pp. 10-12.

[26]Fitzgerald and Shroyer, p. 7.

trained in the use of the ACI prior to the study. (see Appendix C).

Questioning Ratio

A measure of the amount of time teachers spend asking questions with respect to the total amount of time they spend talking. The questioning ratio is derived from data collected using the ACI.[27] (see Appendix C).

$$\text{Questioning Ratio} = \frac{\text{No. of intervals assigned to category } 7}{\text{No. of intervals assigned to category } 7 \text{ \& } 10}$$

Script (Inquiry Script)

A written plan outlining specific activities for teaching a set of related rules and concepts in a science or mathematics unit. Fitzgerald and Shroyer (1979) refer to the script as a "flexible instructional network of activities. A trip-plan--a marked map with comments from someone familiar with the route."[28]

Story Problems

Six "real world" problems were included with activities in the script. The story problems represent pupil cues to specific counting methods and are related to activity challenges. (see Appendix A).

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[27]Caldwell, pp. 10-12.

[28]Janet Shroyer, "The Mouse and the Elephant: an Application Unit," The Oregon Mathematics Teacher, (February, 1979) 10.

Student Perceptions

Student ideas concerning their level of involvement in science lessons and their preference for school subjects. A student perception form was used to collect this information.[29] (see Appendix D).

Summary Phase

The time period in each activity when the teacher and the whole class meet to summarize and evaluate data. Patterns are established and rules are discussed and verified with further example.[30]

Task-Interview

Interviews with selected students prior to and subsequent to exposure to the scripted unit. The purpose of the interviews is to evaluate student knowledge of counting methods presented in the unit.

Teacher Log

The daily record of activities recorded by the classroom teachers during use of the script. Teachers were asked to record the length of each activity phase, note their deviations from the script and student discoveries, and rate student enthusiasm and interest.

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[29]Robert M. Baker, "A Study of the Effects of A Selected Set of Science Teaching Materials (Elementary Science Study) on Classroom Instructional Behaviors," (unpublished Doctoral Dissertation, University of Rochester, 1970).

[30]Fitzgerald and Shroyer, p. 7.

Teacher Perceptions

Teacher views concerning the level of student involvement in science lessons and their awareness of student subject preference. A teacher perception form was used to collect this information. (see Appendix E).

Teacher Training

Two workshop meetings conducted with twelve teachers introducing them to both the scripted unit (Peas & Particles) and the process of unit modification. (see Appendix A).

Unit Achievement Test

The 36 item multiple-choice instrument constructed to evaluate student achievement. A table of specification grid establishes the validity of the test items relative to unit goals and objectives. (see Appendix H).

Assumptions and Limitations

It was assumed that the student behaviors described and analyzed in the study are representative of their usual behavior during science instruction and that science lessons conducted by teachers before use of the script are representative of their usual science teaching. In addition, it was assumed that a review of the relevant elementary science literature would reveal common elements of inquiry teaching situation at that level. While inquiry dimensions were manifest in the literature, they certainly do not exhaust all possibilities. Sources unknown to or

not utilized by the author might yield additional and valid inquiry models.

The study is limited to one school district in New York State. The teachers in this study have been randomly selected from the population of fourth grade teachers in one suburban school district; therefore, the sample is not representative of all fourth grade teachers. However, the random selection of fourth grade teachers may allow generalizations to fourth grade teachers using similar materials in equivalent school settings.

The student population employed in this study represent intact classrooms or units. They are not drawn randomly. The method used in assigning students to classrooms in the school district in which the study was conducted was, essentially, random. It is, therefore, assumed that the "typical" classroom students in the study were heterogeneous in terms of demographic variables, school achievement, intelligence, and similar to the general community in which they lived. The nonrandom selection process mitigates the generalization of findings.

This study will examine only the behavior of teachers and students using Elementary Science Study materials during science instruction. The outcomes should not be compared to science instruction utilizing different materials. The interpretation of results should be extended beyond elementary science instructional settings.

Since the study proposes to examine only verbal

behavior of teachers and students, and the activity and laboratory levels of fourth grade classroom settings during science instruction, findings cannot be equated to non-verbal behaviors observed during science instruction.

Plan of the Study

The design and results of this study are reported in five chapters. Chapter I includes a statement of the problem, a statement of research questions, and the assumptions and limitations emanating from the research design. Contained in Chapter II is a review of selected aspects of elementary science inquiry research and research relevant to the Elementary Science Study curriculum. The chapter includes a review of observational instruments used in elementary science instructional settings. Included in Chapter III is a detailed discussion of unit development, student test development and variables used in the study. In addition, the hypotheses of the study are examined, the research population described, and analysis procedures indicated. Presented in Chapter IV is a detailed analysis and discussion of the data. Included in Chapter V are the summary, conclusions, implications, and recommendations for further research.

CHAPTER II

REVIEW OF RELATED LITERATURE

The literature reviewed in this chapter is divided into three major sections. The first concerns inquiry as it relates to elementary science. Emphasis is placed in determining those characteristics of inquiry models which are well suited to modifying Elementary Science Study (ESS) units. The second section deals with the nature and findings of research which employs ESS curriculum materials as the primary science instructional content system. Section three reviews the research studies in elementary science which apply interaction analysis instruments to determine the level of student involvement in their own learning.

Inquiry

The literature concerning inquiry in elementary science is separated into four areas: (1) historical background and related inquiry terminology in elementary science; (2) characteristics of the inquiry setting; (3) studies dealing with student attitudes and involvement; and (4) studies describing several plans for inquiry. Included is a discussion of their relevance to the development of materials for teachers and students in the present study.

Historical Background

Historically, science inquiry at the elementary level can be traced to the beginning of the twentieth century. A major work of this time, which describes inquiry through the construction of a model or thought, was John Dewey's, How We Think.

At the base of Dewey's model are "chains of reflective thought," which consist of a series of consecutively ordered ideas. Dewey maintains that each idea determines the outcome of the next while each outcome leans back on its predecessors for support, building logically toward resolution of a problem.[1] Dewey maintains that phases of reflective thinking exist which include:

1. State of doubt, hesitation, perplexity, mental difficulty in which thinking originates.
2. An act of searching, hunting, inquiring to find material to resolve the doubt, settle and dispose of the perplexity.[2]

In a further analysis of reflective thinking Dewey outlines an interdependent network of inquiry phases which serve to resolve this perplexity. He states:

> 1. Suggestions, in which the mind leaps forward to a possible solution; 2. an intellectualization of the difficulty or perplexity that has been felt (directly experienced) into a problem to be solved, a question for which the answer must be sought; 3. the use of one suggestion after another as a leading idea, or hypothesis, to

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[1]John Dewey, How We Think (Boston: D. C. Heath & Co., 1910), p. 4.

[2]Dewey, p. 12.

> initiate and guide observation and other operations in collection of factual material; 4. the mental elaboration of the idea or supposition (reasoning, in the sense in which reasoning is a part, not the whole, of inference); 5. testing the hypothesis by overt or imaginative action.[3]

The influence of Dewey's problem solving methodologies is noted by Herbert Smith (1963) who states:

> Dewey's contributions were numerous, but, perhaps the most significant for the developing field of elementary science was his contention that the methodology of science is at least of equal--or perhaps of greater--significance than the knowledge accumulated. The present emphasis on "science as inquiry" would seem to be a reaffirmation of a position Dewey took nearly half a century ago.[4]

In 1932 the National Society for the Study of Education devoted its thirty-first yearbook to the problems of science education emphasizing concern for inquiry in elementary science education:

> The schools will prepare children for their responsibilities by providing experiences with a body of subject matter 1. that has been tested for truthfulness, 2. that exercises the methods that have been used in solving problems, and 3. that furnishes practice in the use of these methods..."[5]

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[3]Dewey, p. 107.

[4]Herbert A. Smith, "Historical Background of Elementary Science," Readings in Science Education for the Elementary School, ed. Edward Victor and Marjorie S. Lerner (3d. ed.; New York: MacMillan, 1975), pp. 6-7.

[5]Guy Montrose Whipple, ed., "What are some of the contributions of Science to Liberal Education," A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, (Chicago: University of Chicago Press, 1932), p. 40.

Reference to inquiry was equally evident in a similar volume published by the National Society for the Study of Education in 1947, as indicated in the following statement. "...ample provision should be made for the utilization of the elements of the scientific method in the solution of problems."[6]

More recently, the fifty-ninth yearbook, prepared by the National Society for the Study of Education, in 1960 is devoted to science education. The report, emphasizing "process or inquiry" rather than the accumulation of factual knowledge, is indicative of the change that was occurring in elementary science.[7] The report states:

> One function of the elementary school has always been to help children learn a part of what they need to know from the world's storehouse of knowledge. In recent years this function has embraced more and more science. Scientific methods of investigation, by which knowledge may be acquired and tested, are now very much a part of our culture. The elementary school should help children become acquainted with these methods.[8]

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[6]Nelson B. Henry, ed., "Materials and Methods of Teaching Science in the Elementary School, Science Education in American Schools, Forty-Sixth Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1947), p. 105.

[7]Nelson B. Henry, ed., "Developing Science Programs in the Elementary School," Rethinking Science Education, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I (Chicago: University of Chicago Press, 1960), pp. 112-113.

[8]Henry, pp. 112-113.

The new emphasis on the inquiry process occurred when teams of scientists and educators began altering the course of elementary science curriculum.[9]

In a statement about "science as inquiry," William Kessen (1963) writes: "Science is more than a body of facts, a collection of principles, and a set of machines for measurement; it is a structured and directed way of asking and answering questions."[10]

The result of these efforts is demonstrated by science materials produced during the decade of the 1960's. Paul DeH. Hurd (1964) refers to some of the major science curriculum studies in the following statement:

> At the elementary level, curriculum studies developed by the American Association for the Advancement of Science, the Educational Services Incorporated, the University of California, the University of Illinois, the Maine Math Science Project, the School Mathematics Study Group, and the United States Office of Education have offered new insights into science teaching.[11]

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[9]American Association for the Advancement of Science, Commentary for Teachers: Science-A Process Approach, (Xerox Corp., 1963), p. 2.

[10]William Kessen, "Statement of Purposes and Objectives of Science Education in Schools, "Commentary for Teachers: Science A Process Approach, American Association for the Advancement of Science (Xerox Corp., 1963), p. 2.

[11]Paul DeH. Hurd, "Toward a Theory of Science Education Consistent with Modern Science, "Readings in Science Education for the Elementary School, Ed. Edward Victor and Marjorie S. Lerner (3rd ed.; New York: MacMillan, 1975), p. 21.

Brehm (1968) suggests that among the reasons for these new programs are the influence of high school revisions, the explosion of knowledge, new advances in learning theory, the involvement of elementary educators in a "grass-roots" process of curriculum development, the need to keep in touch with emerging knowledge, and the encouragement from scientists for curricular change.[12]

Brehm notes that one of the common elements shared by all of these programs:

> A similarity between these experimental programs is the change in emphasis from science as a content subject to science as a "skill" subject as well. The skill in this case has been variously labeled critical thinking, problem-solving, discovery approach, or even creative thinking in science.[13]

Inquiry Terminology

The words problem-solving, discovery, guided discovery, and inquiry are important terms in the language of elementary science education. An inspection of the literature indicates that they are often used interchangeably in elementary science education. Researchers have analyzed meaning and application of these terms and certain distinctions can be made. For example, Kornbau (1977) in an analysis of the words "discovery" and "inquiry" concludes

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[12]Shirley A. Brehm, "The Impact of Experimental Programs on Elementary School Science, "Reading in Science for the Elementary School, ed. Edward Victor and Marjorie S. Lerner (3d ed.; New York: MacMillan, 1975), pp. 181-185.

[13]Brehm, p. 186.

the following: "discovery is differentiated from traditional teaching in placing emphasis on the student as an active agent."[14] He continues, "the process evolves into a state of self learning."[15] In contrast Kornbau asserts:

> Inquiry implies the asking of questions. One form is exemplified by the teacher asking all the questions, as typified in the Socratic method. Another form casts the student in the role of principal interrogator.[16]

Suchman (1977) indicates that goal setting represents a major difference between problem-solving and inquiry. In problem-solving the goal is set by an outside agent such as the teacher, whereas in inquiry the learner sets his own goals.[17]

Robert Glaser (1966) in discussing variables of discovery learning states that, "...learning by discovery is defined usually as teaching an association, concept or rule which involves 'discovery' of the association, concept or rule."[18]

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[14]Charles Harrison Kornbau, "The Practical Implications of an Informal Conceptual Analysis of the Words Inquiry and Discovery as Used in Contemporary Science Education," Dissertation Abstracts International, XXXVII (1977), 7662A (Temple University).

[15]Ibid. [16]Ibid.

[17]J. Richard Suchman, "Heuristic Learning and Science Education," Journal of Research in Science Teaching, XIV (May, 1977), 263-272.

[18]Robert Glaser, "Variables of Discovery Learning," Learning by Discovery: A Critical Appraisal, ed. Lee S. Shulman and Evan Keislar (Chicago: Rand McNally, 1966), pp. 15-26.

Jerome Bruner (1961) asserts that "Discovery... is in its essence a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so reassembled to additional new insights.[19] Gagne (1974) draws a distinction between discovery and inquiry in the following statement:

> Discovery appears to be a very fundamental principle of good instruction. It applies to all conceptual learning, the learning of principles and generalizations, and may even apply to the learning of a simpler sort such as the memorization of names or facts. But discovery, as a very fundamental condition of most learning, should not be equated with enquiry, which is the exercise of all the various activities making up what we have identified as the terminal capability.[20]

Gagne refers to the "terminal thinking process" as inquiry with "discovery" representing one of the possible instructional conditions utilized by the learner to attain this goal.[21]

Robert Gagne (1974) discusses discovery learning in the context of learning a rule. He outlines that when students are provided with several practical examples, each of which fits a particular rule, that a fair proportion of

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[19]Jerome S. Bruner, "The Act of Discovery," Readings in Science Education for the Elementary School, ed. Edward Victor and Marjorie S. Lerner (3d ed.; New York: MacMillan, 1975), p. 79.

[20]Robert M. Gagne, "The Learning Requirements for Enquiry," Readings in Science Education for the Elementary School, ed. Edward Victor and Marjorie S. Lerner (3d ed.; New York: MacMillan, 1975), p. 96.

[21]Gagne, p. 97.

students would not recognize the rule being emphasized.[22] To correct this, Gagne offers alternatives which include more guidance toward discovery. They include the following:

> The teacher might proceed with the event by communicating the rule and have students provide examples. She might organize small homogeneous groups, thus facilitating guidance. Students might attain objectives by spending more time recalling prerequisite skills and perhaps by receiving more detailed learning guidance, such as more hints or fuller prompts.[23]

Welch (1981), in a study of "the role of inquiry in science education,"[24] defines inquiry in the following passage:

> We consider inquiry to be a general process by which human beings seek information or understanding. Broadly conceived, inquiry is a way of thought. Scientific inquiry, a subset of general inquiry, is concerned with the natural world and is guided by certain beliefs and assumptions.[25]

Characteristics of the Inquiry Setting

One aspect of the inquiry setting is the amount of teacher guidance evident. Hawkins (1970) indicates that, while a plan for inquiry is necessary, children's discoveries need not be limited to a pre-set agenda. He refers to this as a "multiply programmed" learning situation, in which

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[22]Robert M. Gagne, Essentials of Learning for Instruction, Principles of Educational Psychology Series, ed. William and Carol Rohwer (Hinsdale, Illinois: The Dryden Press, 1974), p. 126.

[23]Gagne, p. 127.

[24]Wayne W. Welch, et al., "The Role of Inquiry in Science Education: Analysis and Recommendations," Science Education, LXV (January-March, 1981), 33-50.

[25]Welch, et al., p. 33.

materials are available which the student will recognize as helping him along in evolving his own way of approaching a subject.[26]

In contrast to Hawkins, Gagne, a proponent of guided discovery, states that "discovery without guidance makes the learning of concepts a terribly slow process."[27] Gagne describes situations where guidance may be minimized or non-existent. In Essentials of Learning for Instruction, he gives the following example:

> When working with a group of bright students applying newly learned arithmetic rules of verbally stated examples, the teacher may find it desirable to provide a minimal amount of guidance, or none at all, and thus emphasize "discovery learning."[28]

Similar to Gagne, Ausubel (1963) emphasizes time as an element of guidance in stating that:

> Autonomous discovery enhances intuitive understanding, but as a primary method of transmitting subject matter content, this approach is much too time consuming and inefficient simply on a time-cost basis.[29]

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[26]David Hawkins, "Messing About in Science," The ESS Reader, Educational Development Center (Newton, Ma.: Educational Development Center, Inc., 1970), pp. 37-44.

[27]Robert M. Gagne, "Varieties of Learning and the Concept of Discovery," Learning by Discovery: A Critical Appraisal, ed. Lee S. Shulman and Evan Keislar (Chicago: Rand McNally, 1966), pp. 135-150.

[28]Robert M. Gagne, Essentials of Learning for Instruction, Principles of Educational Psychology Series, ed. William and Carol Rohwer (Hinsdale, Illinois: The Dryden Press, 1974), p. 113.

[29]David P. Ausubel, "Some Psychological Considerations in the Objectives and Design of an Elementary Science Program," Science Education, XLVII, (April, 1973), 278-284.

In all forms of inquiry there exists a time for guidance, a time for structure. Hawkins refers to the value of summarizing and extending ideas through teacher-student dialogue in, "...the full colloquium of children and teacher,"[30] and the need for guiding questions during the "multiply programmed" phase of the learning environment.[31]

A second characteristic of the inquiry learning situation concerns the student's ability to recognize a problem. Hudgins (1966) states that identification of a problem is prerequisite to its solution.[32] According to Hudgins the teacher must assist students in recognizing that previously learned behavior may be useful toward solution of new problems, that the demands of a problem suggest the general dimensions of a solution, and the required properties for solution are available.[33]

Huff (1977) contends that educators' misconceptions or neglect for the role of the problem is one of the serious errors of inquiry instruction. The result of this is incomplete inquiry teaching.[34]

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[30]Hawkins, pp. 37-44. [31]Ibid.

[32]Bryce B. Hudgins, Problem Solving in the Classroom, The Psychological Foundations of Education Series (New York: MacMillan, 1966), p. 2.

[33]Hudgins, pp. 2-3.

[34]James W. Huff, "The Concept of a Problem in Inquiry Teaching," Dissertation Abstracts International, XXXVIII (1978), 2641 (University of California, Los Angeles, 1978).

Freundlich (1978) outlines several factors which assist the student in the recognition of a problem. He encourages educators to present problems in a context students are familiar with and which utilize conceptual schemes already possessed by the learner. Freundlich asserts, "A clearly formulated problem itself directs us to 'reasonable' methods for its solution."[35]

Several studies focus on the questioning patterns of both teacher and students as a factor in inquiry settings beside finding out what pupils know. Arthur Carin (1970) lists the following as additional purposes for teachers' questions:

1. to arouse interest or motivate children.
2. to evaluate a pupil's preparation or to see if previous work has been mastered.
3. to review or summarize what has been taught.
4. to develop insights by helping children see new relationships.
5. to stimulate critical thinking and development of questioning attitude.
6. to stimulate pupils to seek out additional knowledge on their own.[36]

Carin, in outlining strategies for improving teachers questions, adds that part of the lesson should be devoted to divergent and/or convergent questions. Divergent questioning should be utilized to broaden the line of exploration

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[35]Yehudah Freundlich, "The Problem in Inquiry," The Science Teacher, XLV, (February, 1978), 19-22.

[36]Arthur Carin, "Techniques for Developing Discovery Questioning Skills," Science and Children, VII, (April, 1970), 13-15.

and may be thought of as productive questions. Convergent questioning should be utilized in focusing on the answer to a specific problem and may be thought of as questions leading toward closure.[37]

Studies dealing with teacher questioning are usually concerned with teachers' use of higher cognitive questions. Redfield and Rousseau (1981) use the following definition to discern questioning type:

> Higher cognitive or divergent questions are those requiring that the student mentally manipulate bits of information previously learned to create or support an answer with logically reasoned evidence. Operations presumed to underlie responses to higher cognitive questions most closely correspond to application analysis, synthesis, and evaluation in Bloom's taxonomy. Lower cognitive or convergent questions are defined as those calling for verbatim recall or recognition of factual information previously read or presented by a teacher. Those questions correspond most closely to the levels of knowledge and comprehension in Bloom's taxonomy.[38]

Researchers, utilizing observation techniques, have established questioning categories other than those developed by Bloom. Bassett (1971) employs the following question types in a study dealing with the oral questioning

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[37]Carin, pp. 13-15.

[38]Doris L. Redfield and Elaine W. Rousseau, "A Meta-Analysis of Experimental Research on Teacher Questioning Behavior," Review of Educational Research, ed. Laurence Iannaccone and James W. Pellegrino, LI (Washington, D.C.: American Educational Research Association, 1981), pp. 237-245.

process in elementary science classrooms: 1. Neutral, 2. Rhetorical, 3. Factual, 4. Clarifying, 5. Associative, 6. Critical Thinking, and 7. Value.[39]

Johnson (1969) develops a model providing feedback for teachers to analyze their questioning levels. Johnson concludes:

> That certain lesson formats, particularly student investigations, were more instrumental in setting the conditions for teachers to ask questions above the level of pupil recall.
>
> Patterning and purposeful sequencing of questions were germane to the development of effective questioning strategies.[40]

Kondo (1968) uses five question types including routine, cognitive-memory, convergent, evaluative, and divergent to analyze the questioning behavior of teachers in discovery vs. invention lessons in elementary science.[41]

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[39]Jimmy F. Bassett, "An Analysis of the Oral Questioning Process and Certain Causal Relationships in the Elementary School Science Classroom," Dissertation Abstracts International, XXXII (1972), 5080A (East Texas State University, 1971).

[40]Robert Walter Johnson, "A Model for Improving Inservice Teacher Questioning Behavior in Elementary School Science Instruction," Dissertation Abstracts International, (1970), 1666A (Wayne State University, 1969).

[41]Allan Kiichi Kondo, "A Study of the Questioning Behavior of Teachers in the Science Curriculum Improvement Study Teaching the Unit Material Objects," Dissertation Abstracts International, XXIX (1969), 2040A (Columbia University, 1968).

Kondo maintains that, "the way the lesson is approached has a greater influence on the type of questions asked than the type of lesson per se." He suggests that when the teacher is demonstrating or conducting a hands-on investigation along with the children that, "the percentages of routine questions are relatively low and the percentages of cognitive-memory questions are relatively high.[42]

Hypothesis formation is another important characteristic of inquiry. Quinn and George (1975) suggest that, "contemporary models for the teaching of science place the formation of hypothesis high among the skills necessary for problem solving."[43]

Rachelson (1977), views the term hypothesis as, "...an imaginative preconception of what might be true in the form of a declaration with verifiable deductive consequences."[44] He suggests that "a complete model of scientific inquiry must include descriptions of both hypothesis generation and testing."[45] Rachelson identifies five

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[42]Kondo, p. 2040A.

[43]Mary Ellen Quinn and Kenneth D. George, "Teaching Hypothesis Formation," Science Education, LIX (July-September, 1975), 289-296.

[44]Stan Rachelson, "A Question of Balance: A Wholistic View of Scientific Inquiry," Science Education, LXI, (January-March, 1977), 109-117. see also P. B. Medawar, Induction and Intuition in Scientific Thought, (Philadelphia: American Philosophical Society, 1968).

[45]Rachelson, p. 109.

elements of hypothesis generation:

1. The hypothesis generation component arises from a problematic situation and after fruitless analysis of the problem.

2. Hypothesis generation proceeds via a voluntary abstention from conscious thought on the problem.

3. Hypothesis generation is a diffuse, nonlinear and imaginary process which is not guided by explicit methodological rules.

4. Hypotheses are generated in a variety of formats and are not restricted by the element of time.

5. Hypothesis generation is synthetic, wholistic information processing strategy.[46]

Atlin (1958) in a study concerning the formulation and testing of hypotheses among elementary school pupils and concludes that children are capable of employing a variety of sources when hypothesizing, such as authority, observation, and "original" guess.[47] These sources can be utilized by encouraging children to evaluate them, select the best, and improve their problem solving capabilities.[48]

Student Attitude and Involvement

Additional aspects of the inquiry setting noted by many researchers as crucial to the elementary school science

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[46]Rachelson, p. 115.

[47]J. Myron Atkin, "A Study of Formulating and Suggesting Tests for Hypotheses in Elementary School Science Learning Experiences," Science Education, XLII (December, 1958), 414-424.

[48]Atkin, p. 424.

classroom include commitment, cooperation, and attitude.

Viewing the learner both as initiator of questions and lines of inquiry may be important factors if successful problem solving is to occur. Nash (1966) states, "...the most active role in education is not the teacher's but the student's."[49] The role of the teacher as leader is to evoke commitment by guiding students' endeavors, through example and demonstration. Most importantly the teacher assists students in seeing that the problems are not only soluble but worth solving.[50]

Tjosvold and Santamaria (1978) extend the theme of cooperation into the areas of commitment and decision-making in an inquiry situation. In their study, a cooperative learning structure is reinforced for students by informing them that:

(A) Their goal was to learn together.

(B) They were to share and help each other learn the material.

(C) They should discuss and list their ideas together.

(D) They would take a group test in which each person would contribute to the answers.[51]

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[49]Leonard K. Nash, "Teachers Don't Teach," Harvard Alumni Bulletin, (September 30, 1966), 22-23.

[50]Nash, p. 23.

[51]Dean Tjosvold and Philip Santamaria, "Effects of Cooperation and Teacher Support on Student Attitudes Toward Decision Making in the Elementary Science Classroom," Journal of Research in Science Teaching, XV (May, 1978), 381-385.

The goal set for the students in the competitive group, in the Tjosvold-Santamaria study, includes learning the material better than the others in their group, working independently, not sharing ideas, and taking a test to see who learned the most.[52] Students in the cooperative group are also encouraged to make their own decisions and are told that they are capable of making good decisions. The results of the study indicate that teachers can facilitate confidence and commitment to decision making by directly supporting student competence and that they can increase children's positive expectations about decision-making by creating cooperative learning environments.[53]

In another study, dealing with the subject of cooperation, Johnson (1976) finds that students working in a laboratory-inquiry format perceive themselves in a cooperative venture with other students.[54] In this study, Johnson compared three groups all using "newer" science materials. The instructional modes of the three groups included "traditional" or textbook only, text and laboratory, and laboratory inquiry. Johnson also notes that students in all three groups show a preference for cooperation, with

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[52]Tjosvold and Santamaria, p. 382.

[53]Tjosvold and Stnatmaria, p. 384.

[54]Roger T. Johnson, "The Relationship Between Cooperation and Inquiry in Science Classrooms," Journal of Research in Science Teaching, XIII (January, 1976), 55-63.

those in the lab-inquiry group indicating significantly greater enjoyment of their learning situation.[55] The effect of cooperation is highlighted in the following statement by Johnson: Examination of research on the effects of classroom goal structures indicates that cooperation results in higher achievement than competition in studies involving some type of problem-solving activity.[56]

Current inquiry science programs express a need for and the expectation of the development of favorable attitudes toward science.[57]

Johnson, Ryan and Schroeder (1974) compare the effects of three different teaching situations on the attitudes of sixth grade students toward science. The three treatments are (a) textbook only, (b) textbook and supporting laboratory activities, and (c) activity centered open-ended inquiry.[58]

Their results support the activity centered open-ended inquiry situation as having the most positive effects on student attitude. They also suggest that there is no significant loss of attitude when textbook reading is mixed with laboratory activity. An additional finding is that the activity group students exhibit more divergent thinking

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[55]Johnson, p. 62.

[56]Johnson, p. 56.

[57]Roger T. Johnson, Frank L. Ryan and Helen Schroeder, "Inquiry and the Development of Positive Attitudes," Science Education, LVIII (January-March, 1974), 51-56.

[58]Johnson, Ryan, and Schroeder, p. 52.

in their experimenting and comments.[59]

Inquiry Plans

Richard Suchman's Inquiry Development Program represents an oral inquiry plan. Suchman's plan relies on visual or demonstrated discrepant events. These events are used to motivate students by upsetting their concept of how things should be. This is intended to stimulate their curiosity enough to follow a line of verbal inquiry toward resolution of the discrepancy. The teacher's role is to guide questioning and assist students by pointing out important aspects in lines of inquiry.[60] Suchman states, "...our purpose in Inquiry training has been to help children develop a set of skills and broad schema for the investigation of causal relationships.[61]

Mark and Salstrom (1972) used the Suchman plan in a comparison study with a gameboard technique stressing individual inquiry. In the gameboard method each child is told to select cards from a board which includes groups of randomly arranged hypothesis-questions. Yes or no responses are recorded on the back of each card and

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[59]Johnson, Ryan, and Schroeder, p. 52.

[60]J. Richard Suchman, The Elementary School Training Program in Scientific Inquiry, (Champaign-Urbana, Illinois: 1962), pp. 1-25.

[61]Suchman, p. 125.

serve as clues to the direction of questioning.[62] The results of the study provide evidence that students may require more guidance than can be provided through a Suchman type oral inquiry session. The findings also provide tentative support for the possibility of improving individual student conceptualization. Children may select their own route toward learning a concept through the additional cues provided by a set of written questions.[63]

Drawbacks of a verbal-inquiry model are outlined by Ivany (1969). Ivany suggests that verbal-inquiry models suffer from the lack of a hands-on experience. He cites studies indicating "that from one-quarter to one-third of elementary students are prone to be dependent on kinesthetic rather than visual experiences for interpreting the environment."[64] The major weakness, then, is relying too heavily on abstracting from a concrete situation by presenting only visual stimulation to the children. Ivany concludes, "a visual problem provides for some students what may be an impossible task at this age, (10-13 years) the demand that he think abstractly about the phenomenon. Provided with a concrete situation which he can actively

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[62]S. J. Mark and Davis Salstrom, "Use of a Science Game to Aid Conceptualization During a Sixth-Grade Guided Discovery Lesson," Science Education, LVI (April-June, 1972), 155-161.

[63]Mark and Salstrom, p. 125.

[64]George Ivany, "The Assessment of Verbal Inquiry in Junior High School Science," Science Education, LIII, (October, 1969), 287-293.

manipulate allows him to participate in inquiry in a more meaningful manner."[65]

While there are apparent weaknesses in Suchman's plan, its merits as an oral questioning model include the following:

1. Concrete problems that are immediately intelligible to the learner.
2. Freedom to perform data-gathering operations. (By the inquirer)
3. A responsive environment. Data is available and may be used by the inquirer at any time.
4. Elimination of extrinsic rewards. The motivation for inquiry should be intrinsic in the search of itself.[66]

In another inquiry plan Atkin (1958) outlines a set of behaviors characteristic of many problem-solving situations. These include:

1. Sensing a problem and deciding to find an answer to it.
2. Defining the problem.
3. Studying the situation for all factors on the problem.
4. Making the best tentative hypothesis as to the solution to the problem.
5. Selecting the most likely hypothesis.
6. Testing the hypothesis.
7. Drawing a conclusion.

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[65]Ivany, p. 293.

[66] Suchman, p. 127.

8. Making inferences based on this conclusion when facing new situations in which the same factors are operating.[67]

Atkin stresses the flexibility of any plan which might including omitting steps from the list, omitting steps already present in the plan, or rearranging the order of these steps.[68]

Esler (1970) describes a set of procedures for structuring inquiry for the classroom including presenting a discrepant event, a problem-solving event, an anecdote (with demonstration) or an invitation to inquiry (without demonstration). This last recommendation may take the form of an anecdote, compilation of data, or pictorial stimulation.[69] The teaching techniques he suggests include teacher question-student answer, student question-teacher answer, or experimentation.[70] Similarly Armstrong and Heikkinen (1977) call for the use of open-ended problems as a means for initiating inquiry.[71]

Fitzgerald and Shroyer (1979) have identified

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[67]J. Myron Atkin, "A Study of Formulating and Suggesting Tests for Hypothesis in Elementary School Science Learning Experiences," Science Education, XLII (December, 1958), 414.

[68]Atkin, pp. 414-415.

[69]William K. Esler, "Structuring Inquiry for Classroom Use," School Science and Math, LXX (May, 1970), 454-458.

[70]Esler, p. 455.

[71]Terry Armstrong and Michael Heikkinen, "Initiating Inquiry Through Open-End Problems," Science and Children, XIV (March, 1977), 30-31.

three instructional phases for an inquiry plan used in a study concerning a sixth grade mathematics unit. The three phases include: launching, exploring, and summarizing.[72] The phases are described as follows:

> a. Launching. Using whole class instruction, the teacher introduces the activity by clarifying the necessary new concepts and reviewing the old ones, conducting a mini-challenge modeled after the major challenge to ensure that the task, information and directions are understood, and issuing the major challenge.
>
> b. Exploring. While the students are pursuing the solution to the challenge in small groups or individually, the teacher moves about the room maintaining on-task behavior by assisting, correcting, prodding and offering extra challenges to those students who are reading and interested to further their understanding and knowledge.
>
> c. Summarizing. Returning to whole class instruction, the teacher elicits and displays results in an organized fashion to encourage searching for patterns and relationships. Rules which are identified can be recorded in mathematical symbols and verified with further examples.[73]

SUMMARY

The review of the literature on inquiry suggests several generalizations regarding its role in elementary science education. Many of the concerns relevant to inquiry in elementary science over the past seventy years can

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[72]William M. Fitzgerald and Janet Shroyer, "A Study of the Learning and Teaching of Growth Relationships in the Sixth Grade," (unpublished research study, Department of Mathematics, Michigan State University, 1979).

[73]Fitzgerald and Shroyer, pp. 6-7.

be traced back to the writings of John Dewey. More recent changes were born during the mid-fifties when scientists and educators across the country began developing new curricula based on inquiry processes.

Inquiry has been identified in a variety of ways and its meaning is often interchanged or used with such terms as problem-solving, discovery and guided discovery. Broadly conceived, inquiry describes the process of seeking information and understanding. In the elementary science classroom setting inquiry implies the asking of questions by either the inquirer, the student, or the leader of inquiry, the teacher. Problem solving has been identified as inquiry with a pre-set goal established by the teacher. Discovery may represent an instructional condition emphasizing the student as an active agent of inquiry. Guided discovery is understood to include a greater amount of teacher control in the learning environment.

Characteristics of inquiry include a combination of instructional conditions and learning strategies.

Researchers have utilized various degrees of guidance to assist students in the inquiry setting. Many agree that some guidance is necessary if students are to solve problems within a reasonable time and with some success.

Another aspect of inquiry is the students' ability to recognize a problem. Means for assisting students with problem recognition include: presenting problems in a familiar context, looking for properties of the problem, and

making the student aware of the role of previously learned material.

The nature of questioning is the distinguishing characteristic of inquiry. Various organizational schemes have been suggested which facilitate the structuring of questions to reflect higher levels of cognitive understanding. These models have led researchers to tentative conclusions about improving questioning techniques. Recommendations include careful planning and sequencing of questions by the teacher. Hands-on or investigation type lessons also appear to be instrumental in setting the conditions for teachers to ask questions above the level of pupil recall.

Hypothesis formation is also considered to be an important skill necessary for successful problem-solving. A hypothesis may be defined as a preconception of what might be true in the form of a declaration which must be verified and tested.

Hypotheses may be generated in a variety of situations, not necessarily according to any pre-set rules and are considered to be elements of an information processing strategy. Apparently, children can improve their hypothesizing by analyzing their sources of hypotheses with some selectivity.

Laboratory-inquiry may be successful when groups of children work together cooperatively to solve problems. When decision-making, commitment, and cooperation are

encouraged by the teacher, students may have positive attitudes toward the learning situation.

The literature suggests that plans for inquiry share some common elements which include:

1. A challenge, discrepancy of focus-setting event to motivate students.
2. A period of exploration, hypothesis generation and testing.
3. A time for summarizing, concluding and making inferences about situations similar to those observed.

Elementary Science Study

The review of the literature related to Elementary Science Study is conducted for the purpose of determining whether previous studies would reveal recommendations concerning implementation, teacher training and evaluation of ESS curriculum materials and methods.

This section is separated into three areas: 1. Background information including historical information, and philosophical and psychological characteristics of the ESS program; 2. research dealing with teacher training, curriculum implementation, and evaluation; and research comparing Elementary Science Study to other science curriculums.

Background

In 1960 the Elementary Science Study (ESS), sponsored by the Educational Development Center, Inc., began to develop material for science from kindergarten through the eighth grade.[74]

Unlike other elementary science programs, the materials in ESS are "...not based on a specific theory of how children learn, or on the logical structure of science, or any concept of the needs of society."[75] ESS has been

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[74]Educational Development Center, The ESS Reader (Newton, Ma.: Educational Development Center, Inc., 1970).

[75]Robert E. Rogers and Alan M. Voelker, "Programs for Improving Instruction in the Elementary School," Science and Children, VII (January-February, 1970), 35-43.

described as the science program of concrete and intuitive experiences, involving exploration and discovery.[76] David Hawkins (1965) describes the program as "...ways of learning that are concretely involving and esthetically rewarding, that move from play toward apprenticeship in work."[77]

Proponents of ESS reject the idea that the program emphasizes any particular set of concepts or is organized around learning specific skills. Randolph R. Brown, Director of ESS from 1967 to 1969, voices his concern about the direction of education in the following statement:

> The general emphasis on the mastery of concepts, and skills to the almost total exclusion of personal development is one reason for such concern. We are more and more convinced that such mastery of prescribed skills, concepts, and techniques is only a shadow of education and does not, by itself, encourage the development of drive or whatever else it is that distinguishes a committed person from an indifferent one, a human from a machine.[78]

One of the most influential leaders of ESS from a philosophical viewpoint is David Hawkins.[79] In his work, "Messing About in Science," Hawkins describes a framework involving three phases for conducting science investigations.

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[76]Rogers and Voelker, pp. 36-37.

[77]David Hawkins, "The Informed Vision: An Essay on Science Education," The ESS Reader (Newton, Ma.: Educational Development Center, Inc., 1970) pp. 71-85.

[78]Randolph R. Brown, "Not Yet a Reform," The ESS Reader (Newton, Ma.: Educational Development Center, Inc., 1970) pp. 123-124.

[79]Sylvia Fogelquist Johnson, "A Cognitive Study of an Elementary Teacher's First Experience Teaching A 'New Science' Unit and its Relevance to the Implementation of Science Programs," (unpublished Doctoral dissertation, University of Illinois, 1979) p. 27.

He stresses that the order of the three phases may be juxtaposed to reflect both the situation and the group conducting the study. The phases include "Messing About... Children are given materials and equipment--things and are allowed to construct, test, probe and experiment without superimposed questions or instructions."[80] After a period of free exploration children select routes for further investigation. Each child or group of children then proceeds to the next phase, called "multiply programmed." This phase is marked by exploration guided by questions or routes discovered during previous experiences. The third phase is described by Hawkins as a colloquium, where ideas, theories, practical insight founded on experience are shared. In an ecological way the phases are interdependent. The colloquium involves discussion between the teacher and child, child and child, and includes the formulation of theories and ideas for further "multiply programmed" activities or toward an entirely different topic involving new material and more "messing about."[81]

Understanding the psychological factors affecting a curriculum is important in understanding its goals. Wideen (1975) suggests that ESS is identified with the "cognitive restructuring approach," which is associated with the work of Jerome Bruner.

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[80]David Hawkins, "Messing About in Science," The ESS Reader (Newton, Ma.: Educational Development Center, Inc., 1970) pp. 37-44.

[81]Hawkins, pp. 38-44.

Bruner describes three developmental stages of cognitive growth in the child. The child matures to a point where he can internalize information and operate mentally. An example of Bruner's cognitive restructuring concept is found in his description of an operation. He states, "an operation is a means of getting data about the real world into the mind and there transforming them so that they can be organized and used selectively in the solution of problems."[82]

The three levels of maturation described by Bruner include: the enactive level, where the child manipulates materials directly; the iconic level, where the child deals with mental images and/or models; and the symbolic level, where the child manipulates symbols rather than mental images of the objects.[83]

Shulman (1968) describes Bruner's method as essentially the learning by discovery method whose proponents, "...advocate the teaching of broad principles and problem solving through minimal teacher guidance and maximal opportunity for exploration and trial and error on the part

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[82]Jerome Bruner, "Readiness for Learning," Readings in Science Education for the Elementary School, ed. Edward Victor and Marjorie S. Lerner (3d ed.; New York: MacMillan, 1975) p. 72.

[83]Jerome S. Bruner, Toward a Theory of Instruction, (Cambridge, Ma.: Harvard University Press, 1960) pp. 11-18.

of the student.[84]

The general learning process represented by Bruner's model begins with the child manipulating concrete objects. After a period of initial exploration, the teacher begins asking leading questions, often used Socratically, to elicit discovery patterns. Through further discussion rules are generated and new situations presented where some of the organized regularities may apply.[85]

Wideen (1975) conducted a study comparing the "cognitive restructuring approach," identified with ESS to the "behavioral approach," characteristic of Science--A Process Approach (SAPA). His study compares the patterns of teacher behavior in the classroom, through observation and interview, and teachers' expectations of the ESS and SAPA programs during in-service work by the teachers. The study also serves to compare students within the two curriculum environments with respect to interest, process, and cognitive measures. The interest measure consisted of fifty-three items and was administered as a pretest only. Questions concerned the student's interest in engaging in science activites and other subjects. The process measure consisted of seven items in a multiple choice format and the cognitive measure consisted of presenting students with two problem situations designed to assess students' ability

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[84]Lee S. Shulman, "Psychological Controversies in the Teaching of Science and Math," The Science Teacher, XXXV (September, 1968), 34-35.

[85]Shulman, p. 35.

to make observations and inferences. Six teachers participated in the study with three teachers using ESS materials and three using SAPA materials. The research population included eighty-four ESS and seventy-nine SAPA subjects.[86]

Observational and anecdotal evidence suggested that the two environments were perceived differently by teachers and functioned differently in practice. Some objective evidence is also available that indicates that student learning is also sensitive to the two environments.[87]

Teacher Training

Avdul (1970) surveys one hundred thirty-three instructors of elementary science methods courses representing ninety-four colleges and universities in Ohio, Kentucky, Pennsylvania, and West Virginia. The survey examines the status of teacher-training in the "new elementary science programs," including Elementary Science Study, Science Curriculum Improvement Study, Elementary School Science Project, Science--A Process Approach, Intermediate Science Curriculum Study, and Minnesota Mathematics and Science Teaching Project. Avdul concludes that the major obstacles for implementation include lack of teacher training, lack of educational theory for teaching science, lack of desire

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[86]Marvin F. Wideen, The Psychological Underpinnings of Curricula: An Empirical Study, U. S. Educational Resources Information Center, ERIC Document ED 103 953, March, 1975, p. 2.

[87]Wideen, p. 5.

for changing the established programs and the cost of the new programs.[88]

Bratt (1973) compares the teaching methodology suggested by the new science curriculum projects to a traditional mode of teaching in an undergraduate methods course. Utilizing an attitude scale developed by the researcher, the study indicates that the "humanistic approach," represented by the newer curricula, fosters more positive attitudes toward teaching elementary science, than the more traditional approach.[89]

Futrell (1975) utilizes materials from ESS to develop a home study course for rural elementary teachers. The program requires that teachers experience science for themselves by using the materials at home and then applying these experiences in their respective classrooms. Futrell concludes that the course was successful in that knowledge of ESS curriculum materials increased and attitudes toward science teaching improved.[90]

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[88]Richard N. Avdul, "An Investigation of the New Elementary Science Programs in Teacher Training Institutions of Ohio, Kentucky, Pennsylvania, and West Virginia," Dissertation Abstracts International, XXXI (1970), 2766A (Ohio University, 1970).

[89]Herschell M. Bratt, "A Comparative Study to Determine the Effects of Two Methods of Elementary Science Instruction on the Attitudes of Prospective Elementary Science Teachers," Dissertation Abstracts International XXXIV (1973), 3174A (Purdue University, 1972).

[90]William M. Futrell, "An Elementary Science Study (ESS) Instructional Program for Geographically Isolated Elementary Teachers," Dissertation Abstracts International, XXXVI (1975), 4219A (University of Wyoming, 1974).

Stepans (1976) compares pre-service and in-service teachers enrolled in methods courses involving ESS activities with respect to their agreement with the philosophical approach of the ESS program. Stepans concludes that the pre-service group exhibits a greater change in attitude toward agreement with the philosophy of ESS than the in-service group and that intermediate in-service teachers exhibit a greater gain on this measure than in-service primary teachers. The teachers in the two groups were pretested before enrollment in their respective pre-service or in-service courses and posttested at the completion of each course. Twenty-nine pre-service and thirty-two in-service teachers participated in Stepans study.[91]

Dickson (1976) assesses the attitudes of in-service teachers trained in the use of ESS and SCIS materials with the attitudes of teachers who did not participate in the project. The research focuses on the diffusion of ideas and materials by teachers participating in a workshop on their non-participating colleagues. Dickson calls this diffusion of ideas the "multiplier effect." Student achievement and attitudes are also compared. Dickson finds that trained teachers may have a measurable effect on their untrained counterparts' attitude. There was no significant

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[91]Joseph I. Stepans, "Influence of Instruction Upon Pre-Service and In-Service Teachers Agreement With the Philosophical Approach of the Elementary Science Study (ESS)," Dissertation Abstracts International, XXXVI (1975), 4386A (University of Wyoming, 1974).

increase in attitudes or achievement by students in either group with the exception of a more favorable attitude toward science exhibited by third graders taught by workshop-trained teachers.[92]

Potts (1974) evaluated fifty-three classrooms in thirty-three schools in Indiana to determine if the successful implementation of new, activity based elementary science programs, including ESS, had occurred. "Successful and unsuccessful implementations are identified on the basis of the degree of the critical thought process that was present.[93] Evaluation is conducted through classroom observation and personal interviews with teachers and administrators. Based on the information collected in this manner Potts concludes that successful implementation in schools using ESS materials may be identified as sharing the following commonalities: Presence of a science oriented individual, in-service activities which include teachers in the decision making process, administrative support, and adequate funding. In addition, successful support systems must include periodic workshops during post-implementation years.[94]

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[92]Earl W. Dickson, "The Impact of the Multiplier Effect on Teachers and Students Involved in an ESS and SCIS Science Program," Dissertation Abstracts International, XXXVII (1976) 6387A (Illinois State University, 1975).

[93]Kenneth L. Potts, "The Evaluation of Implementation and Support Procedures in Selected Indiana Corporations that Adopted Either SCIS, SAPA, or ESS Elementary Science Programs," Dissertation Abstracts International, XXXV (1974) 6439A (University of Northern Colorado, 1973).

[94]Ibid.

Similarly, Craven (1978) examines the implementation and dissemination of science materials, including ESS materials. The study involves a survey of two-hundred eighty-four teachers, twenty-nine of whom had participated in a National Science Foundation in-service project sponsored by Washington State University. A portion of the survey deals with processes within school districts that enhance change efforts. Findings suggest that the support of administrative staff and adequate funding are particularly important in the implementation process.[95]

Waski and Nicodemus (1969) use an interaction analysis observation instrument to determine the effects of a science workshop and the use of ESS materials on fifth grade science classroom practices. Four measures are taken from the data supplied by the observation instrument, and include student activity, teacher activity, student group activity, and materials used by the activity groups. Ninety-one teachers in twenty-eight schools located in Montgomery County, Maryland participated. Three groups are compared: (a) teachers having no workshop experience and no ESS materials; (b) teachers with ongoing workshop experience

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[95]Evelyn Monson Craven, "An Evaluation of an Implementation and Dissemination Model for Elementary School Science," Dissertation Abstracts International, XXXIX (1978) 661A (Washington State University, 1977).

who also have ESS materials; and (c) teachers who had completed a workshop experience, but had no ESS materials.[96]

The researchers find that only in circumstances where teachers were receiving training and were using ESS materials are the "new instructional strategies" being used. "The results suggest that the materials are the focus of major change and that the different instructional strategies learned in the workshop and utilized in the classroom with the materials did not persist when the materials were removed."[97]

Evaluation and Comparison Research

Several studies concern the evaluation of Elementary Science Study curriculum materials and student learning as a result of experience with the ESS program. Researchers have also conducted studies comparing ESS to other science programs.

Henson (1973) evaluates the cognitive and affective performance of children in the ESS program using three measures: The STEP II Test of Achievement; the AAAS Semantic Differential Scale; and a learning environment inventory to measure the social climate of the classroom. Three groups

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[96]John L. Wasik and Robert B. Nicodemus, "A Study of the Effects of a Workshop and the Use of Specially Developed Science Materials on Fifth Grade Science Classroom Practices," Science Education, LIII, (1969), 347-355.

[97]Wasik and Nicodemus, p. 353.

of thirty, nine, ten, and eleven year old children are evaluated using a pre/post test design. The treatment consists of experiences with ESS materials.[98]

Henson finds that the nine year olds improved in all areas of achievement, the ten year old group increased in knowledge and comprehension, and the eleven year olds improved in comprehension only. None of the groups show significant gains in attitude toward science. No change is shown in the classroom learning environment in terms of assessments of competitiveness, difficulty, cohesiveness, and satisfaction. Implications of these findings are that children may gain in achievement in the ESS program and ESS may provide an opportunity for creativity.[99]

Huntsberger (1972) uses the Torrence Test of Creative Thinking, figural and verbal forms, to assess students. Huntsberger uses the ESS unit "Attribute Games and Problems" to help children develop "divergent-productive thinking." He defines divergent-productive thinking as "the strategies of instruction involving the manipulation of the blocks in a framework of activities which requires the student to create

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[98]Stanley Henson, A Study of the Cognitive and Affective Performance of Children in the Elementary Science Study Program, U. S. Educational Resources Information Center, ERIC Document ED 076 648, September 1973, pp. 1-3.

[99]Henson, p. 12.

new ideas (divergent-production of implications) as well as producing uncommon or clever responses (divergent production of transformations)."[100]

Although the finding may be mitigated by the relatively small research population, the results support the assumption that ESS materials may improve students' divergent productive thinking in the areas of vergal originality, figural flexibility, and figural originality.[101]

In a similar study Piyush Swami (1972) examines the effects of ESS on children's creativity. The Torrence Test of Creative Thinking is administered in a pre- and post-test design to two third grade experimental classroom groups and two third grade control classroom groups. The treatment consists of eight weeks of instruction with ESS materials. His findings are significant on both the test of verbal creative thinking and the test of figural creative thinking. Swami concludes that children exposed to instruction with ESS materials may improve their creative abilities.[102]

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[100]John P. Huntsberger, "A Study of the Relationship Between the Elementary Science Study Unit Attribute Games and Problems and the Development of Divergent-Productive Thinking in Selected Elementary School Children," (unpublished Doctoral dissertation, Oregon State University, 1972).

[101]Huntsberger, p. 26.

[102]Piyush Swami, Creativity and Elementary Science Study Materials, U. S. Educational Resources Information Center, ERIC Document ED 089 944, July, 1972.

Swami also produced a test of observation and classification. The test is based on the notion that process oriented science programs enhance creativity and that third graders are able to grasp the concepts of observation and classification. The instrument consists of two activities. The first activity involves students describing an object in as many ways as possible. The second activity involves children classifying twenty-one objects in as many ways as possible. The observation activity is scored for "relevance" and "fluency" according to standards established by the author and the Torrence Test of Creative Thinking with each correct response awarded one point. The children are awarded one point for flexibility for each criterion of classification they have derived.[103]

Labinowich (1970) attempts to identify learning objectives for the ESS science unit "Tangrams." After identifying learning outcomes, Labinowich develops the "Test of Area Concepts," to measure primary children's abilities on tasks involving conservation of area, area measurement, and area subdivision.[104] Results indicate no significant gains by students having experience with the ESS "Tangram" unit as measured by this instrument.

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[103]Swami, p. 53.

[104]Edward P. Labinowich, "A Study in Summative Evaluation of Elementary School Science Curricula," Dissertation Abstracts International, XXXI (1970), 1077A (Florida State University, 1969).

The production of an evaluation instrument and the process of unit evaluation to identify attainable outcomes and grade level placement are considered important results of this study.[105]

Wideen (1975) constructs a test for students involving two problem situations. The teacher demonstrates two discrepant events to the children, who are asked to explain each event. A six-category classification system is used to analyze student responses.[106]

A study dealing with the evaluation of ESS units and the development of student tests is Nicodemus' (1968) work on analyzing two ESS units using Science--A Process Approach.

Fifty-two objectives are identified for the ESS unit entitled "Small Things" and forty-eight objectives are identified for the ESS unit "Kitchen Physics". A test based on the content objectives was developed for the "Small Things" unit as well as a process test unrelated to specific content.[107]

The tests were administered to fifty-five pupils randomly selected from eleven classrooms in pre- and post-test design. Nicodemus' findings related to the content test do not support significant student improvement in the

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[105]Ibid. [106]Wideen, pp. 4-5 and 9.

[107]Robert B. Nicodemus, An Evaluation of Elementary Science Study as Science--A Process Approach, U. S. Educational Resources Information Center ERIC Document ED 027 217, September, 1968.

achievement of objectives. The results suggest that the content test is not significantly related to any of the skills specified in the fifty-two objectives written for the "Small Things" unit. The process test indicates improved performance on the part of students as a result of working with ESS units.[108]

The value of examining a science unit's content, outlining its objectives and developing tests is in providing a structure by which the sequential development of content may be examined. This is useful for teachers in planning the teaching of a unit. The heirarchy helps the teacher avoid unnecessary repetition and assure that students possess necessary behaviors for learning more complex tasks.[109]

Other researchers have identified a need for writing objectives for ESS units. An analysis of ESS units was conducted by William Aho and others (1974) on behalf of the California Test Bureau. Their efforts produced a guide to all ESS units. The guide includes representation of each unit's goal areas and evaluation objectives written according to the process skills involved. The guide is written to enable teachers to understand the goals and objectives of ESS units.[110]

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[108]Nicodemus, pp. 1-4. [109]Nicodemus, pp. 74-76.

[110]William Aho, et al., The McGraw-Hill Evaluation Program for ESS, (New York: McGraw-Hill Book Co., 1974).

Comparison Studies

Vanek and Montean (1977) compare students receiving instruction with the Laidlaw science texts to children experiencing ESS units. Student progress is measured on Piagetian classification tasks, a science attitude scale, and a science achievement test. No significant difference is found for the treatment, grade level or sex.[111]

Smith (1971) studies the achievement in science of over two-thousand students. He compares those utilizing "modern curricula," including ESS, to those receiving instruction through a textbook in science. His findings are supportive of the textbook approach. No data is presented to support the content validity of the test items, nor was any attempt made to sort out comparisons among sub-groups.[112]

Two studies are reviewed that compare different methods of instruction with ESS materials.

Blomberg (1974) compares the laboratory, reading lecturing and audio-visual methods of instruction in a

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[111]Eugenia P. Vanek and John M. Montean, "The Effect of Two Science Programs (ESS and Laidlaw) on Student Classification Skills, Science Achievement, and Attitudes," Journal of Research in Science Teaching, XIV (January, 1977), 57-62.

[112]Ben A. Smith, "Modern Elementary Science Curricula and Student Achievement," Dissertation Abstracts International, XXXIII (1972) 4202A (Western Michigan University, 1971).

study of four groups of sixth graders. All three instructional methods are utilized to teach the ESS units "Kitchen Physics," "Pendulums," and "Eggs and Tadpoles." The sixth graders receive instruction on a rotating basis so that each child is exposed to all three instructional methods.[113]

While relatively few students are involved in Blomberg's study and considerations for student attitudes and receptiveness toward instructional modes remains uninvestigated, Blomberg finds no significant difference between treatments based on pre- and post-tests for each of the units. She concludes that, at the sixth grade level, the cost of ESS material support may not be justified.[114]

Anderson and Butts (1975) also conduct a study comparing methods of teaching sixth graders with ESS materials. The study includes a series of worksheets developed for students to work independently on activities from the ESS unit "Batteries and Bulbs." Three sixth grade classes use the worksheets method while two other sixth grade classes cover the same material using a lecture-discussion method. No significant differences are found between the two groups on attitude and achievement measures.

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[113]Karin J. Blomberg, "A Study of the Effectiveness of Three Methods of Teaching Science in the Sixth Grade," Dissertation Abstracts International, XXXV (1974) 3290A (University of Minnesota, 1973).

[114]Ibid.

Most students show a preference for the discussion method. The authors conclude that both methods are legitimate and that neither method should be used exclusively.[115]

Summary (ESS)

The review of the literature concerning Elementary Science Study includes many ideas concerning its philosophical and psychological base, teacher training and implementation procedures, evaluation of ESS units, and comparisons with other elementary science programs.

Developers of the ESS program do not claim to subscribe to any specific guidelines in developing the units for the program. However, researchers have identified the ESS program with the philosophical viewpoint of David Hawkins and his "messing about" model for learning instruction. The psychological foundation for ESS is identified with the "cognitive restructuring approach" of Jerome Bruner. This approach is also described as the learning by discovery method.

Studies concerning teacher training and implementation yield several important considerations for adopting the ESS program. Teacher attitudes toward ESS when it is adopted initially are usually positive; pre-service teachers are usually more positive in attitude toward ESS than in-service teachers; and there is some evidence that student

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[115]Charles Anderson and David Butts, A Comparison of Individualized vs. Group Instruction in a Sixth Grade Electricity Unit, U. S. Educational Resources Information Center, ERIC Document ED 108 869, March, 1975.

attitude is also favorable toward the ESS program. Obstacles to adoption may include: lack of teacher training: the teachers' lack of an educational theory for teaching science; and the cost of the ESS program. Schools where ESS has been implemented successfully share the following characteristics: presence of a science oriented individual, the inclusion of the teachers using the materials in the decision making process, administrative support, adequate funding, and additional in-service training sessions in post-adoption years. Another finding is that the presence of the materials in the classroom may be important to the change in instructional practices.

Evaluation studies indicate that students may improve in achievement as a result of exposure to the ESS program and that ESS may provide a means for children to improve their creative thinking skills. Researchers have also identified ways of analyzing the content of ESS units and in presenting learning outcomes as process objectives. Several studies have also been concerned with developing test instruments for particular units so that students may be evaluated.

The process objectives of Science--A Process Approach have been utilized in this analysis procedure. Unit goals and process objectives have also been written for the ESS units by a group representing the California Test Bureau.

Studies comparing the Elementary Science Study program to other science programs or methods show mixed results.

Conclusions cannot be drawn concerning the merit of one program over another at this time.

Different methods for instructing with ESS materials have also been analyzed. There does not seem to be any clear support for a particular method of instruction based upon the two studies reviewed.

Interaction Analysis

This section deals with that research related to methods of observing in elementary science inquiry settings. The literature is separated into two areas: (1) background information including a description of some of the instruments available for use in elementary science, and (2) methods and instruments used to observe in elementary science inquiry settings.

An observational tool used to analyze elementary science teaching is the interaction analysis schedule. Several instruments have been developed and utilized for this purpose. One of the most widely used systems is the Flander's System of Interaction Analysis (FSIA). The focus of Flander's instrument is on verbal interaction. One use of the data resulting from the use of the FSIA is to characterize teaching as either direct or indirect. According to Simon and Boyer, "indirect teaching relates more than direct teaching both to positive pupil attitudes, to pupil

cognitive growth as measured by achievement tests, and to I.Q. scores in primary grades."[116]

Flander's instrument focuses on verbal interaction because the major portion of time spent in classrooms is spent talking, and, according to Flander's rule of two thirds, teachers dominate this verbal interaction. Flanders states:

> The present, average domination of teachers is best expressed as the rule of two-thirds. About two-thirds of the time spent in a classroom, someone is talking. The chances are two out of three that this person is the teacher. When the teacher talks, two thirds of the time is spent by many expressions of opinion and fact giving, some direction, and occasionally criticizing the pupils.[117]

Simon and Boyer (1974) outline several dimensions that must be considered when selecting an interaction analysis instrument. Each observation schedule is designed with specific aspects of the teaching-learning situation in mind. For instance, Flander's system is mainly concerned with the affective dimension. In Mirrors for Behavior: An Anthology of Observation Instruments, Simon and Boyer have categorized observation instruments using the following

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[116]Anita Simon and Gil E. Boyer, eds., Mirrors for Behavior III: An Anthology of Observation Instruments, (Philadelphia, Pa.: Research for Better Schools, Inc., 1974), p. 283.

[117]Ned A. Flanders, "Intent, Action and Feedback: A Preparation for Teaching," Journal of Teacher Education, XIV, (September, 1963), 252.

dimensions:

Category Dimensions

1. Affective - Emotional component of communication.
2. Cognitive - Intellectual component of communication.
3. Procedure and Routine - 'Getting ready to work,' 'working on the content,' and 'administrative routine.'
4. Physical Environment - Physical space along with specific materials or equipment being used.
5. Psychomotor - Behaviors exhibited during communication including non-verbal posture, facial expressions, gestures and position in relation to other students.
6. Sociological Structure - Who is talking to whom, if it designates the role of the person or persons, if it notes the number of people interacting, or provides information about those interacting such as gender, race, age, and so forth.
7. Activity - Record of activities people are engaged in such as watching a film, reading, etc.[118]

Other considerations important in the selection of an interaction analysis instrument include: the number of coders required, equipment needed, the classroom setting, the number of subjects observed, and the type of coding unit used.[119]

Observation Systems for Elementary Science

Charles Matthews developed the Science Curriculum Assessment System (SCAS) for teachers and students. SCAS

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[118]Simon and Boyer, pp. 29-31.

[119]Simon and Boyer, p. 132.

is designed to describe the teacher's behavior relative to student behavior. The full use of the system requires an individual interview with each student to record his/her interpretation of the classroom environment.[120] This is a lengthy and time consuming procedure.

Altman's Science Observation System (SOS) is employed to research many dimensions of the science classroom. "This instrument contains groupings of categories which reflect the level of abstraction of communication, whether student activities are 'directed' or 'non-directed'; the amount of time spent in 'instructional' as contrasted to 'procedural' activities; and an affective dimension (support or criticism of student behaviors)."[121] The use of the system requires coders to learn thirty-three symbols for the various dimensions.

Hunter developed the Revised Verbal Interaction Category System (Revised VICS) for the evaluation of science training programs in New York Public Schools. The system is based on the VICS developed by Amidon and Hunter and includes categories from Flander's affective dimensions and Aschner and Gallagher's cognitive dimensions. Hunter's instrument also includes categories describing a physical environment dimension.[122] The system includes fourteen

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[120]Simon and Boyer, pp. 389-400.

[121]Simon and Boyer, pp. 116-120.

[122]Simon and Boyer, pp. 309-312.

categories and twelve sub-categories. It does not include activity or laboratory dimensions.

The Activity Categories Index (ACI) provides a method for classifying and recording the extent in which students are actively involved in science classes and the time teachers spend teaching with various activities, including laboratory experiences. The system is based on Flander's system and includes non-verbal roles as well as verbal behaviors of teachers and students. Caldwell's ACI includes the following categories: laboratory experiences (open-ended and structured), group projects, student demonstrations, student library research, student speaking, teacher questioning, workbook work, teacher demonstrations, lecture and general havoc.[123]

Reynolds, Abraham and Nelson (1971) developed the Classroom Observational Record (COR), and interaction analysis instrument specifically designed for analysis of classroom discussion strategies in problem solving situations. The instrument consists of twenty categories called "moves". The researchers define "move ...as any discrete verbal utterance having a single cognitive focus."[124] The

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[123]Harrie E. Caldwell, "Activity Categories: A Quantitative Model for Planning and Evaluating Science Lessons," School Science and Math, LXXI (January, 1971), 55-63.

[124]William W. Reynolds, Jr., Eugene C. Abraham, and Miles A. Nelson, The Classroom Observational Record, U. S. Educational Resources Information Center, ERIC Document ED 048 378, February, 1971, pp. 3-4.

moves are divided into five major sub-divisions: (I) Structuring Moves; (II) Soliciting Moves; (III) Reacting Moves; (IV) Responding Moves; and (V) Non-Moves.

Reynolds and his co-workers find that when particular questions dominate, children's problem solving skills are affected positively. They indicate that a shift from the soliciting moves for "recall of information" and "collecting data" toward moves calling for "processing data" and "evaluating or verifying principles and/or conclusions" contribute toward improved pupil problem solving skills.[125]

Observation in Elementary Science Inquiry Settings

Johnson (1979) conducts a case study of an experienced teacher's first teaching of the Elementary Science Study unit "Primary Balancing." Information for the study is collected on video tapes of actual teaching sessions and audio tapes of post-lesson interviews with the teacher. The researcher presents the teacher's experiences in an analysis based upon "frame of reference domains." The set of domains include: the teacher's beliefs about teaching and teaching science, as well as her conceptualization of the phenomena associated with balancing.[126]

Johnson concludes that successful implementation must take into account the teacher's current belief systems

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[125]Reynolds, et al., pp. 9-10.

[126]Sylvia Fogelquist Johnson, "A Cognitive Study of an Elementary Teacher's First Experience Teaching A 'New Science" Unit and Its Relevance to the Implementation of Science Programs," (unpublished Doctoral dissertation, University of Illinois, 1979) 254-255.

She also stresses the importance of several phases in the implementation process which include the belief systems of those participating in the curriculum development-implementation process. Johnson writes: "Curriculum implementation is actually thought of by this researcher as a dynamic succession of cumulative communications between curriculum developer, curriculum implementer, teacher, and student.[127]

Fitzgerald and Shroyer (1979) utilize teacher logs and other observation forms as a way of collecting information about teachers' perceptions of their own performance. In particular the logs are used to record student responses, expand upon teachers' reactions, and serve to modify the curriculum developer's teaching model, called a "script." The information collected from the teachers is utilized in further revision of the script.[128]

Baker (1970) conducts a study to determine the effects of science teaching materials on teachers' verbal behavior during elementary science instruction. Flander's system of Interaction Analysis is used to compare twenty-five sixth grade teachers using textbook materials to

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[127]Johnson, p. 264.

[128]William M. Fitzgerald and Janet Shroyer, "A Study of the Learning and Teaching of Growth Relationships in the Sixth Grade," (an unpublished research study, Department of Mathematics, Michigan State University, 1979).

twenty-five sixth grade teachers using ESS materials. Baker concludes that teachers using ESS materials are more indirect in their teaching and student initiated talk is greater in classrooms using ESS materials. There is no significant difference in the number of questions asked by teachers and students in either situation.[129]

Baker also uses student and teacher perception forms to collect information concerning their own observations of the classroom environment.

His findings suggest that teachers and students in the ESS group are in agreement in their respective perceptions of a relatively low amount of teacher talk during science. In contrast, teachers and students in the textbook group are in agreement in their perception of a relatively high amount of teacher talk.

Baker also finds that ESS teachers and students perceive a relatively high amount of active involvement by students during science classes. Teachers and students in the textbook group are in agreement as to the passive involvement of students in science classes.[130]

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[129]Robert M. Baker, "A Study of the Effects of a Selected Set of Science Teaching Materials (Elementary Science Study) on Classroom Instructional Behaviors," (unpublished Doctoral dissertation, University of Rochester, 1970).

[130]Baker, pp. 88-89.

Summary

The review of the literature concerning interaction analysis instruments serves to identify several dimensions that may be considered when observing in science classrooms. These include: affective, cognitive, procedural, physical environment, psychomotor, sociological structure, and activity categories.

Many instruments focus on verbal interaction because, as Flanders suggests, verbal communication is dominant in most classrooms.

Simon and Boyer have produced a collection of over one-hundred observation instruments. They describe and evaluate several interaction analysis systems for use in elementary science inquiry teaching situation.

Researchers have identified the need for particular types of planned questions in facilitating children's problem-solving abilities. In particular, questions focusing on the processing of data and the evaluation of principles and/or conclusions seem to contribute most to students' gains in this area.

Implementation plans should consider the role of the curriculum developer, implementer, teacher, and student. Methods for collecting information from these participants in the teaching-learning situation include the use of

student and teacher perception forms, teacher logs and interviews with teachers following their teaching with a particular plan and/or set of materials.

CHAPTER III

METHODOLOGY

This chapter is divided into three sections. The first section deals with a description of the script representing the instructional treatment. The second section begins with a discussion of the research design and limitations of the study. This is followed by a brief description of the context in which the present research was conducted and includes details of procedures employed in the selection of both teachers and students comprising the research population. The third section presents the instrumentation employed in the study, a description of observer training procedures and the teacher training plan. The chapter concludes with a presentation of the major research hypotheses and an outline of analysis procedures.

Development of Instructional Materials

Problems in using ESS materials in the elementary classroom include the lack of established goals and

objectives for the units and a clearly stated inquiry model.[1] The instructional treatment is represented by an inquiry script based on the ESS unit "Peas & Particles." The script represents an attempt by the researcher to, first, identify goals and objectives for the unit "Peas & Particles" and second, structure activities of the unit according to an inquiry plan.

The goals of the unit "Peas & Particles" as identified by the California Test Bureau and the investigator are presented as unit goals and activity objectives.[2] They include:

Unit Goals:	Activity No.
Understand and appreciate measurement as a means for standardizing and communicating. (Standard = a model and/or rule for measuring.)	1 & 10
Understand that there are several ways to estimate quantity and that estimation is a valuable skill that can be utilized in practical situations.	1 & 10
Understand that counting can be accomplished utilizing a variety of strategies.	10
Understand that there is a relationship between counting and measurement.	10

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[1]Marilyn Appel and Joanne Stolte, Assessment of Existing Elementary Science Programs (Philadelphia: Research for Better Schools, Inc., 1970) Educational Resources Information Center, ERIC Document ED 062 163, June, 1970; see also William Aho, et al., The McGraw-Hill Evaluation Program for ESS (New York: McGraw-Hill, 1974).

[2]William Aho, et al., pp. 148-150.

Activity Objectives:	Activity No.
Will recognize measurement as an estimate or approximation.	1 & 10
Recognize numerals to one-million and verbalize an example of a million "things."	1 & 10
Will recognize the need for several trials as a means of improving accuracy of estimate.	1 & 10
Will understand averaging as it pertains to data collected in a sampling activity in several trials.	1 & 10
Will understand the relative accuracy of the counting methods used.	1 & 10
Will recognize rules for rounding off numbers.	2
Will demonstrate an ability to round off to tens, hundreds, thousands, and ten thousands place.	2
Will demonstrate ability to count in multiples with particles.	2
Will be able to apply a counting strategy of multiples in estimating a quantity of particles.	2
Will be able to describe a quantity as an order of magnitude.	3
Will recognize symbols for orders of magnitude as another name for a numeral or number representing a quantity.	3
Will measure using a non-standard sample and apply a counting strategy of sampling in estimating a quantity of particles.	3
Will understand a rule for finding the area of a rectangle in the context of counting with particles. Example: number of particles long times the number of particles wide.	4
Will be able to apply the counting strategy of area in estimating a quantity of particles.	4

Activity Objectives:	Activity No.
Will understand a rule for finding the volume of a rectangular solid in the context of counting with particles. Example: Number of particles long times the number of particles wide times the numbers of layers of particles.	5
Will be able to apply the counting strategy of volume in estimating a quantity of particles.	5
Will be able to double a quantity of particles at least four times.	6
Will be able to halve a quantity of particles at least four times.	6
Will be able to apply a counting strategy of first halving a quantity of particles and then doubling a counted portion to arrive at an estimate.	6
Will understand how to use an equal-arm balance.	7
Will use a balance to halve a quantity, successively, reducing it to an easily counted amount and then doubling the counted amount to arrive at an estimate.	7
Will be able to measure a sample using a spring scale.	8
Will be able to count the quantity in a weighted sample and use the information to estimate a larger quantity of known weight.	8
Will be able to rank order a set of identically sized jars according to the quantity of particles in each, from the jar containing the greatest quantity to the jar containing the least. The particulate matter in each jar would differ.	9
Recognize and apply the concept of ratio as it applies to the relationship between particles of different size. Example: $\frac{1 \text{ lima bean}}{3 \text{ navy beans}} = 1:3 = \frac{1}{3}$	9

Activity Objectives:	Activity No.
Will be able to use the counting strategy of ratio to estimate an unknown from a known quantity by recognizing the ratio of the particles to each other. Example: $\frac{1 \text{ lima bean}}{3 \text{ navy beans}}$ A jar contains 100 limas, hence the estimate of navy beans in a similar jar is 300.	9

It is intended that all objectives be introduced through concrete experiences; it is recognized that some of the objectives may be difficult to master by nine and ten year old children. The researcher refers to these objectives as intended learning outcomes at the exposure level, or as the introduction of concepts as opposed to expected mastery of concepts. Children are expected to demonstrate abilities to manipulate real objects, not only symbols for the objects. These intended learning outcomes served as the basis for the unit achievement test and the task-interview test. (see appendix A for Script Background Information for Teachers and The Script.)

The script takes the place of the ESS guide "Peas & Particles." Script has been defined by Fitzgerald and Shroyer (1979) as "A trip plan, a marked road map with comments from someone familiar with the route."[3] The

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[3]Janet Shroyer and William M. Fitzgerald, "The Mouse and The Elephant: An Application Unit," The Oregon Mathematics Teacher (February, 1979) pp. 10-13.

script represents a skeleton for instruction as opposed to a verbatim plan. The skeleton includes an overall challenge (problem) and activity challenges, each focusing on a specific rule, skill, or concept. Story challenges are also used with some activities to introduce an activity. The story challenges also represent practical applications of particular strategies introduced in the activity. During the presentation of the challenge the whole class reviews the previous day's activity, discusses the story challenge and is guided toward an understanding of the challenge and various strategies to be used in solving the problem. A second phase of the script is the exploration period. During this time materials and data recording sheets are distributed and children work in small groups, collecting data, inventing new strategies and discovering new techniques for working with the particles. The teacher circulates among the groups asking the questions, as suggested by the script, which require students to predict, act, observe, look for relationships, explain, and express their feelings. In turn she responds to student questions with cues and suggestions for further exploration so that they may answer their own questions. Before the final phase the materials are collected and the children meet again as a whole class. During this final, summary phase, the data collected by children is analyzed. Children share their new techniques, discoveries and the direction for the next activity is outlined.

Research Design

The one-group pretest-posttest design detailed by Campbell and Stanley (1963) was adapted in evaluating data yielded by observations of teachers with the Activity Categories Index and unit achievement test results of students participating in the study. Campbell and Stanley refer to the design as quasi-experimental and slightly better than the one-shot case study.[4]

Borg and Gall (1976) outline two problems encountered when collecting observational data. They are: "The degree to which the presence of the observer changes the situation being observed," and they state that "to provide reasonably sound data and to permit reliability estimates, observational studies usually require that at least two independent observers evaluate the situation being observed."[5]

They point out, as a solution to the first problem, that frequent visits by the observer serve to relax the class and generally students become accustomed to the observer's presence. In the present research, observers are in continuous contact with teachers and students in the district in the normal performance of their duties

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[4]Donald T. Campbell and Julian C. Stanley, Experimental and Quasi-Experimental Designs for Research (Chicago: Rand McNally, 1963) p. 7.

[5]Walter R. Borg and Meredith D. Gall, Educational Research: An Introduction (New York: David McKay Co., 1976) pp. 224-225.

as math-science consultants. With regard to the second problem, at least fifty percent of the observations made in the present research were conducted by two independent observers. The use of two observers in half of the observations is also important in controlling for possible observer bias.

Borg and Gall also discuss the possibility of "leniency" as a rating error associated with observers who work with those being observed.[6] This may be a limitation in the present study. However, observers were observing descriptive variables of elementary science teaching situations as opposed to inferential or evaluative variables which alleviates this problem to some extent.

The major threats to internal validity in this design are the rival hypotheses associated with history and maturation. This is particularly true of student learning situations. An attempt was made to minimize the length of time between pre- and post-testing with students (six - eight weeks) to mitigate the effects of these confounding variables. A variable affecting observational data is concerned with instrumentation. Campbell and Stanley state:

> If classroom participation is being observed, then the observers may be more skillful, or more blase, on the second occasion.[7]

The number of observations of each teacher (four) were included to minimize the effects of this rival hypothesis.

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[6]Borg and Gall, pp. 235-237.

[7]Campbell and Stanley, p. 9.

Threats to external validity are discussed by Campbell and Stanley (1963) and Borg and Gall (1976) under the headings of reactive effects of testing, and selection.[8]

The possibility exists that the pre-test with students sensitized subjects to the treatment. Teachers may also have been affected by observations made before exposure to the scripted materials.

Certainly, generalizability of findings are confined to students in the same grade level and who reside in a similar suburban residential setting. At no time were students told of their participation in a quasi-experimental program. The fact that the science program is ongoing and utilizes similar laboratory materials was important in maintaining a natural setting. Teachers, while knowing of their participation in a research study, were encouraged to participate as contributors to a curriculum improvement study. They were assured that their teaching was not being evaluated.

Limitations in the Research Design

The quasi-experimental approach discussed in the preceding section is an attempt to achieve the best design possible given the constraints present in observing and testing, and in the instructional situation. The limitations on the researcher's time, along with the time required

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[8]Campbell and Stanley, pp. 16-22, and Borg and Gall, pp. 368-370.

by other math-science consultants as full-time employees of the district to make additional observations, precluded the possibility for establishing a separate control group.

Certainly, the failure to establish a control group is the principal confounding factor separating quasi-experimental approaches from the true experiment.

Generalizability of the results reflects the experimenter's ability to control internal and external sources of invalidity. The differing interval between pre- and post-testing (six to eight weeks) and the fact that seven of the classes received treatment in the latter part of the first semester and five classes participated in the second semester represents additional confounding factors. Scheduling, material limitations, and personnel considerations dictated this situation.

The role of the researcher as a math-science consultant within the district and in one of the elementary schools in which treatment took place was a "mixed blessing." On the one hand, being "one of the boys" reduced the access-to-subjects difficulty often encountered by researchers, facilitated working relationships with colleagues, and minimized logistical problems. On the other hand, the researcher recognizes the introduction of experimenter bias.

The researcher trained observers, conducted workshops with classroom teachers, distributed materials, and conducted observations of subjects. The researcher did not

work directly with subjects during the treatment program. Copies of all relevant instrumentation were never distributed to teachers for their consideration. The Assistant Superintendent for Operations, the Science Department Chairman, and the building principals of the six elementary schools received instrumentation and agreed to its use.

The response mode on the student tests and appropriate responses were established well in advance of administration to subjects. Scoring on the unit achievement test was objective, as was the coding of teacher behavior with the observation instrument.

A t-test for matched pairs was used to analyze observation ratios of teachers obtained before work with the scripted material and during instruction with these materials. Student results from the pre- and post-test unit achievement test were also analyzed using a t-test for matched pairs. Student and teacher perceptions are compared to observational information utilizing Pearson Correlation Coefficients. Results are presented in Chapter IV.

Selection of the Population and Samples

The study is limited to one selected school district in New York State, the Three Village School District, Setauket, New York. The Three Village District is located on the North Shore of Long Island, approximately sixty miles east of New York City. It is mainly a middle to upper middle class area surrounding the State University of

New York at Stony Brook.

The Three Village District has an elementary science department consisting of one full-time director and six full-time math-science consultants. One consultant is assigned to each of the six elementary schools. The schools are Arrowhead, Minnesauke, William Sidney Mount, Nassakeag, North Country, and Setauket Elementary School. Responsibilities, in science, of each of the math-science consultants include operation of science laboratories, supplying and enriching classroom programs, and curriculum development. The commercial programs currently used in the district include Elementary Science Study and Science Curriculum Improvement Study materials.

The research population is limited to fourth grade teachers in the district and students assigned to that grade. Six elementary schools were involved, with a total population of thirty fourth grade teachers and seven-hundred fifty fourth grade students. Students are assigned to classes in a generally random manner.[9] Twelve teachers were randomly selected in the following manner. All teachers in the population were assigned a random number. The first twelve teachers selected were contacted and four declined to participate. The next four randomly selected were then contacted to complete the sample. Before the teacher selection process began the Assistant

[9]The term generally connotes a usual practice subject to vary in light of individual cases in which certain students (e.g., emotional, familial, difficulties, etc.) warrant special placement consideration.

Superintendent for Operations, the science department chairman, and the building principals were contacted and the researcher met with each individual separately. The assistant superintendent also encouraged principals to participate in an administrative meeting. A written outline was presented to each individual contacted and the nature of the study, its purpose, and need was discussed at these meetings. (see Appendix B.) Permission to conduct the study was granted by all of the administrators contacted. A request to meet with teachers was also made at the meetings with individual building principals. Initial meetings with the teachers selected was on a personal basis. After reviewing and discussing the nature and purpose of the study, the teacher was asked to participate. A brief, written description of requirements on the teacher's time and talents was given to them as well. (see Appendix B.)

The teachers, children, and schools were assured complete anonymity through utilization of a coding system on all research instruments. All were precoded for the teacher and her students to insure anonymity and accuracy on handling the data collected throughout the investigation. In addition, the investigator kept a log of research activities describing when the data was collected.

Instrumentation

The question posed for the study necessitated a choice of instruments which would enable the investigator to analyze objectively the verbal interaction and activities

occurring in the science classroom during science instruction. Student and teacher perception forms were used to ascertain perceptions of each, relative to a unit activity. These perceptions were compared to each other as well as to equivalent categories of the ACI. A questionnaire on teacher background was also utilized in the description of the teachers to provide background data relative to the study. The data yielded by the ACI and perception forms were used to analyze questions concerning the effect of the unit on teaching behavior.

Teachers kept a log of their teaching with the scripted unit for each activity, and three selected teachers were observed and interviewed concerning their deviations from the script, reasons for these deviations, and the types of questions used with students. This information along with unit evaluation was used to analyze scripting and to contribute toward further refinement of the unit.

As part of the unit modification two forms of a unit achievement test and a task-interview were also developed. An item analysis, and validity and reliability data were collected for the unit test. The task-interview was examined with regards to its content validity and its practicality for inclusion as part of a model for unit modification as well.

Interaction Analysis Instrument

General observation systems have been developed to analyze many aspects of learning environments. Many

instruments were considered in a search for one appropriate for the proposed investigation.

In selecting an interaction analysis instrument, several sources were consulted. Mirrors for Behavior III: An Anthology of Observation Instruments describes several of these instruments.[10] Instruments considered for the study included: Matthew's "Science Curriculum Assessment System," Altman's "Science Observation System" and Hunter's "Revised Verbal Interaction Category System."[11] These observation systems were written specifically for use in elementary science classroom settings. Matthew's system was rejected because requirements for the full use of the schedule require individual interviews with students. This was considered too time consuming and therefore impractical in a local school district situation. Similarly, Altman's system requires coders learn thirty-three symbols for the various categories. This was also considered inappropriate for the model of curriculum modification. Hunter's system includes affective, cognitive, and physical-material dimensions; however, the system does not include an activity dimension considered basic to the research study. Important in the selection process was the choice of an instrument

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[10]Anita Simon and Gil E. Boyer, Mirrors for Behavior III: An Anthology of Observation Instruments (Philadelphia: Research for Better Schools, Inc., 1974)

[11]Simon and Boyer, pp. 389-395, pp. 116-119, and pp. 309-312.

that teachers would view as nonthreatening in terms of the evaluation of their teaching, and one that would provide a basis for evaluation of science units.

Other observation instruments considered included those used to evaluate the Unified Science and Math in the Elementary School (USMES) program as reported in the USMES Evaluation Report on Classroom Structure and Interaction Patterns.[12] In the study two observations forms were used, one appropriate for large group instruction and one for small group instruction. It was reported that the instruments were especially designed for the study. Shapiro and Aiello (1974) failed to report reliability information. This constraint and the fact that only two activity categories were included led the researcher to reject the instrument for this study.

In selecting an instrument, an attempt was made to identify one that would be acceptable to teachers from both the standpoint of providing feedback relative to activities and the overall instructional setting, rather than focusing on only one aspect of instruction. It was hoped that teachers would accept such an instrument as a tool to assist in planning science activities and that this instrument could become a part of a unit modification model.

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[12]Bernard Shapiro and Thomas Aiello, USMES Evaluation Report on Classroom Structure and Interaction Patterns: 1972-73. Educational Resources Information Center, ERIC Document, ED 116 918, June, 1974.

The Activity Categories Index (ACI) was chosen because it considers the activity dimension of elementary science teaching and should be viewed by teachers as non-threatening. It is an instrument intended to evaluate the unit, not the teacher.

As Caldwell points out, the ACI yields data "...regarding the extent students are actively involved in science classes and measures the time teachers of science spend teaching with various types of activities."[13] It is a measure intended to determine how much time a teacher serves as coordinator of student learning versus the time spent imparting information directly. Caldwell states:

> ACI was originally developed for a research project and has been used in observations of over three-hundred elementary school science classes to provide measures of time teachers spend with certain types of activities. ACI also provides a quantitative model to guide planning, analyzing and evaluating of science programs or units of study. The instrument has been used for this purpose in several methods courses both at West Virginia University and at Syracuse University.[14]

The format and use of the ACI was based on the work of Flanders. The ACI consists of eleven categories, including: laboratory experiences (open ended and structured), group projects, student demonstrations, student library research, student talk, teacher questioning, workbook work,

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[13]Harrie E. Caldwell, "Activity Categories: A Model for Planning and Evaluating Science Lessons," School Science and Math, LXXI (January, 1971), 55.

[14]Ibid.

teacher demonstrations, lecture, and general havoc. (see Appendix C.)

The ACI yields three ratios, the activity ratio, the laboratory ratio, and the questioning ratio.[15] The activity ratio is the comparison of the amount of time spent teaching with indirect activities (laboratory, group projects, demonstrations, library research and student talk) to direct activities (workbook work, teacher demonstration and lecture). Category (7), teacher questioning, is not included in the comparison but influences the ratio. As the teacher spends more time questioning and less time lecturing, the activity ratio is larger. This is true since the student talk category increases as they respond to the questions. The denominator shrinks as the teacher asks more questions, and the numerator grows as the questions elicit more student talk.

$$\text{Activity Ratio} = \frac{\text{No. of intervals assigned to categories } 1,2,3,4,5, \text{ \& } 6}{\text{No. of intervals assigned to categories } 8,9, \text{ \& } 10}$$

If the value of the activity ratio is greater than 1.0, the implication is that the teacher is acting as a coordinator of activities rather than imparting knowledge. If the ratio is less than 1.0, the reverse may be true.

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[15]Harrie E. Caldwell, Evaluation of In-Service Science Methods Course by Systematic Observation of Classroom Activities. Educational Resources Information Center, ERIC Document, ED 024 615, September, 1967, pp. 10-12.

The laboratory ratio measures the percent of time spent with laboratory activities. It is the ratio of the time spent with laboratory activities to the total time spent teaching science.

$$\text{Laboratory Ratio} = \frac{\text{No. of intervals assigned to categories 1 \& 2}}{\text{No. of intervals assigned to all ten categories}}$$

A laboratory ratio of 0.25 indicates that the teacher spent one-fourth of the time (excepting category 11, general havoc) on laboratory experiences.

The questioning ratio measures the amount of time teachers spent asking questions to the total time teacher talking was recorded.

$$\text{Questioning Ratio} = \frac{\text{No. of intervals assigned to category 7}}{\text{No. of intervals assigned to category 7 \& 10}}$$

Application of the ACI

In the classroom the observer uses a notebook which has the categories and ground rules on the inside cover. On the opposite page is placed the recording grid. A stopwatch is used to measure the five-second intervals that he will use to record one of the eleven categories. The recording grid has twelve cells in each row, representing the number of categories recorded in one minute. As the lesson begins, the stopwatch is started and a numeral representing one of the eleven categories is recorded every five seconds until the lesson is completed. At the end of

the lesson a series of numbers is obtained. They represent the types of activities occurring as well as the order in which they occurred and the amount of time each activity occupied in the lesson. The observer notes at the end of the lesson the science topic taught during the period of observation.

On the reverse side of the recording grid the observer subjectively notes the following: In general, the type of questions asked. For example, were they recall or knowledge type questions, or were they thought-provoking explanation type questions? Additional questions addressed by the observer are: Was the focus of the lesson clear?; Was the subject matter clearly defined in the lesson?; Was the class structured or unstructured?; Did students have an opportunity to inquire?; or were their questions overlooked?

Student and Teacher Perception Forms

The Student Perception Form was developed by the Science Curriculum Improvement Study, University of California for use as a feedback instrument in soliciting students' perceptions of elementary science lessons. The use of the instrument is intended to gain information about the students' view of a lesson that will include the views of both the teacher and an observer as well. Inferences may be drawn from student perceptions relative to those of the observer. Baker (1970), in a study comparing ESS to the "textbook" approach, uses student and teacher perceptions

compared to information collected by an observer using Flander's Interaction Analysis Categories.[16] Baker finds that "the ESS teachers perceptions of their amount of talking has a higher degree of relationship to the Flander's analysis of this teaching behavior than did the textbook teachers."[17] Students' perceptions in both groups, related to teacher talk, had a high degree of relationship to the analysis of that behavior from the interaction analysis results. In the present research the form is used to answer questions about student perceptions relative to observed teacher talk and student activity during instruction with the modified unit. (see Appendix D.)

The Teacher Perception Form is identical to the student form and will be utilized to (1) describe the relationship between the observed behavior of teachers and teacher perceptions of that behavior, and (2) the relationship between student and teachers' perceptions of the same activity. Teacher talk and student activity are the areas of comparison. (see Appendix E.)

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[16]Robert M. Baker, "A Study of the Effects of a Selected Set of Science Teaching Materials (ESS) on Classroom Instructional Behaviors," (unpublished Doctoral dissertation, University of Rochester, 1970).

[17]Baker, pp. 88-89.

The Teacher Background Data Form

The Teacher Background Data Form was used in the description of the teachers participating in the study. It was administered during the workshop for teachers. It includes information about number of years teaching, number of years in a given school, number of credits completed, degrees held, whether or not the teacher taught the ESS unit "Peas & Particles" before, the number of times the unit was taught, the amount of science taught per week, number of college credits in science, and any special workshop or training sessions teachers have attended related to elementary science. (see Appendix F.)

The End of the Unit Evaluation Form

The End of the Unit Evaluation Form was intended to allow teachers to express an overall evaluation of the unit. Teachers were asked to rate concepts, process skills, content, the general attitude of students, activities, grade level, time, and availability of unit supplies. Information from this form would be used in any background information for the analysis of teaching behavior. (see Appendix G.)

Student Tests

A student unit achievement test composed of thirty-six items in a multiple-choice format was produced according to procedures outlined by Ebel (1979).[18]

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[18]Robert L. Ebel, Essentials of Educational Measurement, 3d ed., (Englewood Cliffs, N.J.: Prentice-Hall, Inc., (1979).

The following steps were taken in developing the unit achievement test:

(1) Identification of the intended learning outcomes of the "Peas & Particles" unit.

(2) Stating the intended learning outcomes as behavioral or activity objectives.

(3) Construction of a grid with process objectives on the vertical axis and activity objectives on the horizontal axis.

(4) Writing the test items within the confines of the grid to measure the identified processes within the prescribed subject-matter area.

(5) Pilot testing the items on a small group of students to detect extreme reading and mechanical problems with the items.

(6) Correction and arrangement of the items in two tests Forms A and B, each with thirty-five items.

(7) Administration of both forms as a pre- and post-test to students in the study.

(8) Subjection of the results of the test to an item analysis, indexes of discrimination and difficulty.

(9) Elimination and revision of the test items and review of feasibility for using the unit test with the Peas & Particles unit in the future.

(see Appendix H), (unit specification grid, page 101).

The task-interview called for the student to verbalize his solutions to the questions and problems posed by the interviewer. Student answers were recorded and compared to a set of "expected" responses. The interview was expected to take five minutes per child and was administered by the teachers working with the "Peas & Particles" unit. The purpose of the task-interview was to determine the feasibility of using this type of measurement tool with selected children

Figure 3.1: Unit test specification grid.*

	INFERENCE	PREDICTION	MEASUREMENT	CLASSIFICATION	CONCEPTS	COMMUNICATION
Activity One handfuls	34a,21b 35a,22b 36a,23b				6a,15b 25a,9b	
Activity Two multiples rounding off	8a,36b		19a,7b 13a,30b 10a,8b 9a,35b			12a 25b
Activity Three sample order of magnitude		1a,1b 2a,2b 3a,3b 4a,4b 5a,5b			33a 29b	
Activity Four area	17a,28b 31a,6b				7a,33b	
Activity Five volume			16a 17b		28a 27b	
Activity Six halving and doubling					18a,31b 32a,32b	
Activity Seven balances	26a,26b					
Activity Eight weight		29a 24b				
Activity Nine ratio				20a,11b 21a,12b 22a,13b 23a,14b	11a,34b 30a,10b	
Activity Ten unit challenge				27a 18b		15a 20b

* Pre- and post-test item numbers are used in the unit-test specification grid.

as opposed to a unit achievement test.

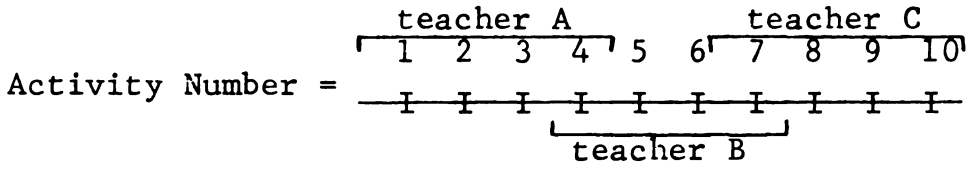
Children administered the task-interview were selected randomly from high, middle, and low achievement groupings as determined by their previous year's results on the California Achievement Test. The total math national percentile was used to place students into one of the three categories. Ten students were randomly selected from each of the three groupings. The "low" group was composed of those students whose national percentile composite mathematics score was between 0 and 58; the middle group, whose scores were between 59 and 85; and the high group who scored between 86 and 100. Thirty children were administered the task-interview before exposure to the unit and thirty children after exposure to the unit. The questions posed in conjunction with a response form of expected responses were included in the task-interview test. (see Appendix I.)

Video-Taped Observations

The investigator observed three teachers four times each during the course of the entire unit. A design for these observations was chosen, which allowed the observer to follow one class in four consecutive activities. This afforded the opportunity to observe the transition from summary to challenge in succeeding lessons. This design also allows the observer to view the same activity twice at two points in the observation schedule, specifically

at activities four and seven. It was hoped that the resulting comparison with two teachers would serve to point out any obvious differences in teacher interpretation of the script. The procedure also allowed for a comparison of questioning types for the same activity.

Observation Model



The focus of these observations was twofold: (1) to observe and record deviations from the script, and (2) to classify the types of questions used by teachers. The puspose is to use this information in the revision of the script.

All observations in this phase of the study were video-taped. Using video-tapes, the observer noted teacher deviations from the script and used a separate observation form to classify teacher questions. The notes focused on the three parts of each activity, launching, exploring, and summarizing. Observed deviations included any digression from the script. An interview following the series of observations was used to explain these digressions. The video-tapes of the activities served to clarify points made by the observer and the teacher.

A second focus of these observations was the teacher's questioning behavior. The observer used the section of

the "Classroom Observation Record" (COR) dealing with teacher "soliciting moves" as an observational tool.[19]

The following are the teacher soliciting moves from COR:

> Soliciting Moves: Any question which (a) initiates a new transaction by establishing a new center of focus and/or (b) maintains an existing center of focus is defined as a Soliciting Move. There are four categories of Soliciting Moves.
>
> Recalling (3): Calling for specific information about a previous cognitive focus from reading or class experience.
>
> Collecting Data (4): Calling for specific information from direct observation of a book, chart, map, etc.
>
> Processing Data (5): Calling for comparisons, grouping, categorizing, labeling, differentiating properties, inferring, developing and using relationships or hypotheses, etc.
>
> Evaluating or Verifying Principles and/or Conclusions (6): Calling for application and testing hypotheses, conclusions, or principles.[20]

The interview with teachers focused on these questions and how the script affects the kinds of questions asked toward revision of the script.

Training Program

Before observations of teachers, and prior to the study, observer training took place. The training occurred over a two-week period and involved all six math-science

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[19]William W. Reynolds, Eugene C. Abraham, and Miles A. Nelson, The Classroom Observational Record, Educational Resources Information Center, ERIC ED 048 378, February, 1971.

[20]Reynolds, et al., p. 4.

consultants, including the investigator. This pertains to training in the use of the Activity Categories Index (ACI). Each of the observers made approximately one-sixth of the total number of observations.

Training occurred in the following manner:

Step 1: At the first meeting the associate observers were given folders containing copies of the categories, ground rules, and a set of recording sheets. They were instructed in how they would be used in observing science classes. They were informed that in order to use the Activity Categories Index they must memorize the categories and rules. A suggested procedure was to practice rating a set of pre-recorded audio tapes of science lessons provided by the researcher.

Step 2: At a second meeting the associate observers and the investigator discussed problems that had occurred in coding the audio tapes. They then coded an additional audio tape together, stopping the tape occasionally to discuss any problems in coding.

Step 3: During the final meeting for training observers the six observers viewed a video tape of a science lesson and independently coded the lesson. Interrater reliability was established at this time. (Appendix C includes training materials.)

The researcher also made one-half of all observations with associate observers. Each observer was separated in the classroom and made independent observations. All

observations made by associate observers were also recorded on audio tape.

Interrater reliability estimates were made using Scott's method.[21] The formula for establishing interrater reliability is:

$$\pi = \frac{P_o - P_e}{1 - P_e}$$

P_o is the proportion of agreement between two observers, and P_e is the proportion of agreement expected by chance. P_e is found by squaring the proportion of tallies in each category and summing these over all the categories.

$$P_e = \sum_{i=1}^{k} P_i^2$$

k=number of categories

P_i=proportion of tallies falling into each category.

π = amount two observers exceeded chance agreement / amount that perfect agreement exceeds chance

Caldwell used the Scott Coefficient to estimate observer reliability in the study used to develop the ACI.[22] Flanders called for bi-monthly checks and cites "...a Scott coefficient of 0.35 or higher a reasonable level of performance.[23]

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[21]Ned A. Flanders, "The Problems of Observer Training and Reliability," Interaction Analysis: Theory Research and Application. Edmund J. Amidon and John B. Hough. (Reading, Ma.: Addison-Wesley Pub. Co., 1967) pp. 161-162.

[22]Harrie E. Caldwell, pp. 12-13.

[23]Flanders, p. 166.

Teacher Training and Data Collection Procedures

Subsequent to meetings with principals, selection of the sample and meetings with teachers participating in the study, the task of observing each teacher twice while teaching science was completed with the ACI. This also occurred before the teacher workshop and teaching of the unit Peas & Particles.

Two workshop meetings introducing teachers to the scripted materials and intentions of both the unit and the process of unit modification were presented in each elementary building. Instructions for use of a packet of materials were presented. The packet consists of background information on unit intentions, the unit, instructions for administering the pre- and post-tests, the teacher logs, and the end of the unit evaluation form. A set of unit materials was assembled and distributed to each school. Finally, during one of the work-shop sessions a teacher background data form was completed.

The pre-tests were administered to children (unit-test with all students, and task interview with selected students) prior to the teaching of the unit. Teachers then taught the unit. The third and fourth observation of each teacher (ACI) was conducted during this phase. At the end of the second ACI observation the observer reminded the teacher to administer the student perception form. They were instructed to read the questions to the class to avoid any problem children might encounter with reading. Teachers

also completed the Teacher Perception Form at this time. Teacher logs were completed after each lesson and completed at the end of the unit. The teacher log forms were inserted at the end of each activity as a reminder to teachers to complete the forms. At the completion of the unit the post-tests were administered and teachers completed the End of the Unit Evaluation Form. Teachers were given feedback on all unit tests at the conclusion of the study. Three teachers were observed and video-recorded four times each, spanning the entire unit. At the end of this series of observations they were interviewed by the researcher. The video-tapes and observer notes served as the basis for the interviews.

Hypothesis and Questions of the Study

The major purposes of this study are: (1) to modify a unit of science material according to an inquiry plan in which each activity is characterized by a challenge, a period of student exploration, and a period of group discussion and summary; (2) identify goals and objectives for the science unit and construct student tests: (3) to investigate teacher behavior, along with student and teacher perceptions of the learning situation; and (4) identify elements of the process that may be used to modify other science and math units.

The nature of the study suggests the hypotheses and questions to follow. The hypotheses are accepted or

rejected at the .05 level of significance.

H_1: ACI activity ratios will be significantly greater for teachers after introduction of the script method of teaching than before its introduction.

Rationale: The higher the value of the activity ratio the more the teacher is acting as coordinator of activities and the more the children are participating in their learning. It was hypothesized that the model for inquiry with its emphasis on student activity would be responsible for greater student involvement in activities.

Instrumentation: The Activity Categories Index (ACI) observation schedule.

Analysis: t-test for matched pairs.

H_2: ACI laboratory ratios will be significantly greater for teachers after introduction of the script method of teaching than before its introduction.

Rationale: The greater the value of the laboratory ratio the more time spent in laboratory activity. It was hypothesized that the model for inquiry emphasis on student exploration with the materials would be responsible for a greater proportion of laboratory activity.

Instrumentation: The Activity Categories Index (ACI) observation schedule.

Analysis: t-test for matched pairs.

H_3: ACI questioning ratios will be significantly greater for teachers after introduction of the script method of teaching than before its introduction.

Rationale: The higher value of the questioning ratio the more time teachers' talk is dominated by teacher questioning. It was hypothesized that the model for inquiry emphasis on challenge and summary phases in science lessons would be responsible for a greater proportion of teacher questioning.

Instrumentation: The Activity Categories Index (ACI) observation schedule.

Analysis: t-test for matched pairs.

H_4: Teachers' perceptions of their amount of talk as perceived by students will be positively correlated with the observed teacher talk (ACI).

Rationale: It is assumed that teachers will recognize the amount of time they spend talking. They will perceive their students as recognizing the amount of talking they do as well.

Instrumentation: Comparison of ACI data on teacher talk with Teacher Perception Form data.

Analysis: Pearson Correlation Coefficients.

H_5: Student perceptions of their activity level will be positively correlated with their observed activity level (ACI).

Rationale: Literature review indicates that children correctly perceive their role in the science classroom.

Instrumentation: Comparison of ACI data on student activity with Student Perception Form data.

Analysis: Pearson Correlation Coefficients.

H_6: Gain scores on the unit achievement test for students participating in the scripted "Peas & Particles" unit will be significant.

Rationale: It is expected that children will learn as a result of exposure to unit material and will demonstrate knowledge of goals and objectives of the unit.

Instrumentation: Pre- and post-test achievement test written for the "Peas & Particles" unit.

Analysis: t-test for matched pairs.

Q_1: What is the usefulness of the items on the test of achievement?

Rationale: "The construction of solid and reliable tests requires consideration of quantitative information regarding the difficulty and discriminating power of each test exercise, or item, that is proposed for use. Such information is provided by item-analysis data."[24]

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[24]Ebel, p. 258.

Instrumentation: Student unit-test, two forms.

Analysis: Index of Difficulty and Index of Discrimination.[25]

Q_2: What deviations from the script were observed and what is the relationship of these deviations to the script?

Rationale: Review of the literature indicates that in implementation the teacher's interpretation of the curriculum developer's intentions are important to the implementation process.

Instrumentation: Video tapes of three teachers, twelve lessons, covering the entire unit. Observer notes.

Analysis: Descriptive text of observer-teacher interview.

Q_3: What is the classification and frequency of questions asked during instruction using the script?

Rationale: Review of the literature indicates that questioning techniques are important to the inquiry teaching situation.

Instrumentation: Video tapes of three teachers, twelve lessons, covering the entire unit. Observer notes.

Analysis: Classroom Observational Record, schedule of teacher "soliciting moves".

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[25]Ebel, pp. 258-273.

Q_4: What information from the end of the unit evaluations, teacher logs, and interviews with teachers indicates need for further revision of the unit?

Rationale: A review of the input of teachers and students should suggest ways of improving the unit.

Instrumentation: End of the Unit Evaluation, Teacher Logs and Teacher Interviews.

Analysis: Descriptive text of the collected information.

Significance Level

The .05 level of significance will be employed to reject or not reject hypothesis testing in the present study. Setting the .05 level results in some danger of Type I error, the rejection of the null hypothesis when it is not correct. It is felt that this danger is outweighed by the insight to be gained which might provide future researchers in this area with significant differences that might otherwise be overlooked if more stringent levels of significance were employed. In using the t-test for matched pairs it is noted by Borg and Gall (1976) that "the t-test for correlated means is less likely than the t-test for independent means to lead to a Type II error (accepting the null hypothesis when it is false)."[26]

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[26]Borg and Gall, p. 305.

CHAPTER IV

ANALYSIS OF THE DATA

The primary purpose of this study was to examine the effects of the modification of an Elementary Science Study Unit, using an inquiry-script, on Teaching and the classroom environment. Observations utilizing the Activity Category Index (ACI) interaction analysis instrument were conducted in a one-group pre-test - post-test design. Data from the ACI are represented in three ratios related to the amount of time spent in elementary science classes on student activity, laboratory work and teacher questioning. The unit was also examined as a possible model for modifying other math and science units. Information from participating teachers was collected through the use of Teacher Perception Forms (TPF), teacher logs of each activity, and an End of the Unit Evaluation Form. A unit test for students was developed and examined for content validity and reliability. Analysis of the unit test items was conducted to determine each item's difficulty and discrimination. The unit test was administered to students in a one-group pre-test - post-test design. Information about student achievement and perceptions of the learning environment were also collected using a task-interview

with randomly selected students (N=30)and a student/perception form (SPF) completed by all students. SPF and TPF information was compared to data from the ACI to determine the correlation between student and/or teacher perceptions of the learning environment and observer perceptions.

The analysis of the data is divided into three sections. The first section deals with teacher and student demographic data and teacher science teaching experience. In addition reliability information for the student unit-achievement test and interrater reliability for observers is presented.

Six hypotheses are then analyzed. They are related to observations of student activity and laboratory time as well as teacher questioning behavior. In addition two hypotheses are presented which compare teacher and observer perceptions of teacher talk and student and observer perceptions of student activity. Finally, analysis of an hypothesis dealing with the student unit-achievement test results is presented.

The final section deals with analyses of four research questions. The information in this section is presented in descriptive form. The questions deal with item analyses for the unit-achievement test, a description of teacher deviation from the script (three teachers), the classification and frequency of teacher questioning behavior (three teachers), and a presentation of information from teacher logs and End of the Unit Evaluation Forms

(twelve teachers). The purpose of this section is to review student and teacher input for improving the script and to identify elements of the process that may be used to modify other science and math units.

Demographic Information

A Teacher Background Data Form (Appendix F) was used to collect information about the teacher sample in the study. Twelve fourth grade teachers were randomly selected from the total district teacher population, at that grade level (N=30). The demographic characteristics of the teacher sample are presented in table 4.1. Although not all the demographic data are employed in the study, they contribute to a better understanding of the research population. Information not represented in the table, but collected from teachers, include the population size of the elementary schools participating and the science program currently used. Three schools have a population of 500 - 750 pupils and three reported populations in excess of 750 pupils. All twelve teachers indicated that no science textbooks were being used in their classrooms. The Three Village School District uses Elementary Science Study and Science Curriculum Improvement Study materials for their science program.

A second table (Table 4.2) is used to describe teacher science teaching experience characteristics. The information is presented to establish the frequency and length of science lessons conducted by the twelve teachers

Table 4.1 Demographic Characteristics of the Teacher Sample for the Study

Variables	Sample N	%	Variables	Sample N	%
1. Sex			2. Age		
Female	8	67	31-40	8	67
Male	4	33	41-50	3	25
			51 +	1	8
3. Years Teaching			4. Years in Building		
7-10	4	33	7-10	7	58
11-15	5	42	11-15	5	42
16 +	3	25	16 +	0	0
5. Academic Background			6. School		
			Arrowhead	2	17
M.S.	1	8	Minnesauke	2	17
M.S.+15	2	17	Mount	2	17
M.S.	5	42	Nassakeag	2	17
M.S.	2	17	North Country	3	25
M.S.+60	2	17	Setauket	1	8

Table 4.2 Background Information on Teachers Science Teaching Experience

Variables	N	%	Variables	N	%
1. Number of Science Periods Per Week			2. Length of Science Lessons		
one	4	33	21-30 minutes	2	17
two	6	50	31-45 minutes	8	67
three	2	17	46-60 minutes	2	17
four	0	0			
five	0	0			
2. Experience With ESS Unit Peas & Particles			4. Number of Times Peas & Particles Unit Taught In Past		
Yes	8	67	once	4	33
No	4	33	twice	2	17
			three times	1	8
			four times	0	0
			five times	1	8

each week. In addition, their experience with the ESS unit Peas & Particles is presented.

Table 4.3 presents teacher science background relative to the number of undergraduate and graduate hours they have accumulated in four science areas and science teaching methods courses. Numbers in the table represent a tally for the number of teachers responding for each area. In addition to the coursework represented in the table, four teachers reported attendance in specialized science workshops dealing with ESS materials. Two teachers attended a week long training program at the Educational Development Center in Newton, Massachusetts, and two teachers attended a week long National Science Foundation workshop at the State University of New York, Stony Brook.

Table 4.4 Background Information: Teachers' Coursework in Science

		Number of Graduate and Undergraduate Credit Hours				
Area	N	0	3-6	7-12	15+	N.R.*
Biology	12	0	9	0	1	2
Physics	12	1	7	2	0	2
Chemistry	12	3	6	0	1	2
Geology	12	2	7	1	0	2
Science Methods	12	2	7	1	0	2

*N.R. = No Response

Table 4.4 presents demographic and achievement test data for the student sample in the study. The total student sample is sub-divided into groups reflecting the different

schools participating in the study. Other categories include sex and the division of the student group into three sub-groups. The sub-groups are derived from student California Achievement Test national percentile scores in mathematics. The "low" group represents those students scoring between zero and the fifty-eighth percentile; the "middle" group represents those students scoring between the fifty-ninth and the eighty-fifth percentile; the "high" group are composed of those students scoring between the eighty-sixth and the ninety-ninth percentile.

Table 4.4 Demographic and Math Achievement Characteristics of the Student Sample

Variables	N	%	Variables	N	%
1. School			3. National Percentile In Math: California Achievement Test		
Arrowhead	46	16.5			
Minnesauke	46	16.5			
Mount	46	16.5			
Nassakeag	46	16.5			
North Country	72	25.8	Low (0-58)	81	29.0
Setauket	23	8.2	Middle (59-85)	118	42.2
			High (86-99)	59	21.2
Total	279	100.0	Not available	20	7.2
2. Sex					
Female	140	50.2			
Male	139	49.8			

Reliability of the Student Achievement Test

Reliability estimates for the student unit achievement test (Appendix J) were calculated for the pre-test and post-test as suggested by Anastasi (1976) and Thorndike

(1955)[1]. Cronbach's (1951) Coefficient Alpha represents the method used to determine internal consistency. Alpha is equivalent to the average of all split-half coefficients for a test and is generally considered the lower bound of true reliability.[2]

Table 4.5 presents the Alpha reliability coefficients for the pre- and post-tests.

Table 4.5 Alpha Reliability Coefficients for the Student Unit-Achievement Tests

	N	Mean	Variance	Standard Deviation	Alpha
1. Pre-test	279	13.08	17.54	4.19	.58
2. Post-test	240	17.88	23.54	4.85	.67

Appendix J presents complete item by item test values for the pre- and post-tests. Test values are the ratio of each item's variance to the sum of the covariances of all other items and is a measure of how closely individual items agree with all other items.[3]

[1]Anne Anastasi, Psychological Testing (4th ed., New York: MacMillan, 1976), pp. 125-127; see also Robert L. Thorndike, "Reliability," Educational Measurement, ed. E. F. Lindquist (Washington, D.C.: American Council on Education, 1955), pp. 606-607.

[2]Lee J. Cronbach, "Coefficient Alpha and The Internal Structure of Tests," Psychometrika, XVI (December, 1951), pp. 297-334.

[3]Personal communication and consultation with Dr. Francis J. Crowley, Fordham University.

Items showing large coefficients (negative or positive) do not relate well with other items on the test. Internally consistent items are represented by low values. Test values for items ranged between -2.51 to 2.09 for the pre-test and .21 to 2.83 for the post-test.

Interrater Reliability of the Interaction Analysis Instrument

Observations of science lessons were conducted prior to use of the scripted ESS unit Peas & Particles and during its instruction in fourth grade classrooms. Interrater reliability was calculated during the training of raters, before treatment and during use of the scripted unit. The researcher conducted all observations in the North Country School where observations were also video-taped. The researcher conducted one-half of the observations in all other schools with the science consultant in each building doing the other half. These observations were conducted with raters seated separately in the classrooms. Interrater reliabilities were then calculated. During the observation conducted by the science consultants, independent of the researcher, audio-tape recordings were made of verbal interaction. This was done to resolve any questions the researcher might have had about observer ratings.

Table 4.6 presents interrater reliabilities for the following observers: A, the researcher; B, the science consultant at Arrowhead School; C, the science consultant at Minnesauke School; D, the science consultant at Mount School; E, the science consultant at Nassakeag School; and

F, the science consultant at Setauket School.

Scott's coefficient "pi" was used to calculate interrater reliability. Flanders (1967) recommends Scott's method for the following reasons:

> It is unaffected by low frequencies, can be adapted to percent figures, can be estimated more rapidly in the field, and is more sensitive at higher levels of reliability.[4]

Table 4.6 Interrater Reliability Coefficients for the Interaction Analysis Instrument Activity Categories Index

Observation Periods	Observer Pairs and Pi Coefficients				
	A-B	A-C	A-D	A-E	A-F
Training	.87	.89	.81	.87	.89
Pre-Treatment	.86	.95	.96	.91	.90
Treatment	.83	.82	.97	.94	*

*Researcher made final two observations.

Caldwell (1970) reported estimated reliability between observers in a study of elementary science classrooms of between .89 and .94 before, during, and at the end of his study.[5] Estimated observer reliabilities in the present study range from a low of .81 to a high of .97.

[4]Ned A. Flanders "The Problems of Observer Training and Reliability," Interaction Analysis: Theory, Research and Application, Edmund J. Amidon and John B. Hough (Reading, Ma.: Addison-Wesley Pub. Co., 1967), pp. 158-164.

[5]Harrie E. Caldwell, Evaluation of An In-Service Science Methods Course by Systematic Observation of Classroom Activities. Educational Resources Information Center ERIC Document, ED 024 615, September, 1967, pp. 13-14.

Flanders (1967) implies that coefficients of .85 and higher represent desirable interrater reliability standards.[6] The number of observers (six) utilized in this study may be one factor accounting for the wide range of reliability coefficients. Caldwell, who also used the ACI, utilized three observers in his study. All of the science consultants were employed as raters because any proposal modifying the science curriculum would naturally involve them. One source for error, upon closer inspection, appears to be discrepancies in coding related to interpretation of talk immediately following a teacher question. In a few instances one coder interpreted this as part of the teacher question, and the other coder classified it as teacher talk. Considering the number of coders utilized in this study and the variety of errors that may occur, the coefficients represented in the table above are accepted as being within a satisfactory range.

Hypothesis Testing

As discussed in Chapter III, hypotheses are accepted or rejected at the .05 level of significance. Hypotheses are stated in the null form to facilitate the statistical analysis.

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[6]Flanders, p. 165.

H_1: Activity Categories Index (ACI) activity ratios before and after introduction of the script method of teaching.

H_o: There will be no significant difference in ACI activity ratios for teachers after introduction of the script method of teaching than before its introduction.

Hypothesis 1 (Chapter III) anticipated an increase in the amount of time children spend actively involved in science lessons as a result of exposure to a scripted science unit. The activity ratio includes the following categories from the ACI: laboratory experience, group projects, student demonstrations, student library research and student talk.

Table 4.7 reports the actual comparison of means for the amount of time students spend actively involved in science lessons before and after introduction of the script method of teaching.

Table 4.7 t-test for Matched Pairs Between Pre-Activity and Post-Activity Observations

Observed Variable	N	$\bar{X}$	S.D.	t	d.f.	p (2-tail)
Pre-Activity	12	3.84	1.72	-1.90	11	0.08*
Post-Activity	12	6.72	5.86			

* Not Significant at .05.

The difference between the pre-treatment mean and the post-treatment mean for activity, while indicating a greater level of student involvement after introduction of

the script, was not significant at the .05 level. Therefore, the null hypothesis is not rejected. The hypothesis that activity levels of students would be greater as a result of exposure to the script method of teaching was not supported.

Discussion

Activity levels were high in pre-treatment observations. All teachers observed were either teaching the ESS unit Mealworms or Colored Solutions during these early visits. These ESS units normally involve greater student activity. The observations made of the teachers during their work with the scripted Peas & Particles unit resulted in higher levels of activity, although the magnitude of the difference was not statistically significant. The fact that increased pre-planning and teacher direction as represented by the scripted materials did not detract from student involvement in science lessons may be considered a positive finding.

The large variance, (represented by the standard deviation) in the post-treatment observations may be responsible for non-significance of the findings for activity. Raw data indicate that observers were present in three cases, for launch and exploration phases only, which resulted in extremely large activity ratios. Those activity ratios were responsible for the large variance.

Baker (1970) compared the ESS program to textbook programs during ESS's adoption in the Monroe County, N. Y.

Schools.[7] In his analysis, utilizing Flander's Interaction Analysis Categories, ESS classrooms fostered a more indirect teaching pattern than textbook classrooms. Indirect teaching is associated with greater student involvement in learning and corresponds to the Activity Ratio of the ACI. The results in both ESS and scripted ESS classrooms in the present study are consistent with Baker's findings in ESS classrooms. The larger proportion of class time is spent in student activity or indirect teaching.

Caldwell (1968) utilizing the ACI to observe elementary science programs employing either a textbook or activity approach, was also able to discern greater differences between the two types of programs.[8] Evidence of larger proportion of student activity time are consistent for Caldwell's activity approach and both treatments in the present study.

Baker and Caldwell were probably able to discern greater differences between groups in their studies due to the fact that they were comparing textbook and activity programs. The findings in the present study, while not significant, may be viewed as supporting the script-method as an activity approach. The findings related to indirect teaching and activity are consistent with those of Baker

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[7]Harrie E. Caldwell, "Evaluation of An In-Service Science Methods Course by Systematic Observation of Classroom Activities," (unpublished Doctoral dissertation, Syracuse University, 1968).

[8]Robert M. Baker, "A Study of the Effects of a Selected Set of Science Teaching Materials (ESS) on Classroom Instructional Behaviors," (unpublished Doctoral dissertation, University of Rochester, 1970).

and Caldwell.

H_2: ACI laboratory ratios before and after introduction of the script method of teaching.

H_o: There will be no significant difference in ACI laboratory ratios before and after introduction of the script method of teaching.

Hypothesis 2 (Chapter III) anticipated an increase in the amount of time children spend in laboratory experiences during science classes. Laboratory experiences are defined in the following statement:

> Students are presented a problem to be solved by manipulation and experimentation with materials. The procedure may or may not be given. They are required to make observations and analyze or interpret their findings.[9]

Table 4.8 reports the actual comparison of means for amount of time students spend in laboratory experiences during science lessons.

Table 4.8 t-test for Matched Pairs Between Pre-Laboratory and Post-Laboratory Observations

Observed Variable	N	$\bar{X}$	S.D.	t	d.f.	p (2-tail)
Pre-Laboratory	12	1.56	0.15	1.15	11	0.88*
Post-Laboratory	12	0.55	0.14			

*Not significant at .05.

The difference between the pre-treatment mean and

[9]Harrie E. Caldwell, Evaluation of An In-Service Science Methods Course by Systematic Observation of Classroom Activities. Educational Resources Information Center ERIC Document, ED 024 615, September, 1967, pp. 10-12.

the post-treatment mean for laboratory activity indicates a lower level of laboratory activity after introduction of the script. The difference was not significant at the .05 level. Therefore, the null hypothesis is not rejected. The hypothesis that laboratory levels of students would be greater as a result of exposure to the script method of teaching was not supported.

Discussion

Laboratory levels were high on the pre-treatment observations. Teachers were working with ESS units during which children openly explore with materials in a laboratory setting. The observations of teachers during their use of the scripted unit resulted in lower laboratory ratios, although not significantly lower. The fact that the script includes increased teacher direction for teacher talk and planning did not significantly limit the amount of time children have to explore with materials in laboratory phases of science lessons may be considered a positive finding.

Caldwell (1968) utilizing the ACI was able to distinguish between a textbook approach and an activity approach when comparing laboratory ratios for the two programs.[10] By comparison, the present study attempted to distinguish a significant difference between two activity approaches, ESS and scripted ESS.

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[10]Caldwell, p. 61.

H_3: ACI teacher questioning ratios before and after introduction of the script method of teaching.

H_o: There will be no significant difference in ACI questioning ratios before and after introduction of the script method of teaching.

Hypothesis 3 (Chapter III) anticipated an increase in the amount of time teachers spend asking questions as compared to the total amount of teacher talk during elementary science lessons. The ratio includes the amount of time teachers spend asking questions compared to teacher questioning plus all other teacher talk.

Table 4.9 reports the actual comparison of means for the amount of time teachers spend questioning students.

Table 4.9 t-test for Matched Pairs Between Pre-Questioning and Post-Questioning Observations

Observed Variable	N	$\bar{X}$	S.D.	t	d.f.	p.(2-tail)
Pre-Questioning	12	0.32	0.22	-1.75	11	0.11*
Post-Questioning	12	0.43	0.24			

*Not significant at .05.

The difference between the pre-treatment mean for questioning and the post-treatment mean for questioning, while indicating a greater frequency of teacher questions after introduction of the script, was not significant at the .05 level. The null hypothesis, therefore, was not rejected. The hypothesis that questioning levels of teachers would be greater as a result of using the script method of teaching was not supported.

Discussion

Questioning ratios in the pre-treatment setting display a mean of .3148 indicating that average teacher talk included approximately 32% questioning. Post-treatment observations indicated that nearly 43% of teacher talk, on the average, was in the form of teacher questioning. While an increase in questioning was evident during the use of the scripted materials, the increase was not significant.

The ACI observation schedule is not sensitive to teacher talk or questioning during the laboratory (exploration) phase of pre- and post-treatment observations. The means for laboratory observations were 0.56 and 0.55 respectively indicating that more than half of science lesson time was spent in laboratory activities. The script emphasizes teacher questioning during the exploration phase of the lesson with the teacher circulating through the class as students work toward solution of the lesson challenge. The analysis of video-tapes (Question 3), discussed later in this chapter, presents information about teacher questioning during all phases of the activities for three teachers. The data suggest that teachers asked a large portion of their questions during the exploration phase. This information suggests that a more sensitive observation instrument might indicate a significantly greater amount of questioning in a post-treatment setting. However, it is noted that the ACI was

sensitive to teacher questioning during pre-treatment laboratory observation either.

Caldwell (1968) was able to observe a significant difference in questioning time in favor of the activity approach as compared to a textbook approach in teaching elementary science.[11] The present study compared two activity programs and found no significant difference. Baker (1970) reports no difference in the questioning behavior of textbook teachers compared to ESS teachers. He reports that the textbook group asked more questions, though the difference with the ESS group was not significant.[12] The findings reported by Baker may reflect the difference in observation instruments. Baker used Flander's Interaction Analysis System which is dominated by verbal categories. Baker's findings are not supported by the results in the present research.

Results of the present research may indicate the need for an observation instrument more sensitive to teacher questioning during the laboratory phase of instruction in future studies.

H_4: Teacher perceptions of their amount of talk (Teacher Perception Form, TPF) compared to the observed amount of talk ACI.

H_o: There will be no significant correlation between teachers' perceptions of their amount of talk as compared to the observed amount of talking they do.

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[11] Caldwell, pp. 62-63.

[12] Baker, p. 60.

Hypothesis 4 (Chapter III) anticipated that teachers would recognize the amount of time they spend talking during science lessons. The TPF data was collected during the treatment period only. There is no attempt to compare teacher perceptions to their pre-treatment observations. In addition, teachers were asked to respond to the questions as they felt their students, as a total group, would respond. Therefore, we have represented teachers' judgment of student perceptions of teacher talk.

Questions one and two of the TPF were compared to observational information (ACI) related to teacher talk. The questions from the TPF are:

1. During the science period, the class

    a. mostly listened to the teacher.
    b. mostly watched the teacher or a boy or girl do experiments.
    c. mostly worked with equipment.

2. Most of the talking was done

    a. by the teacher.
    b. by a few boys and girls.
    c. by many boys and girls.

The data from the twelve teachers' responses to these two questions was compared to ACI, category 10 information from the post-treatment observations. Category 10 is represented as follows:

> The teacher reads aloud, expresses his views, gives directions, makes an assignment or asks a rhetorical question. Students are expected to listen. They may interrupt only when they don't understand. Student reading in the text is also included in this category.

Table 4.9 reports the actual correlation between the TPF and ACI means for questions one and two and category ten, post-treatment, respectively.

Table 4.10 Pearson Product Moment Correlations Between TPF Questions 1 & 2 and ACI Category 10 for Post-Treatment Data Only

Category	N	$\bar{X}$	S.D.	r	p
TPF 1 & 2	12	2.17	0.72	-0.54	.03*
ACI 10	24	72.19	29.72		

*Significant at .05

The correlation between teachers' perceptions of their amount of talk as compared to the observed amount of talk was significant at the .05 level. Therefore, the null hypothesis is rejected. The hypothesis that teachers' perceptions of their amount of talk would be correlated with their observed talk is supported.

Discussion

The negative correlation coefficient occurred as a result of the nature of different coding methods for teacher talk on the ACI and TPF. On the ACI a large "score" indicated more teacher talk, whereas on the TPF a large "score" indicated less teacher talk. The scattergram for the correlational data indicates that as observed talk decreases the perception of the amount of teacher talk decreases as well.

The comparison of observed and perceived teacher talk was conducted to determine whether the science teaching situation as represented by the script would affect teachers' perceptions of this behavior. Results from the analysis of hypothesis 3 indicate that pre- and post-treatment ratios for questioning reflect similar proportions of teacher talk. Results of hypothesis 4 indicate that teachers probably perceive this behavior accurately. The number of cases included (n=12) and the number of observations (n=24) qualify the results. Therefore, a weak relationship exists suggesting that observers and teachers may agree on their perceptions of the amount of teacher talk. Considering the increased direction for teacher talk and structuring of the teaching situation, this may be considered a positive finding.

Baker (1970) found that teachers using ESS materials perceive their amount of talk consistently with an observer's rating of this behavior. The results are comparable to the findings in the present study; however, teachers in Baker's study were not using the script method of teaching for ESS units.[13]

H_5: Student perceptions of their level of active participation in science lessons (Student Perception Form, SPF) compared to observed activity levels of students (ACI).

H_o: There will be no significant correlations between the SPF student activity levels and the ACI observations of student activity levels.

[13]Baker, pp. 65-66.

Hypothesis 5 (Chapter III) anticipated that students would perceive the amount of time they spend actively involved in science lessons and that their perceptions would correlate with observed activity levels.

Five questions related to activity from the SPF were each compared to the three post-treatment observational ratios. The Student Perception Forms were administered to students in twelve classes during the post-treatment period (n=268). The SPF forms were completed immediately following an observed lesson.

The five questions for which correlation coefficients were calculated included:

1. During the science period, the class

   a. mostly listened to the teacher.
   b. mostly watched the teacher or a boy or girl do experiments.
   *c. mostly worked with equipment.

3. Most of the experiments were done

   a. by the teacher.
   b. by a few boys and girls.
   *c. by many boys and girls.

5. I got to work with the science equipment

   a. hardly at all.
   b. about half the time.
   *c. most of the time.

6. When I worked with the science equipment, I mostly did experiments

   *a. planned by the teacher.
   b. planned by the book.
   c. planned by my group.
   d. planned by the class.

7. It is all right to help other students in science

a. not at all
*b. sometimes
c. most of the time.

*The response most frequently chosen.

Each of the five questions were correlated with each of the three post-treatment ratios derived from use of the ACI. They are the Activity Ratio, the Laboratory Ratio, and the Questioning Ratio.

Table 4.11 reports the actual correlations between the SPF questions 1,3,5,6 and 7 and the ACI ratios, activity, laboratory and questioning. The number N in the table represents the number of teachers observed. The number of students completing Student Perception Forms was N-268.

Table 4.11 Pearson Product Moment Correlations Between SPF Questions 1, 3, 5, 6, and 7 and ACI Ratios for Activity, Laboratory and Questioning.

ACI Ratios		Student Perception Form Questions 1	3	5	6	7
Activity	r	0.41	0.08	0.19	0.07	-0.53
	N	12	12	12	12	12
	p	.10	.41	.28	.42	.04*
Laboratory	r	0.60	0.47	0.04	-0.57	-0.05
	N	12	12	12	12	12
	p	.02*	.06	.46	.03*	.44
Questioning	r	-0.59	-0.38	0.03	0.83	-0.31
	N	12	12	12	12	12
	p	.02*	.11	.06	.00*	.17

*Significant at the .05 level.

The correlation between student perceptions SPF Question 1 and the ACI ratios was significant at the .05

level relative to the lab and questioning ratios but not with the activity ratio.

There were no significant correlations between SPF Question 3 and the three ACI ratios.

There were no significant correlations between SPF Question 5 and the three ACI ratios.

The correlation between student perceptions SPF Question 6 and the ACI ratios was significant at the .05 level relative to the lab and questioning ratios but not the activity ratio.

SPF Question 7 correlated significantly at the .05 level with the ACI activity ratio but not the lab or questioning ratios.

Five of the fifteen cells represented in Table 4.11 show significant correlations. There is no consistent pattern of significance, therefore the null hypothesis is not rejected. The hypothesis (overall) that student perceptions of their level of active participation in science lessons would correlate significantly with observed activity levels is not supported.

Discussion

The ACI ratios combining information from several categories, may not correlate well with specific questions, as posed by the SPF. A closer examination of student responses to the five questions of the SPF may yield more accurate information.

Students most frequently chose the following responses to items: (n equals the number selecting a given response).

1. c. (n=170)
3. c. (n=229)
5. c. (n=175)
6. a. (n=135)
7. b. (n=203)

The majority of students indicate the most active role for students in their responses to items 1, 3, and 5. Most students perceived that planning for activities was carried out by the teacher. This represents the choice of least active role for students (item 6 SPF). Item 7 (SPF) is related to cooperation during science activities. Most students indicated that "It is all right to help other students in science, b- sometimes." This would indicate a somewhat active role for students. This information suggests that students perceived themselves as having a fairly active role during science activities with the scripted material. The use of a more sensitive statistical instrument or comparison of other observational and perceptual data may have yielded significant results.

Baker (1970) compared student and teacher perceptions on each item for the SPF and TPF. No statistical test was performed. His findings indicate that the reactions of both ESS teachers and their students are similarly high (active role of pupils) and proportional on items related to student activity.[14] His findings, for equivalent

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[14]Baker, pp. 70-79.

items (1,3,5,6, & 7 SPF), are supportive of findings in the present study. While the present study did not compare teacher and student perceptions, there may be some support for the view that students perceive scripted ESS lessons as fostering an active role for them.

H_6: Student achievement test results before and after exposure to the scripted science unit Peas & Particles.

H_o: There will be no significant difference in student achievement before and after exposure to the scripted science unit Peas & Particles.

Hypothesis 6 (Chapter III) anticipated an increase in achievement for students on objectives established for the Peas & Particles unit as represented by items on the unit test. Students were tested prior to exposure to the unit and immediately following its completion.

A t-test for dependent means was calculated for pairs of student scores (N-227).

Table 4.12 reports the actual comparison of means for the student unit achievement test scores pre- and post-instruction.

Table 4.12 t-test for Matched Pairs Between Pre- and Post-Instructional Scores on The Unit-Test of Achievement

Test	N	$\bar{X}$	Diff. $\bar{X}$	S.D.	Standard Error	t	p (2-tail)
Pre	227	12.94					
			-4.76	4.11	0.27	-17.45	>0.001
Post	227	17.70					

d.f. = 226

The difference in students' gain scores from the unit-achievement test, pre- and post-instructional, were significant at the .05 level. Therefore, the null hypothesis is rejected. The hypothesis that student gain scores on the unit-achievement test would be significant is supported.

Discussion

The low pre- and post-test means indicate that the test was difficult for this sample of students. The reliability coefficients for the unit achievement tests were relatively low. These two factors are probably related and are limiting factors to the claims of significance. Ebel (1979) points out that tests composed of very difficult or very easy items will result in lower reliability coefficients.[15] Item analysis (research question 1) will be discussed in the next section of this chapter.

The value of results on the achievement test may be in providing the researcher with information related to the difficulty of some concepts presented in the script. Nicodemus (1970) analyzed results on a test related to the order of complexity in ESS "Attribute Blocks". He suggests that results from student evaluation experiences are important in developing an heirarchy of behavior for teaching

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[15]Robert L. Ebel, Essentials of Educational Measurement, (Englewood Cliffs, N.J.: Prentice-Hall, 1979), p. 267.

with the materials.[16]

The importance of student evaluation instruments in curriculum planning is also supported by Labinowich (1970). His study dealt with summative evaluation with students who experienced the ESS unit Tangrams.[17] He concluded that evaluation of results from student tests were important in identifying unit objectives, grade level placement and the development of student evaluation instruments as well.

Summary

In general, the findings in this section can be summarized as follows:

1. Reliability for the student Unit-Achievement Test was obtained by measures of internal consistency. (Coefficient Alpha). The coefficients were .58 (pre-test) and .67 (post-test).

2. Interrater reliability coefficients were calculated using Scott's coefficient (Pi). The range of coefficients for paired observers was .81 to .97. Coefficients were calculated for the training, pre-treatment and post-treatment periods. Considering the number of

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[16]Robert B. Nicodemus, "Order of Complexity in Attribute Blocks," School Science and Math, LXX (October, 1970), 649-654.

[17]Edward P. Labinowich, "A Study in Summative Evaluation of Elementary School Science Curricula," Dissertation Abstracts International, XXXI (1970) 1077A (Florida State University, 1969).

observers (six) employed in the study, coefficients indicate the ACI to be satisfactory for use in observing science activities.

3. There is no difference in student activity, student laboratory, or teacher questioning levels before and after introduction of the script method of teaching.

4. Teacher perception of their amount of talk as measured on the teacher perception form correlates positively with the observed amount of teacher talk (ACI). The correlation was significant for the total teacher sample.

5. There was no consistent pattern established by the correlations of student/perceptions of their activity levels (responses to questions 1,3,5,6, and 7 on the Student Perception Form) with observed activity, laboratory, or questioning levels (ACI). The lack of a pattern may be related to incongruities existing between definitions of activity for the observation instrument and the student perception instrument.

6. Students demonstrated significant achievement of the goals and objectives related to the scripted "Peas & Particles" unit as a result of their participation in the unit.

Analysis of Research Questions

In this section four research questions will be analyzed. The data is represented in the form of field notes, anecdotal records, video-tapes of classroom activities, and interviews with teachers. The analysis of questions is preceded by a description of the teaching model used to modify the ESS unit Peas & Particles.

The revision is based on the script inquiry model proposed by Fitzgerald and Shroyer (1979).[18] The script represents a carefully planned unit of instruction.. Each activity in the unit includes teacher background information related to specific strategies, concepts or rules represented by that activity. A second portion of the script includes "teacher talk" related to introducing a problem and demonstration of a mini-challenge with students. This is followed by a few guidelines for a student exploration period and finally an outline of expected student responses is included.

The unit script presents an interesting problem or challenge and includes a sequence of carefully planned activities organized to develop necessary concepts, strategies, and rules to solve the problem. Each activity is characterized by three instructional phases: launching, exploring and summarizing. Launching includes whole class

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[18]William M. Fitzgerald and Janet Shroyer, "A Study of the Learning and Teaching of Growth Relationships in the Sixth Grade," (unpublished research study, Department of Mathematics, Michigan State University, 1979) pp. 2-7.

introduction to an activity and the issuing of a challenge. A demonstration of a mini-challenge is usually conducted during this phase along with a review of previous concepts or rules. During the exploration phase students focus, in small group work, on the challenge through manipulation of materials. During this phase the teacher circulates through the room helping students focus on the problem or maintain on-task behavior. Summarizing includes organizing and displaying data in an organized fashion, discussing results and strategies used to solve the problem and assist students in the recognition of related patterns and rules. The summary is conducted with the whole class.

The script used in the present study represents an interpretation of a science unit (Peas & Particles) related to counting methods, measurement, and estimation. The unit was revised to include a major unit challenge or problem focus. Each activity within the unit represents a measurement or counting method which may be used to solve a mini-challenge related to that activity or provide a strategy that may be used to solve the unit challenge.

The research questions are presented in the following order. Question 1 deals with item-analysis for the unit achievement test and a description of the task-interview test. Questions 2 and 3 are concerned with information collected on video-tape of three teachers' work with the script. These analyses will deal with teacher deviation from the script and teacher questioning categories.

Research question 4 presents data from the teacher logs and end of the unit evaluation forms for twelve teachers. This information deals with teacher deviation from the script, student discoveries, timing as it relates to the length of the three phases of each activity, and student interest and enthusiasm for the activities.

Q_1: What is the usefulness of the items on the test of achievement and the validity information for that test?

Question 1 (Chapter III) deals with the item analysis of unit test questions as well as presentation of the table of specification related to content validity.

In this section item analysis information will be presented concerning indices of discrimination, and difficulty. A discussion of this data will follow including a table of specification grid representing a possible revised unit-achievement test.

Table 4.13 presents the discrimination values for items on the pre- and post-unit-achievement tests. Ebel defines the index of discrimination as "...the difference in a proportion of correct responses between the group of those scoring in the top 27 percent on the total test and the group scoring in the bottom 27 percent on the same test."[19] In evaluating items Ebel recommends the following guidelines for item selection:

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[19]Robert L. Ebel, p. 376.

Index of Discrimination	Item Evaluation
0.40 and up	Very good items
0.30 to 0.39	Reasonably good items
0.20 to 0.29	Marginal items
Below 0.19	Poor items[20]

Table 4.13 Classification of Items from the Unit Achiement Test by Index of Discrimination

Item Evaluation	Index of Discrimination	Item Number*
Very Good	0.40 and up	6, 7, 10, 11, 12, 16, 20 21, 22, 23, 26, 28.
Reasonably Good	0.30 to 0.39	4, 8, 14, 19, 24, 25, 27, 32, 33, 35, 36.
Marginal	0.20 to 0.29	9, 13, 15, 17, 29, 30.
Poor	Below 0.19	1, 2, 3, 5, 18, 31, 34.

*The item numbers are from the post-test (Appendix H)

The sample size used was N-227. Ebel indicates that sample size and the kind of instruction are two factors contributing to sampling error.[21] Therefore, considering this sample and under the instructional conditions represented by this unit, the following may be stated. Twenty-three items are considered reasonably good to very good based on the index of discrimination. Thirteen items are considered marginal or poor based on the index of discrimination.

Table 4.14 presents the difficulty values for items on the pre- and post-unit-achievement test. Ebel defines

[20]Robert L. Ebel, p. 267.

[21]Robert L. Ebel, p. 375.

the index of difficulty as, "...the proportion of examinees in a group who do not answer the test item correctly."[22] Ebel goes on to state that, "...such indices are primarily used to analyze low discrimination items in terms of their extreme ease or difficulty."[23] Ebel recommends items of middle difficulty and notes "...the somewhat higher reliability of the scores from those tests composed of items more nearly in the mid-range of difficulty."[24]

The middle value of difficulty for this test was an index of 27 percent. An index of 54 percent indicates that all students in the group examined answered incorrectly on a given item. The table establishes the following ranges of difficulty:

Index of Difficulty	Item Evaluation
0 to 21 percent	Relatively easy
22 to 32 percent	Moderately difficult
33 to 54 percent	Too difficult

Table 4.14 Classification of Items from the Unit Achievement Test by Index of Difficulty

Item Evaluation	Index of Difficulty	Item Number*
Relatively Easy	0 to 21 percent	4, 7, 8, 11, 12, 15, 17, 19, 22, 28, 30.
Moderately Difficult	22 to 32 percent	1, 3, 5, 6, 10, 13, 14, 16, 20, 21, 23, 26, 27, 33, 35, 36.
Too Difficult	33 to 54 percent	2, 9, 18, 24, 25, 29, 31, 32, 34.

*The item numbers are from the post-test (Appendix H).

[22]Ebel, p. 375. [23]Ebel, p. 264. [24]Ebel, p. 267.

Discussion

Seven items poorly discriminated for students in this sample. Five additional items were considered too difficult for the sample. Combined they represent one-third of the total test. The results may indicate one reason for the relatively low reliability coefficients (.58 and .67 for the pre- and post-tests).

Items with low indices of discrimination may represent difficult thinking skills for this sample. Two items, possibly in this category, required students to evaluate estimation strategies and situations in which estimation of quantity was inappropriate (items 9 & 18, post-test). Four items with low discrimination indices involved the estimation of quantity as viewed in photos (slides) of objects. Teachers noted that the slides were too dark when viewed in rooms not equipped with room darkening shades. Several teachers expressed displeasure with using a test that required projection equipment to administer. (Items 1, 2, 3, & 5, post-test). Item 34 dealt with the concept of ratio. The question required students to apply the concept to a situation not covered in the unit.

One proposal for improving the test would be to eliminate items that discriminated poorly and revise marginal items. Figure 4.1 presents the table of specification grid for the proposed test. Item numbers represented in the table from the post-test. The table shows that activity objectives are maintained.

Figure 4.1 Proposed Unit Achievement Test Specification Grid

	INFERENCE	PREDICTION	MEASUREMENT	CLASSIFICATION	CONCEPTS	COMMUNICATION
Activity One Counting by Ones	21 22 23	16			15	
Activity Two Counting in Multiples & Rounding	36		7 30 8 35		25	
Activity Three Counting a Sample, Orders of Magnitude					29	
Activity Four Area	28 6		19		33	
Activity Five Volume			17		27	
Activity Six Halving & Doubling					32	
Activity Seven Balancing	26					
Activity Eight Weight		24				
Activity Nine Ratio				11 12 13	10	
Activity Ten Unit Challenge						20

Post-test item numbers are used in the specification grid, Figure 4.1, to represent items to be included in the proposed test. In addition items (numbers from the post-test) to be dropped: 1, 2, 3, 4, 5, 9, 14, 18, 31, and 34. The table of specification shows that all activities are represented in the proposed test.

Task-Interview Test

A second student test was used in this study. A randomly selected sample (N-36), including twelve students from each of three groups (high, middle and low), identified by scores on the California Achievement Test, were interviewed pre- and post-test. The actual number interviewed was N=27 on the pre-test and N=33 on the post-test. The two groups were independent.

There are four questions on the task-interview. Students were presented questions orally and expected to respond in the same manner. The questions and directions for administration are included with the scripted unit for teachers (Appendix A). The response sheet for task-interview is included in Appendix I.

Teachers were asked to record student responses as either complete, partial, or as no response. In addition they recorded a description of the counting method (s) given by students and include explanatory comments where necessary.

The task-interview represents a possible alternative

evaluation instrument to the unit-achievement test. The analysis includes teacher reaction to its inclusion as an evaluation instrument as well as a presentation of pre- and post-test results. This analysis was not conducted to determine significance of the comparison; however, a chi-square was calculated to determine the relationship between the pre- and post-test results for three response categories. A second chi-square was calculated for high, middle and low student group categories, comparing pre- and post-test results. The pre- and post-test groups were independent. The responses to three of the four questions on the task-interview were included in the analysis. Question two results were not included since it did not meet the requirement for score independence. Data from all questions are presented in tabular form including percents for each group.

Limitations of this type of testing include the degree to which teachers explain questions to students and the subjectivity involved in rating student responses. The sample sizes and possible discrepancies in the equivalence of the pre- and post-test samples are also limiting factors.

Table 4.15 presents results of the four questions, pre-test, from the task-interview with students. Three columns for four questions present the numbers of students responding whose answers were rated as complete, partial, or as no response. The rows present data for high, middle and low groups and the total group.

Table 4.15 The Number and Percent of Student Responses for the Task-Interview Pre-test

Student Group	Response Rating: Complete		Partial		No Response		Total	
N=27	N	%	N	%	N	%	N	%
High	18	16.7	14	13	76	70.4	108	100.1
Middle	10	9.3	14	13	84	77.8	108	100.1
Low	5	4.6	16	14.8	87	80.6	108	100.0
Total	33	10.2	44	13.6	247	76.2	324	100.0

Table 4.16 presents results of the four questions post-test, from the task-interview with students.

Table 4.16 The Number and Percent of Student Responses for the Task Interview Post-test

Student Group	Complete		Partial		No Response		Total	
N=33	N	%	N	%	N	%	N	%
High	34	25.8	24	18.2	74	56.1	132	100.1
Middle	25	18.9	28	21.2	79	59.8	132	99.9
Low	15	11.4	36	27.3	81	61.4	132	100.1
Total	74	18.7	88	22.2	234	59.1	396	100.0

Table 4.17 presents chi-square results for the following response categories: complete response, partial response and no response.

Table 4.17 Chi-Square as an Index of Association Between Pre- and Post-test Results, (Completeness of Student Response) on the Task-Interview Test

Category	N	χ^2	d.f.	p
Pre-test	27	12.26	2*	.001**
Post-test	33			

*d.f. = the product of the row and column degrees of freedom.
**significant at the .05 level.

The relationship between pre- and post-test results for categories of responses is significant at the .05 level. If a null hypothesis had been proposed it would have been rejected and the alternative hypothesis would have been accepted. Therefore, students were more successful on the post-test than the pre-test. The data show that more "complete responses" were recorded for the post-test and more "no responses" were recorded for the pre-test students.

Table 4.18 presents chi-square results for high, middle and low groups for the total of partial and complete responses between pre- and post-test results.

Table 4.18 Chi-Square as an Index of Association Between Pre- and Post-test Results, (High, Middle and Low Student Groups) on the Task-Interview Test

Category	N	χ^2	d.f.	p
Pre-test	27	0.60	2*	.75**
Post-test	33			

*d.f.= the product of the row and column degrees of freedom.
**significant at the .05 level.

The relationship between pre- and post-test results for categories of achievement was not significant at the .05 level. If a null hypothesis had been proposed it would not have been rejected. These data show that all groups improved in their ability to respond successfully to questions on the task-interview test. This may be considered a positive finding, indicating that unit materials may be responsive to several ability levels.

Discussion

The student responses were categorized in many ways until a system was found for representing the data that was clear and reasonable. Because of the exploratory nature of the task-interview test instrument, hypotheses were not generated.

Several teachers expressed satisfaction with the

task-interview as an evaluation tool. A disadvantage is that it would be impractical to interview all students; therefore, it may not be useful as an evaluation tool for individual students. It may be useful as a monitor of unit content and instruction.

A similar interview test was developed by Wideen (1975).[25] Wideen compared ESS and SAPA (Science--A Process Approach) teaching methods and as a part of the study presented students with a problem situation and asked them to answer orally. Wideen represented responses in a six-category table related to "reasons and causes" for the observed events. He was unable to discern any difference between groups and no statistical test was applied to the results. While the present study did not compare teaching methods and no statistical significance is claimed, results demonstrate a positive difference from pre-test to post-test. The findings may be viewed as encouraging with respect to further development of the task-interview test.

Summary

Index of discrimination indices for the unit-achievement test indicate that twenty-three items were rated as reasonably good or very good.

One-third of the items on the unit-achievement test either discriminated poorly or were rated as being too

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[25]Marvin F. Wideen, The Psychological Underpinnings of Curricula: An Empirical Study, U. S. Educational Resources Information Center, ERIC Document ED 103 933, March, 1975.

difficult for students and may have been responsible for the low reliability coefficients for pre- and post-tests.

A revised unit-achievement test is proposed that would include twenty-six of the thirty-six items from the original test. The items to be included in the proposed test are presented in a table of specification showing that all activities are covered in the new instrument.

Results from the task-interview test for students indicate that students may improve in their ability to explain counting methods and estimation strategies as a result of exposure to the unit materials. In addition, there is some evidence to suggest that student ability to orally describe counting methods may improve as a result of participation in the Peas & Particles unit.

Teachers viewed the task-interview as an acceptable evaluation instrument; however, it may be impractical to interview all students. Therefore, its use may be limited to monitoring unit effectiveness. Results are encouraging and may suggest that further development of the task-interview is warranted.

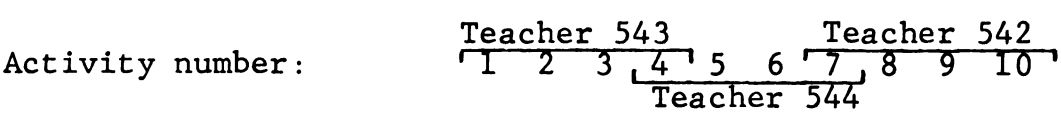
Research questions concerning teaching with the script are presented next. Questions 2 and 3 deal with data collected on video-tape of three teacher's work with the script. These analyses will deal with teacher deviation from the script and teacher questioning categories. Research question 4 presents data from (twelve teachers) teacher logs and end of the unit evaluation forms. This

information deals with teacher deviation from the script, student discoveries, timing as it relates to the length of the three phases of each activity, and student interest and enthusiasm for activities.

Q_2: What deviations from the script were observed and what is the relationship of these deviations to the script?

Question 2 (Chapter III) anticipated that teachers would not necessarily follow the script as written and that these deviations could be related to their interpretation of the script or deficiencies in the script.

This question is addressed from information collected on video-tapes of three teachers. Teachers 542, 543, and 544, all of the North Country Elementary School, were observed four times each during the course of the entire unit according to the following observation model.



The observer (researcher) interviewed each teacher following each observation of his/her teaching. Video tapes were used to stimulate teacher and observer recall of teaching events including deviations from the script. During the interview both researcher and teacher became observers of recorded classroom events. Teachers were able to explain deviations and make suggestions for improving the script.

The following discussion will follow the course of the unit and include a description of teacher digression and

its relationship to the script. The script is found in Appendix A.

Teacher 543 introduced the challenges to each of the first three activities verbally with no teacher demonstrations. In activity four she used the overhead projector to introduce the area counting method. As a result of the short challenges she spent a great deal of time during the exploration phase cueing and leading the children toward use of the counting strategy called for in the challenge. Children did reach the goal of applying the correct counting strategy in each lesson, but much of the time was spent in getting underway. During the interview the teacher indicated that she felt that the intentions of the script were to have children discover the counting strategy.

Teacher 543 spent some time at the beginning of each lesson demonstrating techniques for managing the particles. Children did have some difficulty with funnels and egg cartons when it came time to pour the material back into jars.

During the presentation of the challenge in activity four the teacher alluded to ceiling tiles and floor tiles to assist children with the area method of counting and as an analogy to the peas on the overhead. During the interview she expressed the need for small inch-square tiles for this purpose and as part of the mini-challenge.

Teacher 543 posted extra challenges on the bulletin board and referred students to them during the activities.

Story challenges were generally covered at the end of each activity.

Teacher 544 very deliberately developed the mini-challenges for each of the four lessons observed. Story challenges were covered at the beginning of activities and a demonstration of the counting method was conducted. She also attempted to make real connections between the story challenge and her demonstrations. For example, she referred to the peas on the overhead display as being similar to the heads in the story challenge (people standing on a dock). As a result of the careful introductions children in this class spent more time developing the counting strategies in their own way. Several children used class time in activity four to work on extra challenges. Multiplication of two-place numbers became a problem as children worked with larger quantities. The teacher indicated that the material covered in the unit was part of the fourth grade curriculum, but that many ideas were not covered until the second semester. It is noted that, while teacher 544 spent a greater portion of time than either of the other two teachers observed presenting the challenge, she did express the belief that the students would be expected to discover more on their own.

Teacher 544 indicated that a clear rectangular box would be useful in activity five for demonstrating the concept of "layering" as a counting strategy. Students had the use of small identical plastic trays. The intention

was to have them fill a number of trays, exhausting the supply of peas in one jar. They then would stack them up, use the area method to find an estimate for one tray and multiply by the number of layers (trays). Two strategies developed by children for the volume method included using a ruler as a "dipstick" in a jar of peas to determine the number of layers and filling the lid of a wide-mouthed mayonnaise jar with one layer of peas, dumping these into the jar, and then repeating the process until the jar was filled. A tally of the number of times the process was repeated served as their estimate for the number of layers in the jar.

During the development of the halving and doubling mini-challenge children in teacher 544's class discovered that the number of times the pile of rice displayed on the overhead was halved was one less than the number of piles of rice created. Children had to be reminded to keep a tally of the number of times a pile of particles was halved during the exploration period. This teacher expressed the opinion that the transition to activity seven, where large pan balances were used to halve quantities was important to the children in the following ways: It reinforced concepts learned in activity six and allowed students an opportunity to compare the two methods for halving and doubling.

The third teacher observed was teacher 542 (activities seven through ten). Children in her class had difficulty using the large pan balances required in activity

seven. The teacher expressed the need to instruct children in the use of these balances and the spring scales used in activity eight as a pre-requisite to conducting the activities. Teacher 542 stated that children had difficulty seeing the continuity between activity six and seven because it requires some abstract thinking on their part. Other problems brought up by teacher 542 during the interview included:

- management of materials.
- use of spring scales, reading a scale and the problem of using spring scales calibrated in both the metric and English systems.
- too many children in too small a classroom environment.
- record keeping and the need for data recording sheets for each activity.

Deviation from the script for teacher 542 mainly related to problems with material management. She offered two alternative instructional settings as a means to manage materials better. The first alternative suggested involved setting up a science corner in the room for small groups to explore separately from the rest of the class, and the second included use of shoebox lessons intended for individual exploration. A further suggestion offered by this teacher involved giving each child a copy of the story challenges a day in advance of the planned activity. She then would explain to them that it was related to what they would be doing the next day and ask them to write down ideas for discussion during the mini-challenge. The suggestion

was intended to reduce the amount of time spent on the challenge and provide an opportunity for children to think more on their own.

Teacher 542 stated that the sampling concept was one of the key strategies that children needed to learn and was, in fact, developed by this unit. In activity ten children were encouraged to think of their class as the sample for solving the "popcorn problem" for the school population of children.

During the summary phase of activities none of the teachers were observed stressing record keeping or saving data collection sheets, although it seemed implicit in teacher 544's class. Children in this group were observed using folders for their records and notes.

Teacher 543 stated that the number line was more useful in the summary for activity two than activity one for comparing guesses and estimates. She noted that use of the number line in activity one served to point out wide disparities in guesses and estimates. During the discussion for activity one she pursued the variables involved in handful estimates including size of the hand, the way beans were grasped, definition of a handful, and counting broken particles. In activity two the number line served to highlight the consistency of estimating as compared to the wide range of guesses.

Generally, it was observed that, due mainly to the constraints of time, summaries were cut off before many

ideas were discussed.

Discussion

The concern of teachers 543 and 544 for students' discovering more on their own may reflect their training and years of experience with the ESS program. This concern may be evidence of Hawkin's "Messing About" plan for instruction.[26]

Teacher 543 did not develop mini-challenges as thoroughly as the other two teachers observed and subsequently spent greater portions of exploration time cueing students as to the counting method to be used and its relationship to previously learned material. Observations related to this situation may support Hudgins, Huff and Freundlich who outline several factors related to assisting students in the recognition of a problem and the importance of a clear definition of a problem before exploration work on its solution can begin.[27]

There is some evidence to support the work of Rachelson (1977) concerning hypothesis generation.[28] While this

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[26]David Hawkins, "Messing About in Science," The ESS Reader, Educational Development Center (Newton, Ma.: Educational Development Center, Inc., 1970), pp. 37-44.

[27]Bryce B. Hudgins, Problem Solving in the Classroom, The Psychological Foundations of Education Series (New York: MacMillan, 1966), p. 2; see also James W. Huff, "The Concept of a Problem in Inquiry Teaching," Dissertation Abstracts International, XXXVIII (1978), 2641 (University of California, Los Angeles, 1978); see also Yehudah Freundlich, "The Problem in Inquiry," The Science Teacher, XLV, February, 1978), 19-22.

[28]Stan Rachelson, "A Question of Balance: A Wholistic View of Scientific Inquiry," Science Education, LXI (January-March, 1977), 109-117.

inquiry unit did not emphasize hypothesis generation, it is clear that in several cases, in which children developed strategies for solving mini-challenges, this occurred.

Johnson (1979) in a study concerned with a teacher's first experience with a science unit concluded that curriculum implementation "...is a dynamic succession of cumulative communications between curriculum developer, curriculum implementer, teacher and student.[29] There was evidence to support Johnson's findings relative to communication. The three teachers' in the present study, interpretations concerning the purpose of the launching phase and introduction of the counting methods may be an example of a failure of the training or script to communicate the curriculum developer-implementer's intention.

Summary

Teachers expressed need for more direction from the script in dealing with mini-challenge demonstrations, materials management, pre-requisite information for working with the measurement tools, and record keeping and data collection procedures for students.

There was evidence to support the script as allowing for individual student discovery and use of extra challenges with students.

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[29]Sylvia Fogelquist Johnson, "A Cognitive Study of an Elementary Teacher's First Experience Teaching A 'New Science' Unit and Its Relevance to the Implementation of Science Programs," (unpublished Doctoral dissertation, University of Illinois, 1979) pp. 254-255.

Pacing of activity phases may be a problem, since the summary phase was shortened on several occasions due to the constraints of time.

Teachers expressed the need for additional materials for use in teaching area and volume concepts with students. It appears that the unit may be better suited to the second semester of the fourth grade because of the number and difficulty of math concepts contained in the unit.

Q_3: What is the classification and frequency of questions asked during instruction using the script?

Question 3 (Chapter III) anticipated that teachers would ask students greater number of questions during exploration and summary phases of the scripted unit as compared to the launching phase. Questions were classified according to four categories of "Soliciting Moves" from the Classroom Observational Record (COR) interaction analysis instrument. The categories are: recall, collecting data, processing data, and evaluation level questions. It was anticipated that the greater proportion of questions would be above the recall level during use of the script.

The question is addressed from information collected on video-tape of three teachers: teachers 542, 543 and 544, all of the North Country Elementary School. Each teacher was observed four times, covering all ten activities which comprised the scripted unit.

Table 4.19 presents a tally of the number of questions asked for each phase, and the total number of questions

for each activity. A total for each of the three phases and for all activities is also presented in this table. Finally the table presents the percentage of questions asked for each activity as compared to the total and the percentage of questions asked during each phase for all activities. Note that question frequency as presented in this table represents a one-teacher sample for each activity and may not be representative of all teachers using the script.

Table 4.19 The Number and Percentage of Total Questions Asked for Each of the Ten Activities For the Scripted Unit from Observations of Three Teachers

Teacher Observed	Activity Name	No.	Number of Questions Asked Launch	Explore	Summary	Total	Percentage of Total Unit
543	Handful	1	3	15	64	82	11.0
543	Multiple	2	5	10	45	60	8.0
543	Sample	3	0	55	14	69	9.2
543	Area	4	36	39	n.r.	75	10.0
544	Area	4	3	29	37	69	9.2
544	Volume	5	22	44	9	75	10.0
544	Halve	6	21	13	12	46	6.0
544	Balance	7	7	22	n.r.	29	3.8
542	Balance	7	9	35	15	59	7.9
542	Weight	8	0	50	32	82	11.0
542	Ratio	9	10	39	12	61	8.1
542	Popcorn	10	22	20	0	42	5.6
	TOTALS		138	371	240	749	99.9
	% of Grand Total		18.4	49.5	32.0	99.9	

n.r.=No record.

If questioning were distributed evenly, each activity would include ten percent of the total number of questions asked. This did not occur. The percentage of

questions for each activity ranges from 3.8% for activity seven to 11% of the total number of questions asked for activities one and eight. The low percentage reported for activity seven partially reflects the fact that no record of the summary was made. The class ran out of time and the summary was conducted at a later time when the observer was not available. The second lowest percentage of questions occurred during the final activity (5.6%). There was no summary conducted during this activity by teacher 542. Perhaps the children were too busy eating popcorn. There is no explanation for the third lowest proportion of questioning, recorded for activity six (6.0%). The remaining seven activities range between 7.9 and 11.0 percent. Reasons for the difference in frequency of questioning from activity to activity may be related to teacher background and experience relative to teaching specific counting methods, the degree of difficulty of concepts for specific activities and teacher interpretation of the intentions of the script for each activity. It is not intended that the script provide all questions for teachers beyond encouraging open questioning during the exploration phase and inclusion of several questions for the summary phase based upon expected results.

Table 4.19 shows that, for the three teachers observed and for the twelve observations of activities, nearly fifty percent of all questions were asked during the exploration phase. The summary phase showed the second

highest total; however, these figures may be depressed as the result of the loss of two observations of summary phases.

Table 4.20 presents a tally of the number of questions asked from each of four categories of "soliciting moves" for each of the three activity phases. The percentage of questions asked from each category for each phase is also presented. The numbers represent totals for all ten activities presented in Table 4.19.

Table 4.20 The Number and Percentage of Questions Asked by Category for All Ten Activities for the Scripted Unit from Observations of Three Teachers

Category	Activity Phase	Number of Questions	Percentage for Phase
Recall	Launch	51	37.0
Collecting Data	Launch	25	18.1
Processing Data	Launch	49	35.5
Evaluation	Launch	13	9.4
Total		138	100.0%
Recall	Exploration	79	21.3
Collecting Data	Exploration	187	50.4
Processing Data	Exploration	96	25.9
Evaluation	Exploration	9	2.4
Total		371	100.0%
Recall	Summary	48	20.0
Collecting Data	Summary	110	45.8
Processing Data	Summary	69	28.8
Evaluation	Summary	13	5.4
Total		240	100.0%

The launching phase had the fewest total questions asked of the three phases. During the launching phase a greater proportion of questions occurred at the recall level

as might be expected, since a large portion of the launch involves reviewing the focus of the previous activity. It is noted that a nearly equivalent number of questions were asked during this phase dealing with the "processing of data". Questions arose in this phase as the result of presenting a mini-challenge to pupils involving a counting rule or method. It is further noted that an equal number of "evaluation" questions occurred in the launching and summary phases. While the tally for this category is small at thirteen, it is important to note that higher level questioning did occur during the initiating phase as well as during the summary.

The exploration phase included the greatest number and proportion of questions concerned with "collecting data." This was expected, since data collection represents one of the major tasks of students during this phase. The second greatest number of questions occurring for the exploration phase was concerned with "processing data," with "recall" questions being asked ranking third in frequency. Nearly fifty percent of all questions occurred during the exploration phase. Teachers were observed circulating throughout the room, meeting with groups and assisting students in focusing on the challenge.

The second greatest number of total questions asked occurred during the summary phase (32%). As in the exploration phase, questioning during the summary phase was concentrated on "collecting data", with "processing data"

questions appearing second in frequency. It was expected that the summary phase would include a greater proportion of "evaluation" questions. This did not occur, as only 13 or 5.4% of the questions asked during the summary phase fit this category. This may be related to the fact that two observations have no record of questioning for this phase, and during the observation of activity ten no summary was conducted. A second reason relates to time. It appears that when time runs short, summarizing is the phase that is curtailed.

Table 4.21 presents the tally for the total number of questions for all activities and phases for each of the four categories of questions. This table is included to demonstrate that for the three teachers observed "data collection" questions were posed most frequently, with "processing data" questions and "recall" questions ranking second and third, respectively. "Evaluation" questions appear with the least frequency suggesting a need that more scripted questions be drawn from this category.

Table 4.21 The Number and Percentage of Questions Asked by Category for All Activities and Phases of Activities for the Scripted Unit from Observations of Three Teachers

Category	Number of Questions	Percentage of Total
Recall	178	23.8
Collecting Data	322	43.0
Processing Data	214	28.6
Evaluation	35	4.7
Total	749	100.1

Discussion

Johnson (1969) and Kondo (1968) found that student investigations with hand-on activities were instrumental in setting conditions for teachers to ask questions above the pupil recall level.[30] The findings in the present study, at least in the case of three teachers, may support this finding to a limited degree.

It is noted that processing data and evaluation questions display limited frequency which may indicate the need for more careful planning of questioning agendas.

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[30]Robert Walter Johnson, "A Model for Improving Inservice Teacher Questioning Behavior in Elementary School Science Instruction," Dissertation Abstracts International, XXX (1970) 1666A, (Wayne State University, 1969); see also Allan Kiichi Kondo, "A Study of the Questioning Behavior of Teachers in the Science Curriculum Improvement Study Teaching the Unit Material Objects," Dissertation Abstracts International, XXIX (1969) 2040A, (Columbia University, 1968).

There was little evidence to support Reynolds', et al. (1971) contention that the shift from recall and data collecting questions toward data processing and evaluation questions improved pupil problem solving ability.[31] No shift was observed since a comparison between groups was not made for the questioning categories. However, it is encouraging to note that processing data questions occurred more frequently, for this limited sample, than recall questions.

These findings may support the need for teacher planning with regard to pacing each activity so as not to limit the period of time devoted to the summary phase.

Summary

The frequency of questioning varied greatly from activity to activity. This may be related to teacher background and experience related to teaching specific concepts, the degree of difficulty of concepts for students and teacher interpretation of the script.

More questions were asked during the exploration phase than the other two phases. The summary phase contained the second greatest number of questions, although there was no record of observations for two activities during this phase. There is evidence to support the need

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[31]William W. Reynolds, Jr., Eugene C. Abraham, and Miles A. Nelson, The Classroom Observational Record, U. S. Educational Resources Information Center, ERIC Document ED 048 378, February, 1971, pp. 9-10.

for more careful planning of time so that summary phases are not curtailed.

The script may contribute to a greater frequency of teacher questions occurring above the recall level. This is very tentative considering sample size and the lack of a comparative sample in the study. However, it may represent a possible hypothesis for future study.

The limited frequency of evaluation questions may support the need for more careful planning agendas in future scripts.

Q_4: What information from the end of the unit evaluations, teacher logs and interviews with teachers indicates need for further revision of the unit?

Question 4 (Chapter III) anticipated that, as a result of working with the scripted unit, teachers would have suggestions to make concerning revision of the unit. These suggestions could be represented by explicit remarks made by teachers or by implicit trends found in information collected from all teachers.

The question is addressed from that information collected: (1) through logs of daily activities completed by all teachers during the course of the unit, and (2) those responses found in the "End of the Unit Evaluation Form" completed by each teacher.

The teacher log is composed of three sections. The first deals with the amount of time teachers spend on the launch, exploration and summary phases of an activity. The second section deals with student discoveries and teacher

deviations from the script. The third section calls for teacher's ratings of student attitude toward each activity on a five-category scale.

Information emanating from teacher logs is discussed first followed by an analysis of the results of the End of the Unit Evaluation Form. Table 4.22 presents information concerning the number of logs and End of the Unit Evaluation Forms (EUEF) completed and returned to the researcher. Logs were inserted at the end of each activity as a reminder to teachers and for their convenience. During training teachers were asked to complete the logs as soon as possible following the instructional period. The EUEF was inserted at the end of the unit with a reminder to complete them. Those forms not completed were returned to teachers with a second reminder attached. One teacher (341) did not return any materials to the researcher. Four teachers failed to return the EUEF despite the second reminder.

Table 4.22 Tabulation of Completed Teacher Logs and End of the Unit Evaluation Forms

Teacher Number	Completed Logs 1	2	3	4	5	6	7	8	9	10	Completed EUEF
143	x	x	x	x	x	x	x	x	x	x	x
145	x	x	x	x	x	x	x	x	x	x	x
241	x	x	x	x	x	x	x	x	x	x	no
244	x	no	x	x	x	x	x	x	x	x	x
341	no	no	no	no	no	no	no	no	no	no	no
344	x	x	x	x	x	x	x	x	x	x	x
442	x	x	x	x	x	x	x	x	x	x	x
443	x	x	x	x	x	x	x	no	x	x	x
542	x	x	x	x	x	x	x	x	x	x	x
543	x	x	x	x	x	x	x	x	x	x	no
544	x	x	x	x	x	x	x	x	x	x	x
645	x	x	x	x	x	no	x	x	x	x	no

Timing - Teacher Logs

Timing in this discussion is related to the amount of time spent in each phase of an activity and the total length of each activity. A record of the time spent on each activity and its different phases was collected to determine variations exhibited by teachers in working with the materials. The expenditure of time may shed some light regarding problems with the script and difficulties teachers and children encountered in the presentation and comprehension of certain concepts. Such information also serves to

illustrate the pace of each activity, the amount of time students have working with materials, and the amount of time spent in groups or whole class discussions.

Table 4.23 presents the average amount of time teachers spent in each of three phases and the average length of each total activity. The range, from lowest to highest amount of time, is also presented for each phase and total activity following the average figures. At the bottom of each column in the table the average for all ten activities is presented for launch, exploration, summary and total activity.

It was expected that the time needed to complete activities would vary somewhat from teacher to teacher. The extreme exception to each range and average for given teachers is discussed to determine reasons for these extremes.

Teacher 145 reported extremely long activities. Activity length for this teacher ranged from 90 to 150 minutes. Phases of each activity, for this teacher, have the following ranges: Launch, 15-45; Exploration, 40-60; and Summary, 15-60 minutes. The average activity ran over two hours for teacher 145.

It appears that this teacher allowed a great deal of time for exploration. While he seems to have used the script, it appears that students were allowed great freedom to pursue many avenues of exploration. As an example, on his log from activity two, he indicates, "I spent a great

Table 4.23 Average Time and the Range of Time (All Teachers) For Each of Three Phases and the Whole Activity or Each of Ten Activities; The Average Time for Each Phase Over All Activities And The Average Activity Time For All Activities*

Activity Number	Launch Phase			Exploration Phase			Summary Phase			Total Activity	
	N	Average	Range	N	Average	Range	N	Average	Range	Average	Range
1	9	12.4	5-20	9	23	10-45	9	17.9	5-45	53.3	30-110
2	10	12.5	5-25	10	24.5	10-45	10	17.0	10-60	54.0	35-130
3	10	13.5	5-30	10	30.5	15-60	10	20.6	10-60	64.6	40-150
4	10	15.0	5-30	10	29.7	15-60	10	18.3	10-60	63.0	40-150
5	11	17.1	5-45	11	27.3	15-45	11	14.0	5-30	58.4	35-120
6	10	18.5	5-30	10	35.0	15-60	10	12.5	5-30	66.0	30-105
7	10	14.5	5-30	10	29.5	10-45	10	10.5	5-20	54.5	30-90
8	9	13.6	5-45	9	29.4	20-40	9	13.9	5-30	56.9	30-115
9	10	14.5	5-45	10	35.0	20-60	10	15.0	5-45	64.5	35-150
10	11	10.9	5-20	11	27.0	10-60	11	14.0	5-30	51.9	30-105
Average For All Activities	13.16 minutes			29.09 minutes			15.37 minutes			57.62 minutes	

*All averages and ranges are reported in minutes.

deal of time on order of magnitude"; and in response to reasons for the deviation, he writes, "the children were never exposed to this before." Activity length was 130 minutes. Students in this class were expected to discover the variety of counting methods. He indicated in an interview that much of the launch time was spent in handing out and managing materials. This teacher also spent a great portion of time during activity three on orders of magnitude and scientific notation. The reason given was that children had never been exposed to the idea before.

At the other extreme several teachers indicated that they were uncomfortable when children were handling the particles. On several occasions exploration was limited. Teacher 543 instructed students to either count by twos, threes, fives or tens, then had them deposit their multiples in sections of egg cartons and compute the quantity. The activity was structured carefully and limited to a total time of thirty minutes. Teacher 344 limited the amount of particulate material to be balanced in activity seven to one cupful thereby effectively shortening the activity to a half-hour.

With the extremes removed average activity length ranged from 45 to 55 minutes.

Activity six had the longest average launch time (18.5) with activity ten, the unit challenge, the shortest. Teachers wrote in their logs that halving and doubling (activity six) was a difficult one for children. Teacher

442 stated that the concepts should be taught over two days. The mini-challenge had the potential for several components as some teachers used extra challenges during the launch. The launch for activity ten was short, perhaps because children were familiar with the unit-challenge and had already discussed it in activity one.

Activity six and nine were the longest for exploration. Activity six was the first time children had to work with large quantities of particles (gallon jars full) and the procedure was lengthy. Teachers wrote that children often forgot to tally the number of times a quantity was halved; therefore, they had to repeat steps in the exploration.

Activity nine (ratio) was difficult for children. The script, again called for working with gallon jars of materials. Several teachers indicated that smaller quantities of particles would have been sufficient, since children had already worked with large quantities of particles in preceding activities. In addition, large quantities were not necessary for developing the concept of ratio which is related to comparative particulate size.

The shortest exploration periods occurred for activities one and ten, which was expected since activity one dealt with small quantities and a simple challenge and activity ten was handled more as a total group exploration to solve the unit challenge.

Activity seven had the shortest average summary

time. This activity utilized the halving and doubling method introduced in activity six. This may be one reason for the shorter summary period. As discussed previously, another reason which apparently affected summaries in all activities was time. Several teachers cut summaries short when pressed for time in the classroom.

The averages for all activities emphasize that the exploration phase dominated, with launching and summarizing taking a nearly equal amount of time overall.

Teacher Comments - Teacher Logs

Teachers were asked to comment on student discoveries and their own deviations from the script. The information is discussed with respect to further revision of the script. In this section each activity will be identified by the counting method emphasized in that activity. Information relative to teacher's suggestions for improvement of the activity will be included.

Activity One: Handful estimates, counting by ones.

Several teachers discussed the variables involved in handful estimates. Included were the size of the lima beans, the size of the hand, and the method of scooping up handfuls. In addition teacher 543 wrote that children in her class decided that a handful was not a standard measure. She explored the idea of finding the average handful and establishing a standard, but gave up because she felt students had difficulty understanding the concept of average.

Activity Two: Counting in Multiples.

Teacher 645 indicates that she directed students to count in multiples. She wrote that pupils were so disturbed by the varying "counted" amounts reported for the six quart jars of lima beans that the class decided to recount all the particles. In addition they graphed student guesses and estimates. It is noted that estimates were listed in amounts carried out to the one's place, whereas estimates were reported rounded to the nearest ten.

Activity Three: Counting a Sample.

The story challenge for this activity may be too abstract for students in the fourth grade. Perhaps a story challenge more directly related to the activity would be more appropriate. The script should also encourage rounding off to the hundred's and thousand's place.

Activity Four: The area counting method.

Teachers' comments relative to activity four focused on improving the lesson mini-challenge. The mini-challenge involved displaying peas on an overhead projector in a rectangular pattern. In addition a story challenge asked pupils to estimate the size of a crowd standing on a rectangular fishing dock. The consensus of teacher comments indicated that additional cues were necessary to educe the area counting method from students. Teacher suggestions included: "Compare the peas to people's heads;" "Introduce

a rectangular pattern of ceramic tiles on the overhead first, discuss area, then introduce the peas," and "Start with one row of peas on the overhead and add one row at a time while encouraging pupils to count the total number of rows and then have them multiply that figure times the number of peas in the first row."

Activity Five: The volume counting method.

The use of a hands-on mini-challenge may be necessary in activity five. Perhaps use of the "peas picture" included with the unit would be useful for this purpose. Pupils could use the area method for finding the quantity of peas in one picture (layer), stack several pictures and multiply by the number of layers. Teacher 145 used graph paper in activity four to encourage pupils to use the area method, he then produced a three-dimensional model for the volume counting method by folding the graph paper lengthwise. Several teachers stressed rounding off of length, width and height "counts" to simplify the multiplication.

Activity Six: The halving and doubling counting method.

In activity six, careful development of the mini-challenge is necessary. Teachers noted that many children failed to keep a tally of the number of times they had halved a quantity prior to the doubling procedure. Demonstration of the strategy on the overhead projector with a pile of rice along with having the entire class go through the process by folding the "peas picture," seemed critical

to student success with the gallon jars of particles.

Activity Seven: The halving and doubling method of counting with a large pan balance.

Activity seven may represent two lessons. First, the halving and doubling of quantity using the pan balance and then comparison of a quantity of particles to a standard mass on the balance pans.

Activity Eight: The weight method of counting.

In activity eight the challenge may have been too difficult for students. They were asked to measure, using a spring scale, the weight of a small quantity of particles and then use this information to estimate the quantity of particles in a fifty pound sack. Teachers also indicate that students need more guidance and practice using the spring scales.

Activity Nine: The ratio method of counting.

The concept of ratio may be too difficult for pupils from this age group. The mini-challenge should include a demonstration of ratio as it is used in the activity. Example: fill each of five medicine cups with different particles, count the quantity in each, represent them on the chalkboard, and develop ratios by comparing the particle size as represented in the displayed counts.

Activity Ten: The unit challenge.

Comments for this activity included recommendations for review of the previously used counting methods, and student evaluation of those methods to determine the most appropriate strategy for solving the unit challenge. Two teachers suggested emphasis on the sampling method for activity ten.

Attitude Rating - Teacher Logs

Table 4.24 presents teacher ratings of student enthusiasm and interest for each activity. The teacher log is found in Appendix G.

According to the teachers included in this study children exhibited above average enthusiasm for most activities. Students were rated as being most enthusiastic toward activities one and ten. A moderate enthusiasm characterized student attitude toward most of the other activities. Exceptions were activity five (volume) and nine (ratio) in which children's enthusiasm is rated "average."

The lower overall rating of student attitude for activities five and nine may be related to the difficult concepts involved in those activities. Teachers expressed difficulty in teaching the concept of ratio in activity nine.

This suggests the need for script revision for these activities.

Table 4.24 Teacher Log Rating of Student Attitude for Each Activity

Activity Number	N	Enthusiasm and Interest High	Moderate	Average	Low	Very Low
1	11	7	1	3	0	0
2	9	3	3	3	0	0
3	9	2	4	3	0	0
4	9	2	5	2	0	0
5	10	1	3	7	0	0
6	9	3	4	2	0	0
7	9	2	4	3	0	0
8	10	1	5	3	1	0
9	10	2	3	4	0	1
10	8	5	0	1	2	0

End of The Unit Evaluation

Table 4.25 presents teacher unit evaluation information. The form serves as a table of teacher responses. The number of teachers responding N is listed under the form heading. Numbers on the form represent a tally of teacher responses to each item.

The End of The Unit Evaluation (EUEF) is a nineteen-question survey and was completed by eight teachers. Questions on the survey relate to the scripted unit and deal with its difficulty for children, laboratory time, student attitude, the unit's success, grade level placement, attitudes toward specific activities, and sufficiency of materials and teaching time.

Questions one and two on the survey dealt with the difficulty levels of concepts and process skills presented

in the unit. Six of the eight respondents rated the unit as being difficult for fourth grade pupils on these criteria. The content (question three) was rated by four teachers as being difficult and by four teachers as being satisfactory. Students spent from forty to seventy percent of their time in the exploration phase. Three teachers indicated that sixty percent of their class time was devoted to this phase (question four). Six out of eight teachers noted that there was a sufficient amount of time devoted to exploration (question five). Student enthusiasm and interest was rated as being average by four teachers, moderate by three and high by one respondent (question six). Six teachers rated the scripted unit as being more successful with children than the ESS unit Peas & Particles. Two teachers did not respond to this question (question seven). In response to question eight, six teachers indicated that the unit belonged at the fourth grade level. Two teachers responded negatively and recommended in question nine that the unit belonged in the fifth grade. All teachers completing the form covered all ten activities (question ten). Teachers selected activity nine, dealing with ratio, as the one activity they would eliminate, if necessary.

Question thirteen and sixteen referred to the popularity of specific activities for both teachers and students. No single activity dominated as being the favorite. All were listed with the exception of activities

three, seven, eight and nine. The majority of teachers responding on behalf of themselves and their students listed activity nine as the least popular. Activities five, eight, and ten were also listed as being unpopular with students. Teachers also regarded activities three, seven and eight as unpopular.

The majority of responding teachers indicated sufficient materials and time was available for completing each activity (questions seventeen and eighteen). Five teachers signified that there was sufficient time to complete all unit activities while three wrote that the unit was too rushed (question 19).

Table 4.25 End of the Unit Evaluation of
Peas & Particles

N = 8

1. How would you rate concepts presented in the unit?
_____too difficult __6__difficult __2__satisfactory
_____easy _____too easy.

2. How would you rate process skills presented in the unit?
_____too difficult __6__difficult __2__satisfactory
_____easy _____too easy.

3. How would you rate the content presented in the unit?
_____too difficult __4__difficult __4__satisfactory
_____easy _____too easy.

4. What percent of the time was usually devoted to exploration or lab work in each lesson?
___0 ___20 ___30 _2_40 _2_50 _3_60 ___70 ___80 __90

5. Do you think more time should be devoted to lab time in the future? __2__yes __6__no

6. Rate student attitude for the entire unit.
__1__very enthusiastic
__3__moderate enthusiasm
__4__average enthusiasm and interest
_____somewhat uninterested
_____very uninterested

7. Generally speaking do you think that the children experienced more success with the scripted unit than the same unit as it was taught? __6__yes _____no.
If no, please comment. __2__(no response)
1 noted that she hadn't taught the ESS unit.

8. Do you think that this unit belongs at the fourth grade level? __6__yes __2__no.

9. If no, what grade level would you recommend?
___2 ___3 _2_5 ___6

10. Did you cover all the activities? __8__yes _____no

11. If no, please check the activities you did cover.
___1 ___2 ___3 ___4 ___5 ___6 ___7 ___8 ___9
___10 ___11

12. If you had to eliminate one activity, which one would it be?
Activity No. ___nine (5), eight (2), seven (1), three (1)

13. Which activity did children enjoy most?
Activity No. ___ two (1), four (2), six (2), one (1), ten (2).

14. Which activity did you enjoy most?
Activity No. ___ two (1), four (1), five (1), six (2), one (1), ten (2).

15. Which activity did the children enjoy the least?
Activity No. ___ nine (5), five (1), eight (1), ten (1).

16. Which activity did you enjoy the least?
Activity No. ___ nine (5), three (1), eight (1), seven (1).

17. Did you generally have enough materials to assist you in teaching? 7 yes 1 no.

18. Did you generally have sufficient time to complete an activity? 7 yes 1 no.

19. Did you have enough time to complete the unit?
5 yes 3 no.

Comments Teachers Logs and EUEF

Several unit recommendations were made by teachers on comment sections of teacher logs and End of the Unit Evaluation Forms.

Teacher suggestions related to improving "teacher background" sections of the script included the need for more specific information outlining necessary student mathematics skills for each activity. For example, students will need to be able to multiply two-place numbers in activity four. A second suggestion called for the inclusion of activity objectives (intended learning outcomes) in teacher background information. Teachers asked for more guidance in the launch phase including more cues for pupils in the form of photos and drawings. They also asked for more guidance so that they could conduct more careful demonstrations during the mini-challenge and explanations of the story challenges.

Needs expressed concerning the exploration phase included more guidance in the script for helping pupils manage materials and a better system to insure record keeping on the part of pupils. Possibly data sheets specific for each activity.

Teachers suggested that summary notes include a greater stress on the use of number lines to represent data, and the use of orders of magnitude and rounded numbers.

Discussion

Teacher rating of the unit as including difficult concepts and process skills may be reflected in the results of the student achievement test for the unit. In particular, results on items dealing with concepts teachers indicate as being most difficult for pupils and support to teachers' perceptions.

The reported length for lab time from logs and EUEF coincides with estimates from observational data (ACI). This may support the view that the script does not limit student exploration time. Teacher rating of student attitude was fairly consistent on teacher logs and End of the Unit Evaluation Forms indicating average to above-average interest and enthusiasm for the scripted unit.

Information on the logs and the End of the Unit Evaluation Form are specific for this unit and its instruction at the fourth grade level. The expressed need by teachers for more guidance from the script and more background information is supported by the findings of Fitzgerald and Shroyer (1979).[31]

The cooperative nature of small group work and whole group discussion to solve the problems may have

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[31]William M. Fitzgerald and Janet Shroyer, "A Study of the Learning and Teaching of Growth Relationships in Sixth Grade," (unpublished research study, Department of Mathematics, Michigan State University, 1979), p. 87.

contributed to the positive attitudes of students and supports the findings of Johnson (1976) related to cooperation and attitude, along with those of Tjosvold and Santamaria (1978).[32]

Summary

Data about time from the teacher logs show wide ranges of time for the length of activities. Reasons for lengthy lessons included allowance for open exploration and the need to repeat counting methods during the exploration phase. The shortened activities may relate to teacher misunderstanding of goals and objectives for those activities. Summary phases were curtailed in many instances due to the constraints of time. Information about timing may suggest the need for more thorough teacher training and more direction from the script relative to pacing the unit.

Teacher comments from the teacher logs included several suggestions for improving the script. Teachers' comments were mainly concerned with improving the launch phase. There was an indication that story problems and mini-challenges need to be more congruent with one another and that some of the story problems may be too abstract.

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[32]Roger T. Johnson, "The Relationship Between Cooperation and Inquiry in Science Classrooms," Journal of Research in Science Teaching, XIII (January, 1976), 55-63; see also Dean Tjosvold and Philip Santamaria, "Effects of Cooperation and Teacher Support on Student Attitudes Toward Decision Making in the Elementary Science Classroom," Journal of Research in Science Teaching, XV (May, 1978), 381-385.

Teacher rating of student attitude implies that pupils showed above-average enthusiasm and interest in the activities. Students were not asked to rate their own enthusiasm or interest.

Information from the teacher End of the Unit Evaluation Form supports data from student achievement tests suggesting that concepts, process skills and content for the scripted unit may have been difficult for fourth graders. Several teachers suggested that the unit be taught at the fifth grade level, while the majority indicate that the fourth grade was appropriate.

There was some evidence from the EUEF that supports a need to revise the script. This is based on teacher opinion concerning particularly difficult activities and the concepts presented in those activities.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The first four chapters of this study dealt with the nature of the problem and the purpose of the research, a review of the relevant literature, a presentation of the methodology, and the analysis of the data. The present chapter is divided into three sections: (1) a summary of the study and its limitations; (2) conclusions and implications; (3) recommendations for further research.

Summary of the Study

The early sixties saw the development of several innovative curricula in elementary science. Nearly one-third of the elementary school children are exposed to science programs which emphasize a laboratory approach. The three most predominant inquiry programs include Science-A Process Approach (SAPA), Science Curriculum Improvement Study (SCIS), and Elementary Science Study (ESS). These curricula represent a hands-on inquiry methodology. The materials and guides associated with each of these programs provide for varying amounts of organization and structure of content, process skills, and instructional methodology.

Characteristics of science programs stressing

student investigation are requirements for large quantities of supplies and additional teacher planning time to conduct science activities. In recent years schools have been faced with financial problems which have placed increased pressure on curriculum budgets including funds allocated for elementary science. Another factor affecting the classroom directly is the curtailment of support programs in schools. This has had the effect of limiting the planning time of classroom teachers.

Among the three programs, SAPA, SCIS, and ESS, the most diverse in terms of topic offerings is ESS with over fifty-six units. ESS has been characterized as an open ended freewheeling curriculum with few guidelines for the development of evaluation instruments. Needs associated with ESS unit development and interpretation include: the identification of goals and objectives for the units, a more careful outline of inquiry methodology for teachers, specific student evaluation instruments for the units, and careful outlining of the material needs because of the problem of funding. In addition, science curriculum development implementation plans must consider the viewpoints of the teachers and students working with the activities.

The primary purposes of this study include: (1) the selection of an existing inquiry model through which a "script" providing structure to science units can be developed; (2) determination of the goals and objectives

for a single ESS unit which will facilitate establishment of intended learning outcomes and material requirements for the unit; and (3) the application of the revised unit in an instructional setting, allowing the evaluation of student and teacher perceptions and behaviors as well as student achievement and student-teacher interactions.

It is expected that this process will suggest a model for revising other science and mathematics units. Furthermore, it is expected that the model will be of particular benefit to curriculum planners, local school districts, and classroom teachers who desire to foster the development of inquiry science programs in the elementary school.

Procedurally, this study will seek to achieve these goals; (1) identify, through a review of the literature, common elements of inquiry science teaching methods which can be utilized in modifying ESS units; (2) demonstrate that the inquiry model selected is a useful means to represent the goals and objectives of an ESS science unit in an instructional setting; (3) analyze teaching and learning variables which can be utilized in a unit revision plan.

Related Research

The review of the literature is divided into three areas: (1) inquiry in elementary science; (2) the Elementary Science Study Curriculum; and (3) specific techniques

for elementary school science teaching.

1. Historically, many of the concerns relevant to inquiry over the past seventy years can be traced to the work of John Dewey. Recent changes were made during the mid-fifties when scientists and educators developed new curricula emphasizing student use of inquiry processes. The definition of inquiry is often interchanged with such terms as problem solving, discovery, and guided discovery. The terms have been used to imply various degrees of teacher guidance, control, questioning patterns, student involvement, and goal acquisition. Elementary science inquiry instruction emphasizes a number of learning conditions including: various problem focuses, teacher questioning agendas, manipulative materials, and various plans for hypotheses generation. In addition, attitudes toward inquiry learning situations in science may be enhanced when student decision making, cooperation and commitment are encouraged by the teacher. Finally, the literature suggests that plans for inquiry share the following common elements: a challenge or focus setting event, a period of exploration including hypothesis generation and testing, and a time for summarizing.

2. The review of the research literature relative to the Elementary Science Study curriculum was directed primarily at examining the historical, psychological, and philosophical background of the ESS program; teacher training

and implementation procedures; evaluation of ESS instructional units; and those studies comparing the ESS program with other elementary science instructional programs.

3. A review of interaction analysis classroom observation instruments was conducted. These instruments may be used to focus observations on one or several of the following classroom dimensions: affective, cognitive, procedural, physical environment, psychomotor, sociological structure, and activity categories. Many observation instruments are aimed at verbal interaction since, as Flanders suggests, verbal communication is dominant in most classrooms. Researchers suggest that teacher questioning may be particularly important in facilitating children's problem solving abilities. The literature also suggests that curriculum implementation plans should consider the roles of curriculum developer, implementer, teacher, and student. A number of methods are suggested for collecting information from participants in the teaching-learning situation.

Methodology

An inquiry script was developed for the ESS unit Peas & Particles. Unit goals and objectives were outlined. A teacher training packet describing the inquiry plan and the purpose for the unit revision was written for teachers. This material was included with the ten activities script

for Peas & Particles and presented to teachers during a training session conducted with them by the investigator. Two student tests were developed for the Peas & Particles unit as well. One is a thirty-six item unit-achievement test. The second test consists of four questions intended for use as an orally administered task-interview test for students.

A one-group pre-test - post-test research design was adapted for evaluating data gathered by observations of teachers using the Activity Categories Index (ACI) interaction analysis instrument and unit achievement test results of students participating in the study.

Problems of observational research including "observer presence," observer reliability, and rating error were discussed. It was noted, with regard to "observer presence," that observers in this study were in contact with teachers and students as a normal course of their work. Furthermore one-half of all observations were made by two independent observers and rating error may have been minimized to a certain extent because observations focused on descriptive variables as opposed to inferential or evaluative variables.

Aspects of the design threatening internal validity were also discussed. In particular the effects of history, maturation, and instrumentation were considered as possible cofounding variables. Minimizing the length of time between pre- and post-testing (six - eight weeks) and limiting the

number of observations of teachers (four) may have served to mitigate the effects of these rival hypotheses. Threats to external validity were discussed relative to the effects of pre-testing students and the pre-treatment observations of teachers.

The populations involved in the study included 12 fourth grade teachers and 273 students assigned to their classrooms. Characteristics of each population were described. The study was conducted in six elementary schools in the Three Village School District of Stony Brook, New York.

Several instruments were utilized to analyze verbal interaction and activities occurring in elementary classrooms during science instruction. Perception forms were used to compare student and teacher perceptions to those of independent observers, who used the Activity Categories Index (ACI), of one scripted unit activity. In addition the ACI was used to observe pre-treatment and treatment science lessons focusing on the following dimensions: student activity, laboratory time, and teacher questioning.

Teachers kept logs of their teaching with scripted activities and three teachers were video-taped and interviewed concerning deviations from the script. In addition the video-tapes were analyzed to categorize teacher questioning according to the Classroom Observational Record section relating to teacher "soliciting moves."

This information along with end of the unit evaluation information was used to analyze the merits of scripting and to contribute toward further refinement of the unit.

Observer and Teacher Training and Data Collection Procedures

Observer training occurred prior to conducting the study. This was followed by ACI observations of ESS science teaching (pre-treatment). Following completion of these observations teacher training was conducted to acquaint teachers with the inquiry model and the scripted ESS unit. Student pre-tests were then administered including the unit-achievement test for all students and the task-interview with randomly selected pupils. ACI observations of all teachers during instruction with the scripted materials then occurred along with the video-tape observations of three teachers covering the entire unit. At the end of the second ACI observation the student and teacher perception forms were administered to all pupils. At the completion of the unit, student post-tests were administered and teacher End of the Unit Evaluation Forms were collected. Teacher logs were gathered and teacher interviews conducted to complete the data collection procedure.

The data obtained were analyzed by computer at Fordham University, New York City. Two tailed t-tests and Pearson product moment correlations were employed in the analysis. The .05 level of significance was the standard

applied in the rejection of the null hypothesis despite the danger of a Type I error.

Findings

A summary of the results of the testing of each hypothesis follows:

H_1: ACI activity ratios will be significantly greater for teachers after introduction of the script method of teaching than before its introduction. Hypothesis 1 was not supported by the data. There was a trend observed in post-treatment means toward greater student activity during exposure to the scripted materials; however, the difference was not significant.

H_2: ACI laboratory ratios will be significantly greater for teachers after introduction of the script method of teaching than before its introduction. Hypothesis 2 was not supported by the data. Laboratory levels were nearly the same in pre- and post-treatment science classes. Therefore, there was not support for the hypothesis that student laboratory time would be greater during use of the scripted materials.

H_3: ACI questioning ratios will be significantly greater for teachers after introduction of the script method of teaching than before its introduction. Hypothesis 3 was not supported by the data. There was a trend observed in post-treatment means toward greater teacher questioning during exposure to the scripted materials; however, the

difference was not significant.

H_4: Teachers' perception of their amount of talk as perceived by students will be positively correlated with the observed teacher talk (ACI). Hypothesis 4 was supported by the data. Pearson produce moment correlation coefficients were significant thereby supporting the contention that teachers' perceptions of their amount of talk is related to an observer's rating of that behavior.

H_5: Student perceptions of their activity level will be positively correlated with their observed activity level (ACI). Hypothesis 5 was not supported by the data. While there was an observed trend indicating that students perceived their activity levels similar to an observer's rating, the magnitude of that correlation was not statistically significant.

H_6: Gain scores on the unit achievement test for students participating in the scripted "Peas & Particles" unit will be significant. Hypothesis 6 was supported by the data. The t-test results suggest that student achievement on goals and objectives related to the scripted "Peas & Particles" unit improved as a result of their participation in the unit.

A summary of the results of four research questions follows:

Q_1: What is the usefulness of the items on the unit-test of achievement? Discrimination and difficulty indices for the unit achievement test showed that 26 of the

original 36 items should be useful in a revised student evaluation instrument. The representation of the proposed test items in a table of specification indicates that validity, with regard to unit goals and objectives, is maintained.

There was some evidence from the task-interview test results to indicate that this instrument may be useful as a measure of student knowledge of counting methods for all ability levels. The task-interview functioned well as a measure of unit effectiveness with students.

Q_2: What deviations from the script were observed and what is the relationship of these deviations to the script? Teachers' deviations from the script were related to their expressed need for more direction from the script in the following areas: more detail for dealing with mini-challenge demonstrations, materials management, pre-requisite information for working with measurement tools, and record keeping and data collection procedures for students.

There was some evidence to indicate that the script allowed for individual student discovery and use of extra challenges with students.

Pacing of activity phases may be a problem, since the summary phase was shortened on several occasions due to time constraints. Teacher difficulty in launching the activities dealing with area and volume suggests the need for alternate or additional materials for this purpose.

The unit may be better suited to the second semester of fourth grade because of the difficulty of concepts contained in the unit.

Q_3: What is the classification and frequency of questions asked during instruction using the script? Questioning frequency varied greatly from activity to activity. Most questions were asked during the exploration phase with the second greatest number of questions emanating during the summary phase.

It is suggested that the script contributes to a greater frequency of teacher questioning above the recall level. The limited frequency of evaluation level questions also suggests a need for more carefully planned questioning agendas in scripts.

Q_4: What information from the end of the unit evaluations, teacher logs, and interviews with teachers indicates need for further revision of the script? Information about the timing of activity phases from teacher logs suggests the need for more thorough teacher training and more direction for teachers from the script relative to the allocation of time to activity phases.

Teacher comments show that there is a need for more direction from the script for the launching phase. In addition challenges and story problems should be more closely related to one another. The story problems in their present form may be too abstract for children at this grade level.

Teacher rating of student attitude indicates that pupils showed above-average enthusiasm and interest in the unit activities.

Information from the teacher End of the Unit Evaluation Form supports the analysis of student achievement tests suggesting that concepts, process skills, and content for the scripted unit may have been difficult for this fourth grade sample. The second semester of fourth grade or fifth grade may be a more appropriate placement for the unit. Additional teacher input was noted suggesting a need for revision of certain activities which contained particularly difficult concepts.

Limitations

The teachers in this study were randomly selected from the population of fourth grade teachers in one suburban New York State school district; therefore, the sample is not representative of all fourth grade teachers.

The student population employed in this study represent intact classrooms or units. They were not drawn randomly. The method used in assigning students to classrooms in the school district in which the study was conducted was, essentially, random.

The study examined only the behavior of teachers and students using Elementary Science Study materials during science instruction. Furthermore, only teacher and student verbal behavior and activity and laboratory levels

in fourth grade classroom settings were examined.

Conclusions

1. The content validity of the student unit-achievement test has been demonstrated in the present study. Reliability for the instrument was moderate. Therefore, further revision is necessary to improve inter-item consistency. Support for content validity indicates that the unit-test measures student achievement of the goals and objectives of the unit.

2. The fourth grade population of students in this study demonstrated substantial and significant improvement in learning those concepts and skills found in the scripted ESS unit "Peas & Particles." Scripting is effective in teaching the majority of the concepts and skills prescribed for this ESS unit. The comments of teachers working with the unit suggest that some of the concepts were too difficult for this population of students. No comparison group was established to determine if the scripted unit functioned more effectively than a non-scripted unit with regard to student achievement.

3. Findings from the task-interview test, administered to individual students in an oral testing situation, show that students demonstrated their ability to verbally describe counting rules related to concepts presented in the scripted science activities. This ability to describe counting rules was demonstrated by students

from low, middle and high mathematics achievement groups. This finding is contrary to students' inability to recognize counting rules as presented on the student unit-achievement test. This contradiction may be related to individual pupil and age-related cognitive ability. Implied in these findings is that pen and pencil measures of achievement may represent concepts in a format too abstract for students, whereas oral interviews may offer a more appropriate and valid means of assessing student achievement.

4. Observations conducted using the ACI interaction analysis instrument demonstrate that student activity levels, student laboratory time, and teacher questioning frequency are essentially equivalent in ESS science teaching situations with and without the presence of the inquiry-script. The maintenance of student activity, laboratory time, and teacher questioning is important in view of the increased organization of the unit and direction for teacher talk as required by the inquiry-script. Additional observational evidence demonstrates that the frequency of teacher questioning may be greater in scripted science lessons than in non-scripted science lessons. Support for this is based on video-tape observations of three teachers, where it was found that most questions were posed during the exploring phase of scripted activities. The ACI was not sensitive to teacher questioning during the exploring phase.

5. Fourth grade teachers working with a scripted ESS unit have an accurate perception of their amount of talk during science activities. Comparison of ACI data on teacher talk and teacher recognition of this behavior were related. Therefore, the presence of the script did not affect teachers' view of this behavior. A comparison was not made to determine if teachers accurately assess their talk during ESS lessons without a script.

6. The presence of a script does not affect pupil perceptions of their activity levels. Students perceive themselves as actively involved in scripted science activities. Similarly, independent observers' findings indicate that students are actively involved in inquiry science lessons.

7. Teachers exhibited a need for more guidance from the script in terms of launching activities adequately, managing materials, and the amount of time they allocate for each activity phase. In addition, there is a need for guidance from the script to encourage teachers to pose more questions above the recall level. During the training of teachers it was assumed that they understood the intentions of the inquiry-script model and unit content. Apparently, the teachers included in this study, despite over ten years' experience using ESS units, require more in-depth training in inquiry.

8. Elementary Science Study is an inquiry science program which emphasizes a student "hands-on" laboratory

methodology. It has been demonstrated in this and prior studies that the Activity Categories Index (ACI) observation instrument is a reliable observation tool for determining the degree of active student involvement in elementary science classrooms. ACI findings in this study suggest that science teaching using an inquiry-script is comparable to ESS teaching situations without the script in terms of promoting student activity. This comparability is further supported by the data derived from student and teacher perceptions, teacher interviews, logs, and end of the unit evaluations of the inquiry-script science teaching method. Based upon the observations of twelve randomly selected teachers, the students assigned to their classes, and independent observers, the inquiry-script method, at least for the students involved in this study, does not alter the ESS emphasis on student "hands-on" laboratory activities.

Implications

The implications reached in the study will be discussed in terms of their methodological and curriculum impact.

Methodology

1. The difficulty students encountered with concepts on student measures suggest that several test items were too abstract. This implies that student cognitive development is an important consideration in formulating

student evaluation instruments. The transition from concrete-manipulative laboratory activities to paper and pencil tests must recognize and provide for levels of student cognition.

2. The scripting of an ESS unit and subsequent observational comparisons to unscripted ESS teaching indicates that added structure and organization does not detract from student activity, laboratory time and teacher questioning. This implies that scripted units can function at a level outlined in the related literature as characterizing "desired" inquiry science teaching situations.

3. Information contributed by teachers and observational evidence suggesting teacher misinterpretation of the intentions of the script suggests a need for additional training for teachers and revision of the script to include more explicit directions for the inquiry model.

Curriculum

1. An ESS unit was first modified utilizing an inquiry-script model, then applied in a teaching-learning situation with "typical" fourth grade pupils in a predominantly white, middle-class community. There is reason to believe that the unit-scripting process can be applied to other ESS units. There is reason to believe that the scripted unit "Peas & Particles" can be employed with a larger proportion of elementary school children with similar demographic characteristics.

2. There is reason to believe that where an inquiry methodology is desirable in other curriculum content areas, an inquiry-script model can be utilized successfully.

3. Other plans to modify ESS units, which outline goals and objectives for units, provide a definite plan of instruction, and a means for measuring student achievement have not been employed in the Three Village School District. In addition projects that delimit material requirements and facilitate teacher planning have not been applied to the science curriculum. Considering the limitations that have been placed on teacher planning time, and the restrictions on science budget allocations, the need for ESS unit revision is apparent. The inquiry-script model and elements of the modification process may be helpful in future elementary science curriculum revision plans in the Three Village School District.

Furthermore, there is reason to believe that the process may prove useful in other districts with similar staffing, geographic, and demographic characteristics.

Recommendations

The conclusions of the study and the implications therefrom lead to several recommendations regarding methodology and curriculum.

Methodology

1. The ACI observation instrument used in the study could be revised to reflect the behavioral dimensions

of inquiry science teaching situations including specific aspects of the script model. Perhaps a separate rating schedule for each phase could be developed. The launching phase might include categories for teacher coverage of new concepts and the review of previously taught concepts, aspects of the mini-challenge presentation, and the posing of the activity challenge. The exploring phase might include categories related to the extent to which the teacher maintains student focus on a problem, structures student exploration, clarifies student problems, presents clues, and accepts student ideas. The summary phase might include the following categories for teacher questioning: data collection; data processing; probes for specificity, operations or rules; and evaluation questions.

2. A future study would involve the use of a refined script in a comparison study. The teaching of the ESS unit "Peas & Particles" with and without the script.

3. The use of the perception forms might extend to the observer(s) as well as the students and teachers. Additional questions could be included reflecting student and teacher roles during each of the phases of inquiry-script activities.

4. It is recommended that additional research be conducted comparing various student evaluation models. For example, a comparison of paper and pencil unit-achievement tests with task-interview or lab-practicum test models. In addition student achievement should be compared for scripted

and non-scripted ESS teaching.

5. In using video-taping for observing teachers the following recommendations are made: 1) The teacher should have a microphone on his/her person; 2) two cameras would be desirable (long shot), and close-up for teacher-student interaction; 3) an independent observer, other than the camera operators, should be making observational notes and; 4) several video-taping sessions should be conducted with students prior to the study to acquaint them with the procedure as well as eliminate any bias created by the novelty of having video-taping equipment present in the classroom.

6. Teacher logs could be more specific for each activity phase. The portion of the log concerning the launching phase could include questions for teachers about the nature of additional explanations, analogies, demonstrations or examples they used to help students with their understanding of the mini-challenge. For the portion of the log concerning the exploring phase, teachers could be asked to explain actions they took to assist students with problem-focus, materials management or with extra challenges. In addition teachers could be asked to comment on student operations performed to collect data, the nature of student data and record keeping, and additional instructions required.

7. It is recommended that the task-interview test include more careful direction for teachers to eliminate

the possibility of teacher prompting. An outline, for teachers, of expected student responses to minimize subjective interpretation of student answers is advised.

8. Additional work on the unit-achievement test would include refinement of items to reflect the concrete level at which children are working with the materials of the unit.

9. Recommendations for further unit revision include the need to present story problems that are related to student experience and to outline mini-challenges for each activity. The unit activities should include, in teacher background:

1. a list of goals and objectives for that activity.
2. an explanation of the counting method.
3. materials management tips.
4. an outline of specific math skill requirements for the activity.
5. possible distribution of story problems to students a day in advance.

The launching phase should include:

1. a more thorough description of mini-challenge presentations for teachers.
2. additional pupil clues such a photos or drawings of counting method techniques.
3. explicit student directions for materials management.

4. estimated launching phase length (timing).

The exploring phase should include:

1. data collection forms or directions for record keeping.
2. notes on expected student problems with counting method.
3. an agenda of recommended teacher questions.
4. estimated exploring phase length (timing).

The summary phase should include:

1. sample data organization procedures, including number lines, order of magnitude number lines, tables, and graphs.
2. expected student responses.
3. teacher questioning agenda.
4. estimated summary length (timing).

Curriculum

1. The inquiry-script model could be used in the modification of other Elementary Science Study units in an overall plan to restructure the elementary science curriculum in the Three Village School District. The modification of other units could result in a clearer representation of each unit's intended learning outcomes, an inquiry teaching plan for each unit, and student evaluation procedures. The plan could facilitate teacher planning and delimit unit materials requirements.

2. The inquiry-script could be utilized to restructure other mathematics and science units, as well, in the

process of developing new units. It could become useful in identifying common elements of inquiry instruction necessary in the development of interdisciplinary units in mathematics and science, and social studies and science.

3. The difficulty level of concepts presented in the ESS unit "Peas & Particles" suggests that the unit is appropriate to either the second semester of fourth grade or a higher grade level.

APPENDIX A

SCRIPT BACKGROUND INFORMATION FOR TEACHERS AND THE SCRIPT FOR PEAS & PARTICLES

A MODIFICATION OF THE ELEMENTARY SCIENCE STUDY UNIT PEAS & PARTICLES USING AN INQUIRY-SCRIPT

BY JOHN B. BEAVER

FOR

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DESCRIPTION OF THE UNIT

This section will include, 1) a description of the unit, 2) the teaching model (inquiry), 3) the intended learning outcomes and 4) a basic list of materials.

"Peas and Particles introduces the process of estimating through activities which emphasize mathematical sciences, quantitative relationships, large numbers and the scientific processes of observing and measuring."[1]

The unit also deals with the concepts of "about" and "approximate." Various counting and measuring techniques are explored relative to estimating large quantities of material. It is intended that a recognition of measurement as a skill in labeling and standardizing quantities is variable depending on the method and desired use of the measure, among other factors. In communicating quantities and amounts varying estimates or measures may be applied. Children gain insight concerning large numbers and quantities through practice with them. They also begin to understand where an

[1] William R. Brown and Edwin P. White, Delta Project Cards, Peas & Particles, Nashua, N.H. Delta Education Inc., 1978, card 2

approximation may be more useful than a precise answer, and where precise answers may not be possible or desirable. It is also expected that children will see that a number estimate is often a better way to describe quantity than merely using words like "many."

The unit has been observed in use and used by this researcher for the past twelve years. During that time a variety of teaching styles, methods and strategies were seen being used by teachers. In their attempt to convey the contents of the unit, teachers are required to determine the goals of the unit and measure their achievement through observations of the children working. Among the variables of instruction noted over the years, I include the following:

1. Length of time spent on the unit.
2. Number of topics covered and activities included.
3. Major focus and/or challenge of the unit.
4. Objectives of the unit and measured outcomes.

It is the purpose of the modified unit to provide a means for a more careful representation of what is to be taught, areas to be covered, approximate time needed to explore these areas, and provide a more consistent means for evaluating the learning outcomes. It is intended that the person teaching the unit have the

greatest influence in further modifying the unit and that the unit as presently written not be considered the final word or product. The activities presented are intended to be basic, and additional activities that individual teachers have used in the past should remain a part of their plan in teaching this material. The intentions of the unit are represented as an inquiry-script. What is actually taught will be discerned through the use of observations of the unit, written feedback from teachers and interviews. Learning will be measured with two test models, the task-interview and a unit-test.

Fitzgerald and Shroyer have utilized a script for a problem solving unit in math they developed, entitled: The Mouse and The Elephant, a study of the teaching and learning of growth relationships in the sixth grade.[2] They describe the script as a flexible network of activities characterized by launch, exploratory and summary phases. Each launch consists of a challenge intended to focus the activity on a concept, skill or rule necessary in solving an overall unit problem. The exploratory phase serves through hands-on work with

[2]William Fitzgerald and Janet Shroyer, The Mouse and The Elephant, Unpublished research study partially supported by the National Science Foundation, Michigan State University, 1978.

materials, to introduce, maintain, correct or extend the ideas presented in the launch. The summary phase is intended as a time when general discussion and sharing as a whole class, which may serve to broaden the children's experiences and inspire them. It is also a time when rules and generalizations may be drawn from the data collected.

The activities are used in a whole class setting, therefore additional challenges are included for those completing the basic work early. This serves to extend their understanding of the concept while providing time for others to complete the main work, thus allowing the teacher an opportunity to circulate throughout the room to offer assistance to those meeting the expectations of the primary challenge.

The unit, Peas & Particles, is built around six counting methods used to estimate large quantities, they include:

1. Counting in multiples.
2. Taking a sample. This strategy involves using a small container (paper cup), counting the quantity in a sample (cup) and then finding out how many samples are equivalent to a large container of particles. Finally multiplication is used to arrive at an estimate.
3. Counting by area and volume. (Number of particles along width X number of particles along length when arranged in a rectangular array.) In finding volume the added dimension of height is included when particles are

housed in a rectangular solid.

4. Halving and doubling. In this method a quantity is continually halved until it is reduced to an easily counted amount and then the process is reversed mathematically to determine an estimate.

5. Weighing. A sample is weighed, counted and the weight of the total amount is found. Using this information an estimate is made.

6. Counting by ratios. This method is applied when comparing to different sized particles in separate containers of equivalent capacity.

The above mentioned activities are built around the following concepts and skills.

Concepts	Skills
area	counting
volume	organized counting
mass	counting in multiples
orders of magnitude	rounding-off
capacity	adding
ratio	multiplying
multiples	

INTENDED LEARNING OUTCOMES (ILO's)

The goals of the unit as identified by the California Test Bureau[3] and the investigator are presented here as Intended Learning Outcomes. They include:

	Activity No.
Understand and appreciate measurement as a means for standardizing and communicating. (Standard equals something set up as a rule for measuring or a model.)	1 & 10
Understand that there are several ways to estimate quantity and that estimation is a valuable skill that can be utilized in practical, everyday situations.	1 & 10
Will recognize measurement as an estimation or approximation.	1 & 10
Recognize numerals to one-million and verbalize an example of a million "things".	1 & 10
Will recognize the need for several trials.	1 & 10
Will understand averaging as it pertains to data collected in a sampling activity in several trials.	1 & 10
Understand the relative accuracy of the counting methods used.	1 & 10
Will recognize rules for rounding off.	2
Will demonstrate an ability to round off to tens, hundreds, thousands, and ten-thousands place.	2

---

[3]William Aho, Del Alberti, Victor Perkes, Robert Sheldon, Terry Thomas, and Richard Ward, The McGraw-Hill Evaluation Program for ESS. New York: McGraw-Hill Book Co., 1974, pp. 148-150.

	Activity No.
Will demonstrate ability to count in multiples with particles.	2
Will be able to apply a counting strategy of multiples in estimating a quantity of particles	2
Describe a quantity as an order of magnitude.	3
Recognize symbols for orders of magnitude as another name for a numeral or number representing a quantity.	3
Measure using a non-standard sample, and apply a counting strategy of sampling in estimating a quantity of particles.	3
Will understand a rule for finding the area of a rectangle in the context of counting with particles. Example: Number of particles long times the number of particles wide.	4
Will be able to apply the counting strategy of area in estimating a quantity of particles.	4
Will understand a rule for finding volume of a rectangular solid in the context of counting with particles. Example: Number of particles long X the number of particles wide X the number of layers of particles.	5
Will be able to apply the counting strategy of volume in estimating a quantity of particles.	5
Will be able to double a quantity of particles at least four times.	6
Will be able to halve a quantity of particles at least four times.	6

	Activity No.
Will be able to apply a counting strategy of first halving a quantity of particles and then doubling a counted portion to arrive at an estimate.	6
Will understand how to use an equal arm balance.	7
Use a balance to halve a quantity, successively, reducing it to an easily counted amount and then doubling the counted amount to arrive at an estimate. Must double the same number of times halved.	7
Will be able to measure a sample using a spring scale.	8
Will be able to count the quantity in a weighed sample and use the information to estimate a larger quantity of known weight.	8
Will be able to rank order a set of identically sized jars according to the quantity of particles in each, from the jar containing the greatest quantity to the jar containing the least. The particulate matter in each jar would differ.	9
Recognize and apply concept of ratio as it applies to the relationship between particles of different size.	9
Example: $\frac{1 \text{ lima bean}}{3 \text{ navy beans}}$ or 1:3 or $\frac{1}{3}$	
Will be able to use the counting strategy of ratio to estimate an unknown quantity from a known by recognizing the ratio of the particles to each other.	9
Example: $\frac{1 \text{ lima bean}}{3 \text{ navy beans}}$ A jar contains 100 limas, hence the estimate of navy beans is 300.	
Understand that counting particles can be accomplished utilizing a variety of strategies.	10

	Activity No.
Understand that there is a relationship between counting and measurement.	10

It is noted here that some of the objectives are intended as learning outcomes at the exposure level and that they are all at a concrete level. Children are expected to demonstrate abilities to handle real objects and not symbols for the objects for the most part. These intended learning outcomes serve as the basis, in the table of specification, for the unit test and task-interview presented in the next section. (Script Background Information for Teachers and the Script for Peas & Particles are presented in Appendix F.

Peas & Particles
Materials List

Material Name	1 Class Set	4 Class Sets
quart jars	21	84
gallon jars	5	20
navy beans	12#	50#
lentils	12#	50#
lima beans	12#	50#
peas	12#	50#
popcorn	5#	50#
rice	5#	20#
3 oz. cups	50	200
7 oz. cups	50	200
10-12 oz. cups	50	200
meat trays or geoboards	30	120
graph paper	40 sheets	160
data collection sheets	250	1000
drawing of peas worksheet	30	120
balances	10	40
spring scales	15	60
standard weights	8 sets	32 sets
cardboard boxes	6	24

DEFINITIONS

Estimation - judgment of quantity based upon knowledge and use of a quantification strategy.

Guess - opinion or judgment without knowledge.

Measurement - arbitrary or standard quantification of particles to varying degrees of accuracy.

Verification - the act or process used to authenticate or check a guess or estimate.

Strategy - plan or method used to arrive at a measurement or estimate of quantity.

Technique - the manner in which details are treated or the individual methods invented by children to solve a problem.

Discovery - the original idea, relationship, method or technique that you have developed or found to help solve a problem or make it easier to solve.

ORGANIZATION OF THE UNIT

Each activity or lesson has the following structure:

Teacher Background Information

Basic Materials Needed

Challenge or Launch of the Activity

Exploration Phase

Summary Phase

Extra Challenges

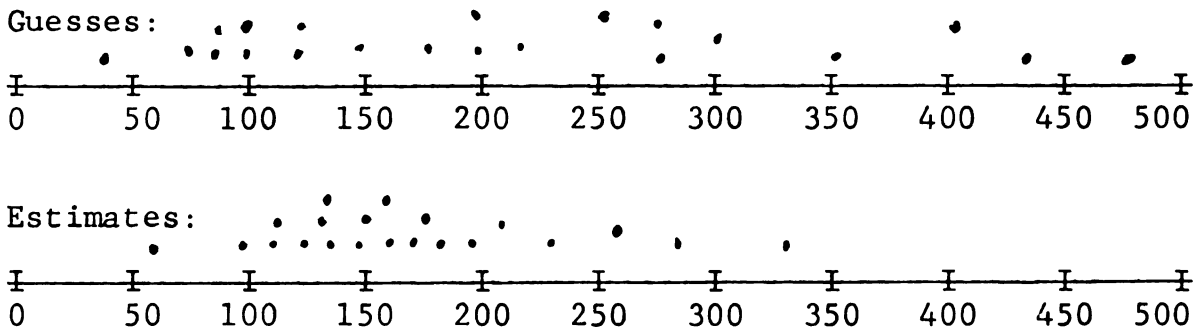
Challenge: The challenge consists of a problem or story intended to motivate and instruct the children. A strategy is introduced and the stage is set for the exploratory phase of the activity.

Exploration: During this phase of the activity the materials are in the children's hands and they are actively

collecting data developing techniques within the strategy presented. It is suggested that the class be broken up into groups of four children and that those groups exist throughout the unit. Children within the groups may decide who is to pick up or replace materials at the beginning and end of each exploratory phase. Large sheets of construction paper may be used to cover the desks thus facilitating return of the particles to the jars. The paper may be rolled into a funnel shape to accomplish this end. The top half of the large two liter "Coke" bottle (plastic) may also be used as a funnel. All children should record data. Name and date should be placed at the top of each data collection sheet along with a record of the strategy used. techniques developed and discoveries made by each child. (See Sample Data Collection Sheet at the end of this section.) These records should be kept in a folder, notebook or looseleaf binder. The teacher should circulate throughout the room during the exploratory phase asking questions and insuring that children are focusing their efforts on the problem. Additional or extra challenges may be issued for work during free time, homework, extra credit or for those ready to work on one during the regular class time.

Summary: All materials should be retrieved and put aside before the summary is conducted. This is a time for sharing ideas, techniques, and discoveries. The teacher's questions probe for data. This data may be displayed on a number line, comparing guesses to estimates as in the

example below:



The summary is also a time when the bridge is established to the next activity. Usually children will have thought of other strategies and will bring them up during the discussion giving you a natural lead-in to the next lesson.

Let it be emphasized that the spirit of ESS as exemplified in the following passage remains a part of the intentions of this unit and its materials. The purpose here is to assist in identifying the basic goals of the unit, offer a means to accomplish these goals in a practical manner, to facilitate evaluation of students and encourage their use in the classroom. Each class is encouraged to explore beyond the scope of these <u>basic</u> activities and utilize all of the activities you have invented and found successful in the past. This unit is not imprinted in stone: it is meant to be a flexible network of activities, to be revised and built upon and most of all serve as a meaningful and practical unit of study.

> Most broadly stated the ESS goal is to bring participation in real science to the average school child, who will grow up to become the ordinary citizen. He should experience science not from the television screen, the textbook, the

teacher or the excerpt "demonstrating nicely," but in his own work--Morrison's words, 'with his own hands, with his own microscope and his own belabored arithmetic...'We are not disturbed by slowness for what goes slow can run deep. And school hours are not all of life. To stroll into reality, the detail of it and the context, to unravel and uncover it, is a better thing than to sprint past, reading the bill boards of science.

Philip Morrison
Elementary Science Information Unit, Far West Laboratory for Educational Research and Development, 1970.

Name_____

Date_____

Strategy:_____

	Guess	Estimate
1.		
2.		
3.		
4.		
5.		

Description of method:_____

_____

_____

_____

Notes:_____

_____

_____

_____

_____

_____

_____

_____

_____

NEED FOR ESTIMATION SKILLS

The ability to estimate is important in many ways. One that comes to mind immediately is in giving meaning to measurement units. I recently had the experience of traveling through Canada where the metric system has been adopted. I found myself going through mental gymnastics to arrive at estimates of the car's speed. I then had to stop for gas (69 liters) which was purchased with American money. About fifteen kilometers beyond the station I realized what the equivalents were and that I had not been short changed. In a different sort of way, equally unreliable is the traditional fisherman's story of the one that got away and the accompanying estimate of the length of the fish. Williams and Shuard point out that:

> This ability to estimate is a useful one for children to cultivate; it ensures that numbers are being used meaningfully and that the units of measurement mean something to the children. Also, the ability to estimate the size of a room, the area of a garden, the speed of a car, the length of a cycle-ride, the cost of a holiday, the number of people at a meeting, or whether the temperature has reached the freezing point, is often useful in everyday life, on occasions when an accurate measurement is impossible or inconvenient.[4]

While this study is not intended to give formal training in estimation using metric units, the analogy serves its purpose. Practice and experience in estimation, whether it is in understanding large numbers as they

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[4]Elizabeth Williams and Hilary Shuard, Elementary Mathematics Today: A Resource for Teachers Grades 1-8, Addison-Wesley Pub. Co., Menlo Park, Ca., 1970, p. 349.

represent corresponding "particles" as in this study, or with measurement units, is the essence.

DIRECTIONS FOR ADMINISTERING THE UNIT-TEST**********

The test is designed to take twenty-five to thirty-five minutes. It is not a timed or speed test. The first five questions, however, are timed and consist of five slides of objects. Children will have five seconds to estimate how many objects are in each picture.

The slides should be set up in the following manner:

Slide 1: Title slide (Peas & Particles)
Slide 2: Example (Stack of Jars)
----------BLANK SPACE IN SLIDE TRAY---------
Slide 3: Question 1: (Bologna)
----------BLANK SPACE IN SLIDE TRAY---------
Slide 4: Question 2: (Can Tops)
----------BLANK SPACE IN SLIDE TRAY---------
Slide 5: Question 3: (Soda Pop)
----------BLANK SPACE IN SLIDE TRAY---------
Slide 6: Question 4: (Bricks)
----------BLANK SPACE IN SLIDE TRAY---------
Slide 7: Question 5: (Paint)
----------END OF SLIDE PRESENTATION---------

Administer the slides in the following way.

I found it best to have all lights in the room off with one blind open to provide enough light for children to see their test papers.

SAY, "I am going to show you a series of slides." "The first slide you see is merely a title photo so that you can adjust to the light in the room." "We will do one example together and then you will be on your own." Have children locate the example on their test papers. This is a good time to make sure they have their names and the date on the test.

EXAMPLE - SAY, "You will have five seconds to look at the picture of a stack of jars, how many jars are in the picture?"

You should either watch the sweep second hand on the classroom clock or count off the seconds to yourself. After the fifth second advance the slide tray to the blank space.

Share the answer (There are ten jars.) with the class. Now tell them that they are on their own for the next five slides.

SAY, "You will make your best estimate and circle the letter next to the answer you think is correct."

SAY, "The next picture is of Bologna, how many packages of bologna are in the picture?"

ADVANCE TO PHOTO OF BOLOGNA.
COUNT FIVE SECONDS.
ADVANCE TRAY TO BLANK SPACE.

REPEAT: Number 2 - SAY, "How many Can Tops do you see?"

ADVANCE TO PHOTO OF CAN TOPS
COUNT FIVE SECONDS.
ADVANCE TO BLANK SPACE.

REPEAT: Number 3 - SAY, "How many cans of Soda Pop are in this picture?"

ADVANCE TO PHOTO OF SODA POP.
COUNT FIVE SECONDS.
ADVANCE TO BLANK SPACE.

REPEAT: Number 4 - SAY, "Look at this Brick Wall, how many bricks are in the picture?"

ADVANCE TO PHOTO OF BRICK WALL.
COUNT FIVE SECONDS.
ADVANCE TO BLANK SPACE.

REPEAT: Number 5 - SAY, "How many Cans of Paint are in the picture?"

ADVANCE TO PHOTO OF CANS OF PAINT.
COUNT FIVE SECONDS.
ADVANCE TO BLANK SPACE.

Turn on the room lights.
Turn off the projector.

DIRECTIONS FOR THE REMAINDER OF THE TEST.

"Read each question carefully. Take your time, this is not a timed test. Circle the letter next to the answer you think is correct. If you have any questions, raise your hand. If you can't read a question, raise your hand. You may use the back of a previous page to make calculations if necessary. Make sure your name and the date is on the paper." "You may begin!"

TASK-INTERVIEW TEST

The following questions will be posed to children. You will record their responses on a response sheet. Give children adequate time to answer each question. Do not give them clues. Just read the questions as printed. You will need a pencil for yourself and the child should have one available to him. The only other materials will be the set of questions, a response sheet, and a jar of buttons.

"Before you begin, tell the child to take his time in answering questions. Tell him that you are going to keep a record of his answers and that there are several answers to some of the questions. He may use pencil and paper if he needs to help explain. He will not have to make any arithmetic calculations, but will be asked to explain how he might solve a problem. The interview should only be five to ten minutes long."

The Questions:

(1) "What is the difference between an estimation and a guess?"

(2) "Explain how you would estimate the number of buttons in this jar?"

"Can you tell me about another method?"

"Are there any other methods that can be used to estimate the number of buttons in the jar?"

To Teacher: Have the child describe as many methods as possible. When he says he can't think of any more, go on.

(3) "Which of the methods you just described would probably be the easiest and fastest for solving the problem?"

"Why?"

(3) "How could you estimate the number of blades of grass on a lawn?"

EXPECTED ANSWERS:

(1) An estimate is based upon information, knowledge, a counting process, or measuring process. Rough calculations are made.

(2) It is expected they will describe the following methods of counting:

a - one by one
b - by a multiple, twos, threes, etc.
c - by a sample
d - by area
e - by volume
f - by halving and doubling
g - by halving and doubling with a balance
h - by weighing a sample and extrapolating
i - by a ratio method (not a good answer for this question)

Place a check mark next to the method described on the response sheet for the child's description of the best method.

The fastest and easiest should be either sample or weighing a sample.

Use comments section of response sheet for notes on reason chosen.

(3) The best response will be to find the area of the lawn, measure off one square foot or inch and count the blades of grass in that area either one by one or use the area method. Use the counted sample to find an estimate for the total lawn area.

Challenge

WE'RE HAVING A SCHOOL FAIR!
YOU ARE GOING TO SELL POPCORN AT THE FAIR.
IF EACH CHILD IN THE SCHOOL PURCHASED ONE BOX, HOW MUCH POPPING CORN WILL WE NEED TO BUY?



ACTIVITY ONE: THE HANDFUL

Teacher Background: The unit is organized into about ten activities. There is much more that can be done with this topic. This material represents some basic ideas. Each activity has three main parts: The Challenge, (launch), Exploration, and Summary. Open questioning is considered important and encouraged.

This activity is intended to allow children to develop some counting methods, strategies and techniques for facilitating their work, and begins the work toward estimating large quantities. The activities actually run from most accurate to least accurate in terms of actually knowing how many? One of the goals of the unit is to learn that it's not always important to know a precise amount.

BASIC MATERIALS:

6-7 quart jars of lima beans.
Data collection sheets.
Construction paper to cover desks. (12" by 18" works best)

Other materials:

Not necessary for conducting the activity, but these materials may serve to "give the children ideas." If available, all the materials listed for the unit should be visible. You might even say to the children, something like, "Here are the materials we're going to use to count and help us count, you may discover some ways to use them and you may think of other materials that could be used."

ACTIVITY ONE: THE HANDFUL

CHALLENGE:

How many beans are in a handful? (lima beans) Guess then verify (count) how many beans you have in one handful. This is not a contest to see who can hold the most beans in one handful. Record your guess then the actual number on the data collecting sheet. Do it at least five times.

Teacher talk: The purpose is to see if they can improve on their guessing. To give them some feeling for the materials. What are the reasons for improving at guessing. Encourage them to discover easier and faster methods for counting.

Disbribute: lima beans, data collection sheets, construction paper.

EXPLORATION: Ask questions as you circulate around the room that are open:

Seeing Relationships: Does the way you pick up particulates affect the amount? Why?
Feelings: How do you feel about your guessing?
Observation: What happened when...?
Explanation: Can you tell me why your guesses are getting better?
Action: How can you...?
Prediction: How many will you pick up in two handfuls?

ACTIVITY ONE: THE HANDFUL

SUMMARY: Did your guessing get better?
Were all the counts the same? Does a handful always mean the same amount? Why?
List one example from each child. Have each child give one actual count out of the five and list them.
Is there a most frequently occurring quantity?
Ask the children to help you define a handful that could represent the entire class? (average) (median)
Tell them that we are going to call the counted quantity an estimate. Try to have them tell you why. (All counts are not the same. There are some situations where handful as a measure is sufficient. Have them give you some reasons why.)
List some of their ideas, discoveries and strategies and explain that the sharing of these ideas will serve them in coming activities.

The following extra challenges are not intended for every student. Some may want or need an extra project.

EXTRA CHALLENGE: HOW MANY CARS GO BY YOUR SCHOOL IN A DAY?
IN A WEEK?
HOW MANY TRUCKS? BUSES?

EXTRA CHALLENGE: WHAT IS THE TEMPERATURE IN YOUR ROOM?
OUTSIDE?
HOW MUCH COOLER WILL IT GET DURING THE NIGHT?
MEASURE THE TEMPERATURE AND CHECK YOUR ESTIMATES?
HOW ACCURATE WERE YOUR ESTIMATES?

EXTRA CHALLENGE: HOW MANY TOYS CAN YOU BUY FOR FIFTY DOLLARS?
MAKE A LIST OF THE TOYS YOU WOULD BUY.
GO TO THE STORE AND CHECK YOUR ESTIMATE.
OR USE A CATALOG.

EXTRA CHALLENGE: CAN YOU ESTIMATE A MINUTE? CLOSE YOUR EYES AND OPEN THEM AFTER YOU THINK A MINUTE HAS GONE BY.
CAN YOU ESTIMATE FIVE MINUTES?
DO YOUR ESTIMATES IMPROVE AFTER PRACTICE?
HOW MANY MINUTES OLD ARE YOU?[6]

[5]The four extra challenges are from the following source. William R. Brown and Edwin P. White, Peas & Particles: Delta Project Cards, (Nashua, N.H.: Delta Education, Inc., 1978).

[6]The question How many minutes old are you? was suggested by Professor William Fitzgerald, Michigan State University.

ACTIVITY TWO: COUNTING IN MULTIPLES

Teacher Background: As a result of the first activity, children will come up with a variety of verification or counting strategies. The activities that follow represent anticipation of their ideas and are presented in an hierarchical order. It is suggested that all children within a class work on the same activity, but that they be encouraged to test their own techniques within the counting strategy used.

Children will count the particles one by one, by twos, threes, fours, fives, and tens or some other convenient grouping method.

Encourage them to develop techniques that will speed up the counting process without interfering with accuracy. Examples: using a pencil to separate multiples, dividing up materials among the group giving each a responsibility for counting a portion, or using egg cartons to divide up the particles.

BASIC MATERIALS:

6-7 quart jars of lima beans
construction paper to cover desks
data collection sheets

Other materials:

Not necessary for conducting the activity, but these materials may serve to "give the children ideas."

egg cartons, tops of plastic soda bottles for funnels, and other counting materials

ACTIVITY TWO: COUNTING IN MULTIPLES

CHALLENGE:

Guess how many beans are in the jar! (lima beans)
Verify your guess.
You must first record a guess on the data sheet, then record the verified amount.
Must round off the verified amount to the nearest ten.
You are encouraged to round off your guesses as well.

Teacher talk: Encourage children to develop counting strategies for verifying their guesses that are fast and accurate. Don't tell them ways to count, but point out what other groups are doing.

Distribute: lima beans, data collection sheets, construction paper.

EXPLORATION: Ask questions as you circulate around the room from group to group that are open:
Seeing Relationships - What other ways can you count?
Is there an easier way?
Is there a faster way?
Feelings - How do you feel about your guess?
How can you improve this technique?
Do you feel there is a better way?
Observation - What happened when...?
Explanation - Can you tell me what you did?
Action - How can you...?
Prediction - If you do it this way what will?

ACTIVITY TWO: COUNTING IN MULTIPLES

SUMMARY: Leave extra materials somewhere in the room where children may get to them.
What ways did you develop for handling the materials?
Did you find an easy way to group the particles into multiples?

Which way is fastest?

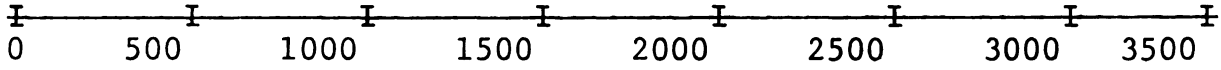
Which is most accurate?

What problems did you encounter?

Did anyone use the egg cartons?

What other strategies are anticipated as a result of this activity?

Use a line chart in discussion to represent where most of the guesses fall. Where most of the verified quantities fell.



The following extra challenge is not intended for every student; some may want or need an extra project.

EXTRA CHALLENGE: The next time you're in the grocery store or supermarket think about all the counting that must go on there to keep the shelves stocked. The following is a list of activities you may wish to try.

1. Important information about the items comes from actually counting them. Give examples in which actual counting yields useful information. (Bell)

2. Some items in the store are countable in theory but in practice an actual one-by-one count would be impractical. In such cases, ways of getting approximate counts are devised. List one or more situations, from the store, described as counts, in which actual counting is probably not accomplished. (Bell)[7]

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[7]Max S. Bell, Karen Fuson, and Richard A. Lesh, Algebraic and Arithmetic Structures. (New York: MacMillan Publishing Co., Inc., 1976), p. 5.

ACTIVITY TWO: COUNTING IN MULTIPLES

EXTRA CHALLENGE: (continued)

3. List some items in the supermarket which could be counted but are sold in some other form. (weight, capacity, etc.)

4. List some sold by count.

5. Sometimes items are measured as well as, or instead of, counting. List some items measured and the form of measurement used to quantify them.

6. Sometimes things are represented or counted by multiples. (one dozen, one gross, etc.) List some items sold in multiples.

STORY: Johnny and his seven friends each received an equal portion of watermelon. Johnny counted the number of seeds in his piece and decided with this information he could estimate how many seeds were in the whole melon. How was he able to do this?



ACTIVITY THREE: SAMPLING

Teacher Background: At some point during activity one, the notion of sampling may come up. You may observe children grouping particles by pile or handful. This activity is an extension of muleiples since a sample is a large multiple.

Children may use one cup to make a repeated sample or fill several cups exhausting the quantity in the jar.

Have them represent guesses and estimates in rounded numerals. Encourage them to decide on rounding to the ten's, hundred's or thousand's place. Accuracy of each should be discussed in the SUMMARY.

You are going to introduce Order of Magnitude in this activity. There are several ideas you may wish to explore:

1) List the first five powers of ten

$1 = \text{one} = 10^0$
$10 = \text{ten} = 10^1$
$100 = \text{one hundred} = 10^2$
$1{,}000 = \text{one thousand} = 10^3$
$10{,}000 = \text{ten thousand} = 10^4$
$100{,}000 = \text{one hundred thousand} = 10^5$

2) Using the Order of Magnitude list above in the SUMMARY you may wish to convey the idea that using estimates based upon order of magnitude are often easy to use and better than just saying "many" to describe an unknown quantity.

BASIC MATERIALS:

6-7 quart jars of navy beans
fifty each of the following sampling devices:
3 oz. cups, 6-7 oz. cups and 10-12 oz. cups
construction paper to cover desks
data collection sheets

Other materials:
Not necessary for conducting the activity, but these materials may serve to "give children ideas".

egg cartons, milk containers, muffin pans, etc.
several jars of peas, macaroni, walnuts, barley, and rice.

ACTIVITY THREE: SAMPLING

CHALLENGE:

> Guess how many beans are in the jar! (navy beans)
> You may not count each bean in the jar.
> You may count the number of beans in a SAMPLE.
> You may use a sampling device. (the handful or cups)
> Your guesses and estimates must be recorded using rounded numbers.
> Please record your guesses and estimates on the data collection sheet.

Teacher talk: We are now going to work in multiples greater than those you used in the last activity. We're going to call each multiple a sample. Example: one-handful is a multiple I will now call a sample.

Distribute: navy beans, data collection sheets, & allow students to select their own sampling device(s).

ACTIVITY THREE: SAMPLING

EXPLORATION: Children should discover that they can verify their guesses by first, finding out how many samples (cupfuls or handfuls) there are in the jar, second, counting the quantity in one sample and last multiplying the counted quantity by the number of samples. Try not to tell them this strategy. Show them the challenge and ask questions in an open manner:

Prediction - What would happen if...?
Action - How can you...?
Observation - What happened when...?
Seeing Relationships - What's going on here...?

Some children are going to finish the initial challenge sooner than others.
Issue a new challenge:

(A) Can you think of a different way to solve this problem?
How many ways are there to solve the problem?
Does your strategy work on a jar of another particle?
Use different strategies of rounding off.
How does this change your estimate?
Try a different sampling device.

SUMMARY: What strategies were used?
What rounding techniques were used?
Can we develop a rule for rounding?

Math is a symbolic language used to communicate many ideas. A quantity or quantities may be represented by numerals as you have been doing here. Mathematicians simplify communications using many symbols. When working with very large quantities they often use what is called an order of magnitude to represent a quantity.
Example: ask for an estimated quantity from the students. For instance, a jar of rice may be estimated to contain 29,300 particles. Round this off to 30,000 and represent it as $3\ (10)^4$ Expand on this. See Teacher Background.
Someone in the class may have poured out the contents of a jar into several cups until the jar was empty. Have them discuss with class:
What they did if they got 8½ cups, or when they rounded off quantity, did they add the number in each cup in a column or multiply?

STORY: A reporter was sent to cover a story concerning a large fish caught off Long Island. When she got there, a large crown had gathered on the dock. As part of the story, she was required to give an estimate of the crowd. How was she able to do it quickly without counting each person and yet be fairly certain that her estimate was a good one?



ACTIVITY FOUR: AREA

Teacher Background: Don't tell them they are working with area in the beginning of the lesson. The idea is to set up the lesson so that they either recall or invent the strategy of counting by area.

Use an overhead projector and a clear geoboard or open wooden frame to contain particles on top of the projector so that they don't roll off onto the floor. Show the children a layer of particles on the projector, peas are good. Tell them that they are going to count the particles in one layer by first guessing and then estimating.

Hopefully they will develop the rule: length X width or number of particles on one edge X the number of particles along an adjacent edge.

BASIC MATERIALS:

6-7 pints of peas
graph paper
data collection sheets
geoboards, frames or straight edges, or plastic meat trays

Other materials:

ceramic tiles, lima beans, navy beans
The ceramic tiles may be used without frames. Have children estimate by placing them in various rectangular patterns and counting them toward developing the rule.

ACTIVITY FOUR: AREA

CHALLENGE:

> How many peas are there in one layer?
> Guess then verify (count) the number of peas in layer.
> Encourage children to represent them in rectangular patterns either by providing them with geoboards or straight edges of some sort.
> They must be only one layer thick.

Teacher Talk: Make sure they record their guesses and estimates. Numbers should be rounded. The children should develop their own shortcuts and rules.

Distribute: peas, data collection sheets, graph paper, geoboards, frames or plastic meat trays.

EXPLORATION: Ask questions as you circulate amongst the groups.

Do you feel that there is an easier way to count the particles?
Did you place the particles in a pattern?
What was the pattern?
Are there others you can use that would be easier?
How can you...?
What happened when...?

If children do begin developing rules, make sure you point out their discoveries to others in the class; better yet, let them explain.

If you're using the plastic meat trays, you'll find that they provide a nice variety of sizes for rectangular patterns. Have students share them and try out their estimating with larger or smaller trays.

Have students try their strategies on other particles.
How is the graph paper being used?

ACTIVITY FOUR: AREA

SUMMARY: Is it easier to count each row?
Is there a shorter method?
Have the children developed a rule for finding area?
Has anyone developed a strategy for layering the particles?
Have they noted that the particles in the jars are in layers?
Is the method children have developed accurate?

During this discussion one might demonstrate pouring the contents of one container onto several trays or geoboards. Have them discuss various ways for finding out how many particles there are in all.

Example: One jar fills 4 geoboards, one geoboard contains 100 particles in a layer 10 particles X 10 particles. How many are there in all? Someone will come up with arraying the four trays into a larger rectangle or stacking them.
Develop rules for each method.
row X column = area
length X width = area
row X column X number of layers = volume
length X width X height = volume
Tell them that tomorrow's activity will involve a challenge utilizing the new strategy.

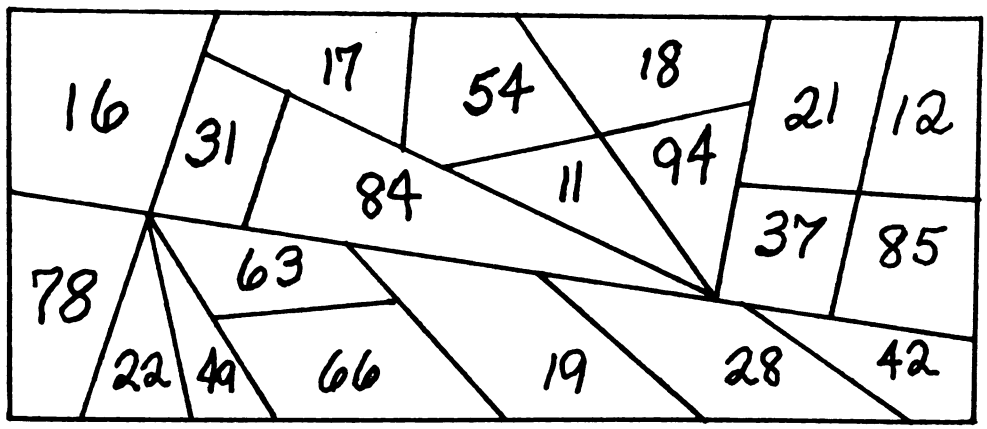
EXTRA CHALLENGE: CAN YOU COUNT THE NUMBER OF TILES IN THE CEILING OF THE CLASSROOM? WHAT IS THE AREA OF THE ROOM? OF ALL THE CLASSROOMS IN THE BUILDING? WHAT ELSE CAN BE USED TO HELP ESTIMATE THE AREA OF A ROOM OR BUILDING? HOW MANY TILES WOULD YOU ORDER TO RETILE THE GYMNASIUM CEILING?

EXTRA CHALLENGE: HOW FAR IS IT TO YOUR HOME? CAN YOU USE YOUR PACE TO MEASURE DISTANCE? HOW LONG WILL IT TAKE YOU TO WALK HOME? HOW CAN YOU CHECK YOUR ESTIMATES?

EXTRA CHALLENGE: HOW TALL IS THE FLAG POLE? CAN YOU CHECK YOUR ESTIMATE?

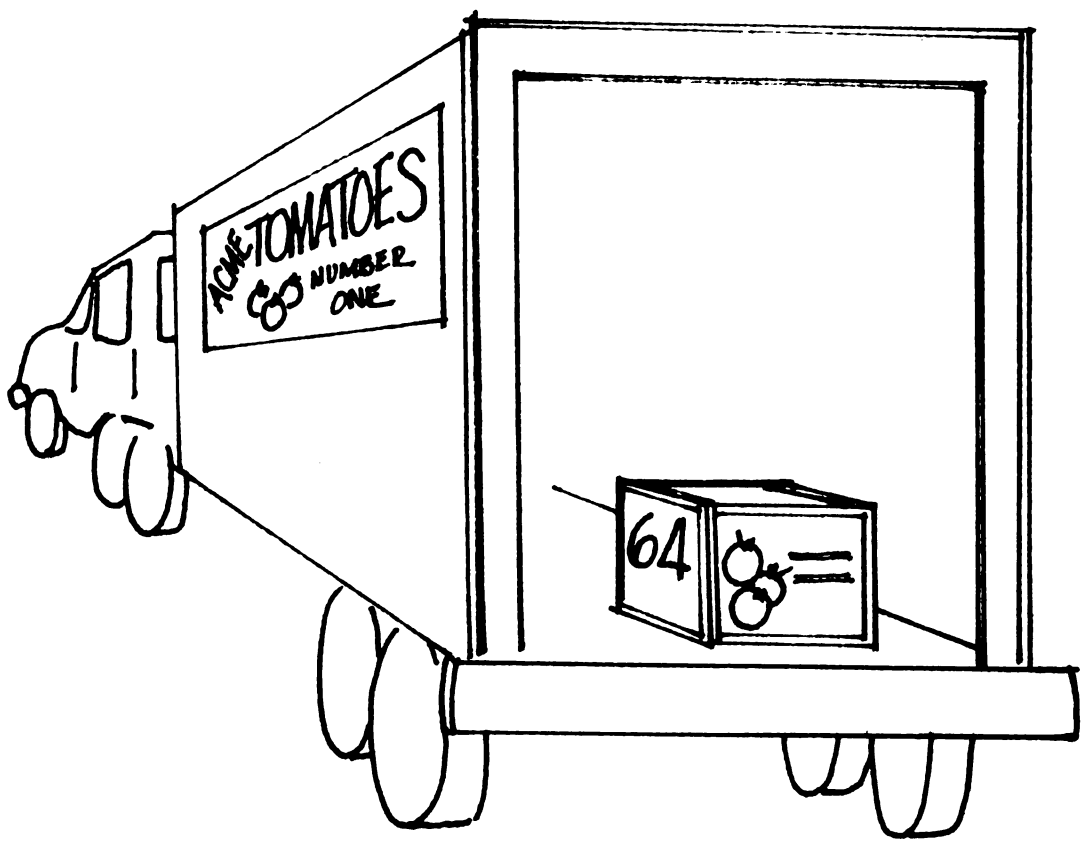
ACTIVITY FOUR: AREA

GAME: Numerals from 10-99 are displayed in random order on the game board. Pupils roll a marker (have them toss a navy bean on the board) to determine the number to be rounded to the nearest ten. He records this number as his score. After three rolls, a player computes his total score. The highest or lowest wins the round. Use several cards: Rounding up or down or mixed, rounding to fives, tens, hundreds, thousands, etc. (Holmes)[8]



[8]Emma E. Holmes, "Teach Estimation? Of Course!", The Arithmetic Teacher, v. 22, n. 5, pp. 367-369.

STORY: A tractor-trailor was being loaded with cases of tomatoes to be shipped from California to New York. Can you find a way to estimate how many cases of tomatoes the truck will hold? How many tomatoes were being shipped to New York?



ACTIVITY 5
VOLUME

ACTIVITY FIVE: VOLUME

Teacher Background: The idea here is to think of volume as area in layers. The graph paper can be used to introduce the idea without initially using the word volume or the formula for it. The children can discover the rule and concept of volume through using the materials.

Use of the geoboards may come in handy for demonstrating the layering of particles. Remember that the meat trays are adequate substitutes for geoboards.

Hopefully a rule will evolve as in work with area; number in a row X number in a column X number of layers
length X width X height

BASIC MATERIALS:

graph paper
meat trays or geoboards
data collection sheets
several jars of peas, pop corn, beans

Other materials:

ceramic tiles, wooden cubes, other counting objects, boxes from the grocery store

ACTIVITY FIVE: VOLUME

CHALLENGE:

> Can you find out how many particles are in the jar using a layering strategy? Guess first and then use the layering strategy to estimate the number of particles. Hint, maybe a rectangular or cube shaped container would help.

Teacher talk: Make sure you've discussed the story. You may want to pass out the graph paper and discuss the layer concept further. How many squares on one sheet, how many in the room, the entire pile of graph paper, etc.?

Some teachers like to develop a rule early for finding volume. Have it come from the children in their words. Graph paper; the number of squares in a row times the number of squares in a column times the number of pieces of paper in the stack.

Demonstration: If you can obtain some ceramic tiles, a further student demonstration would include the same ideas as mentioned above. How many different rectangular solids can be built with a discrete number of tiles. Try 24.

EXPLORATION: Some students may want further verification of their estimates found with area and layers. They may need to use one of the previously learned strategies.

Some will need to work with small quantities of larger particles for quick verification of the strategy and build confidence in the method. This is one of the most difficult concepts.

Help them focus on the problem and desired strategy with questions that require the student to clarify, be specific, and draw upon past examples and information.

Be supportive without telling him the answers, assure him and help him realize that he has the information and help him locate it. Clues to where information can be found and allowing students to share ideas is a good way to expand the data base.

ACTIVITY FIVE: VOLUME

SUMMARY: Share data, discoveries, new strategies.
Define volume in their terms and develop any rules for finding volume.
Students may also introduce the idea of standard units of measure at this time if it hasn't already come up.
Practical applications of estimations could also be discussed. Included might be a discussion of using it to check their own arithmetic computations.

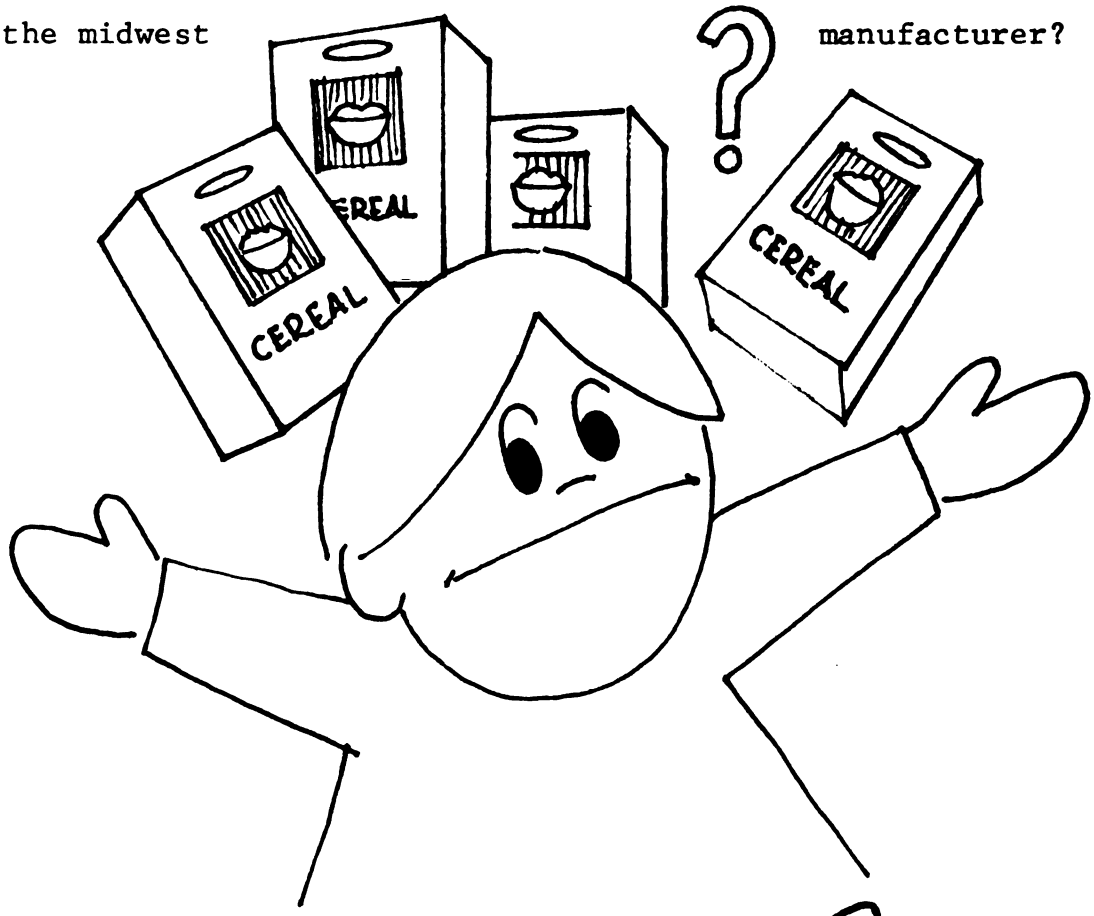
EXTRA CHALLENGE: WHAT'S A MILLION? CAN YOU NAME SOMETHING THAT IS A MILLION? CAN YOU COLLECT A MILLION THINGS? IS THERE A MILLION OF ANYTHING IN THE SCHOOL BUILDING?

EXTRA CHALLENGE: COLLECT NEWSPAPER ARTICLES DEALING WITH LARGE NUMBERS. DO ANY OF THEM INCLUDE OR REPRESENT ESTIMATIONS OF A QUANTITY?

EXTRA CHALLENGE: UTILIZING SEVERAL EMPTY BOXES FROM A GROCERY STORE CAN YOU TELL HOW MANY OBJECTS WERE IN THE BOX? CAN YOU TELL HOW MANY OBJECTS ARE IN A SEALED BOX? HOW MANY SHEETS OF PAPER ARE IN A BOX OF DUPLICATING PAPER?

EXTRA CHALLENGE: CAN A METHOD OF ESTIMATION WITH VOLUME BE APPLIED TO A JAR OF PARTICLES? (FIND THE AREA OF A CYLINDER)

STORY: A cereal manufacturer in the midwest shipped half of the cereal made one day to New York and half to Los Angeles. In New York the amount received was split in half again, with half going to Boston and half staying. The process was repeated again in Boston, half was shipped to Bangor, Maine and half remained in Boston. Bangor, Maine received 1,120 boxes of cereal. How many were in the original shipment from the midwest manufacturer?



ACTIVITY 6
HALVING AND DOUBLING

ACTIVITY SIX: HALVING AND DOUBLING

Teacher Background: The children will probably need lots of hands-on experience with doubling and halving before they can apply it to jars full of material. Practice doubling and halving small quantities and work with the drawing of peas should help. Some children may come up with the idea of using the balance to halve quantity. It's not necessary to make them wait until the next lesson to combine the two ideas.
Have children fold the drawing of peas in half, count half and double the amount for an estimation. Have them repeat with quarters, eighths, sixteenths and thirty-seconds. Discuss which is fastest, which is most accurate, how would you decide which to use?

BASIC MATERIALS:

worksheet, drawing of peas
data collection sheets
gallon jars of materials including rice and lentils
overhead projector

Other materials:

geoboards, other particles, balances
materials from previous activities may also be requested by students and provided.

ACTIVITY SIX: HALVING AND DOUBLING

CHALLENGE:

> Using the halving and doubling strategy can you, first estimate the number of particles in a gallon jar and then verify it using this estimation method?

Teacher Talk: Someone will mention a relationship of this method and the sampling method. This is like sampling without the sampling device. The object is to halve a large quantity successively until you have an easily countable quantity. The number representing this counted quantity is then doubled the same number of times the original was halved to arrive at the estimate.

Distribute: jars of rice, etc., data collection sheets, construction paper. You should distribute and use the drawing of peas first.

EXPLORATION: Using the rice, have the children start with one grain and double it, repeat several times. Keep a record of the number of doubling times and the amount each time. See below:

Number of times doubled	amount of rice
1	2
2	4
3	8
4	16
5	32
6	64
7	128
etc.	etc.

Look for patterns in the numbers. What happens when you add up each column?

ACTIVITY SIX: HALVING AND DOUBLING

EXPLORATION: CONTINUED

Someone may come up with the relationship in measurement of the following quantities:

Gallon		4 liters
½ gallon		2 liters
quart	or	1 liter
pint		½ liter, 250 ml
cup		¼ liter, 500 ml

Use a geoboard with sides, spread a layer of particles over it. Using a rubberband divide it in half. Use another rubberband and divide into quarters, etc.

You may wish to use the following demonstration. Pour the contents of ½ cup of rice on the overhead. Using a ruler, halve the pile (approximately). The amount present two piles, halve it again (4 piles), halve it again (8 piles). Count the quantity in one pile. Have children determine the estimated quantity.

or

1. Repeat as above (1st sentence).
2. Repeat as above (2nd sentence).
3. Now only halve one of the two piles so that you have one large and two smaller piles. (½, ¼, ¼)
4. Repeat halving only one of the smaller piles. You should now have four piles.
5. Can children now estimate the total amount. Hint: The number of steps or times halved is the key here.

Try to help children do most of this. Demonstrations should come from their need and carried out by those "inventing" the technique.

SUMMARY: What techniques are used, discoveries made?
Discuss the data and accuracy of the method.
When is an estimate good enough?
When do we have to know the exact quantity?
Is all measurement really concerned with the concept of "about"? (yes)
Measurement is a way to communicate. Established standards are used but the "measured matter" doesn't always stay constant. How

ACTIVITY SIX: HALVING AND DOUBLING

SUMMARY: CONTINUED

many seconds old are you?
What is the temperature outside right now?
Sometimes an estimate is better than just saying there were a lot of, or many of this or that...

EXTRA CHALLENGE:

CAN YOU FIND THE THICKNESS OF ONE PIECE OF PAPER?

EXTRA CHALLENGE:

GET A CHECKERBOARD. PUT ONE PENNY ON THE FIRST SQUARE. TWO ON THE SECOND SQUARE AND FOUR ON THE THIRD SQUARE. ON THE FOURTH SQUARE PUT DOUBLE THE NUMBER THAT IS ON THE THIRD.
HOW MANY PENNIES WOULD BE ON THE FIFTH SQUARE (DOUBLE THE NUMBER ON THE FOURTH)?
ON THE SIXTH SQUARE?
ON THE TENTH SQUARE?
ON THE LAST SQUARE? (DELTA)[9]

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[9]William R. Brown and Edwin P. White, Peas & Particles: Delta Project Cards. (Nashua, N. H.: Delta Education, Inc., 1978), Cards 34-36.

ACTIVITY SEVEN: BALANCING

Teacher Background: The next two lessons both deal with weight, the first with a balance and the second with spring scales and standard measures. The balance provides a natural progression from the halving and doubling exercise to the use of standard measures. Think of the weighing with standard weights as another extension of multiples or sampling. There is a neat relationship among all of the strategies. Can you find a way to help children see it? Remember, it's the process of description, the use of symbols and communication that are most important in the unit. We sometimes get hung up on the numbers and forget that they merely are used to describe and communicate.

You may want to spend some time at the beginning to make sure that the children know how to use clay as balance riders to achieve "evenness" in the system before it's used to halve the quantities.

Children will establish at least two main ideas in this activity: First, they will halve the original quantity using the balance, again and again until they have a countable amount. Second, they will think of using a standard of some sort on one side and balance that with the particles on the other side. This second method leads us directly to the next activity.

BASIC MATERIALS:

6-7 equal arm balances fitted with pans for counting particles
Gallon containers of particles
data recording sheets

Other Materials:

steel washers or some other standard gram weights

ACTIVITY SEVEN: BALANCING

CHALLENGE:

> CAN YOU USE THE BALANCE TO HELP YOU ESTIMATE THE QUANTITY IN THE JAR WITHOUT COUNTING EACH PARTICLE? HINT: DOES THE LAST ACTIVITY GIVE YOU OR DID IT GIVE YOU ANY IDEAS THAT CAN BE APPLIED HERE?
>
> WHAT STRATEGIES DO YOU DEVELOP?
>
> WHAT DISCOVERIES CAN YOU MAKE?

Teacher Talk: Some will think of weighing the whole container. If they do, help them realize that they have to subtract the weight of the container and account for it as part of the proportional weight in dealing with a counted-weighed sample.

What particulate matter are we accustomed to seeing sold by weight or some other measure?

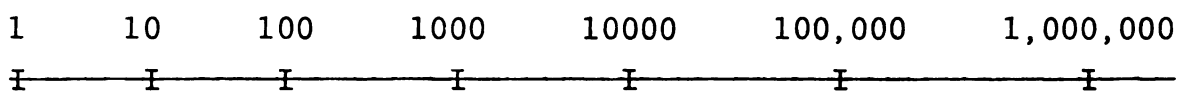
Have them represent answers in an order of magnitude.

EXPLORATION:

CIRCULATE AROUND THE ROOM. Provide guidance and assistance. Ask questions that help students focus on the challenge. Encourage them to write down not only their guesses and estimates, but also any discoveries or strategies they use. Explain how the balance is an important tool of commerce. Tell them they will have an opportunity to share the ideas they write down later.

SUMMARY:

Use an order of magnitude number line to represent where most of the guesses and estimates fall. Use the line to compare data from other activities.



ACTIVITY SEVEN: BALANCING

SUMMARY: CONTINUED

Optional: a.) Consider the population of the school. For each population given below, respond concerning these aspects and any others you wish to consider:

What part of the school district population do you know well?

What part of the school district population do you know by sight?

How far could you walk in fifteen minutes?

How far could a car go in fifteen minutes?

How many teachers will there be?

How many principals will there be?

How many schools will there be?

How many books will there be?

How many bricks in the buildings will there be?

How many ceiling tiles like the ones in your room will there be?

1	10	100	1000	10000	100,000	1,000,000
one	ten	one-hundred	one-thousand	ten-thousand	one-hundred thousand	one-million
$1(10)^0$	$1(10)^1$	$1(10)^2$	$1(10)^3$	$1(10)^4$	$1(10)^5$	$1(10)^6$

ACTIVITY SEVEN: BALANCING

b.) A person can walk five miles per hour, a car can go about fifty miles per hour, and a jet can fly about five hundred miles per hour. Record changes in your own life that these different orders of magnitude would make; if people could only walk (if there were no cars, planes or animals), if people had cars but no planes, and finally if you could fly on a plane. (Bell)[10]

[10]Adapted from: Max S. Bell, Karen C. Fuson, and Richard A. Lesh, Algebraic and Arithmetic Structures. New York: MacMillan, 1976, p. 370.

STORY: An apple orchard used a pick-up truck to haul apples. The truck was weighed each time it reached the storage area and the manager would record an estimate of the number of apples in the load. How was he able to do this?



ACTIVITY EIGHT: WEIGHT

Teacher Background: Before you use the spring scales, make sure you spend some time adjusting them and showing the children how to adjust them to zero before they weigh anything with them. You adjust them by holding them vertically and sliding the numbered face plate up or down until the spring controlled marker lines up with zero. Paper cups on string are used as the containers for particles. Make sure the children record the weight of the cup and subtract that from any measure of particles.

This is a pretty straightforward activity. Children are encouraged to weigh samples, count the number of particles in a sample and then use this information to determine the number of particles in a larger container.

BASIC MATERIAL:

8-25 spring scales
gallon containers of particles
data recording sheets
standard weights (some children may want to use standard weights to calibrate the scales)

Other Materials:

Balance beams, spring scales calibrated to handle weights up to 2 kilograms, and other counting materials.

ACTIVITY EIGHT: WEIGHT

CHALLENGE:

> NAVY BEANS FOR THIS ACTIVITY WERE PURCHASED IN A FIFTY POUND SACK. HOW MANY BEANS WERE IN THAT ORIGINAL SACK? MAKE A GUESS AND THEN ESTIMATE USING THE NUMBER USING ONLY A SPRING SCALE AND A JAR OF NAVY BEANS.

Teacher Talk: Children may want to invent their own challenges based upon this one. How many grains of sand in a ton, grains of rice in a fifty pound sack, etc.

Students may also think of other scales, such as bathroom scales, market scales, those found in doctors' offices, etc.

EXPLORATION:

There's real freedom in knowing that you can solve problems way beyond the materials at hand. Extrapolation is a goal of the unit. Help children reach this goal. Keep after them to think, record data, analyze the data, draw ideas from it, think of ways they can use the information from other activities and this one to solve problems outside the classroom. Ask their parents where they use estimation strategies.

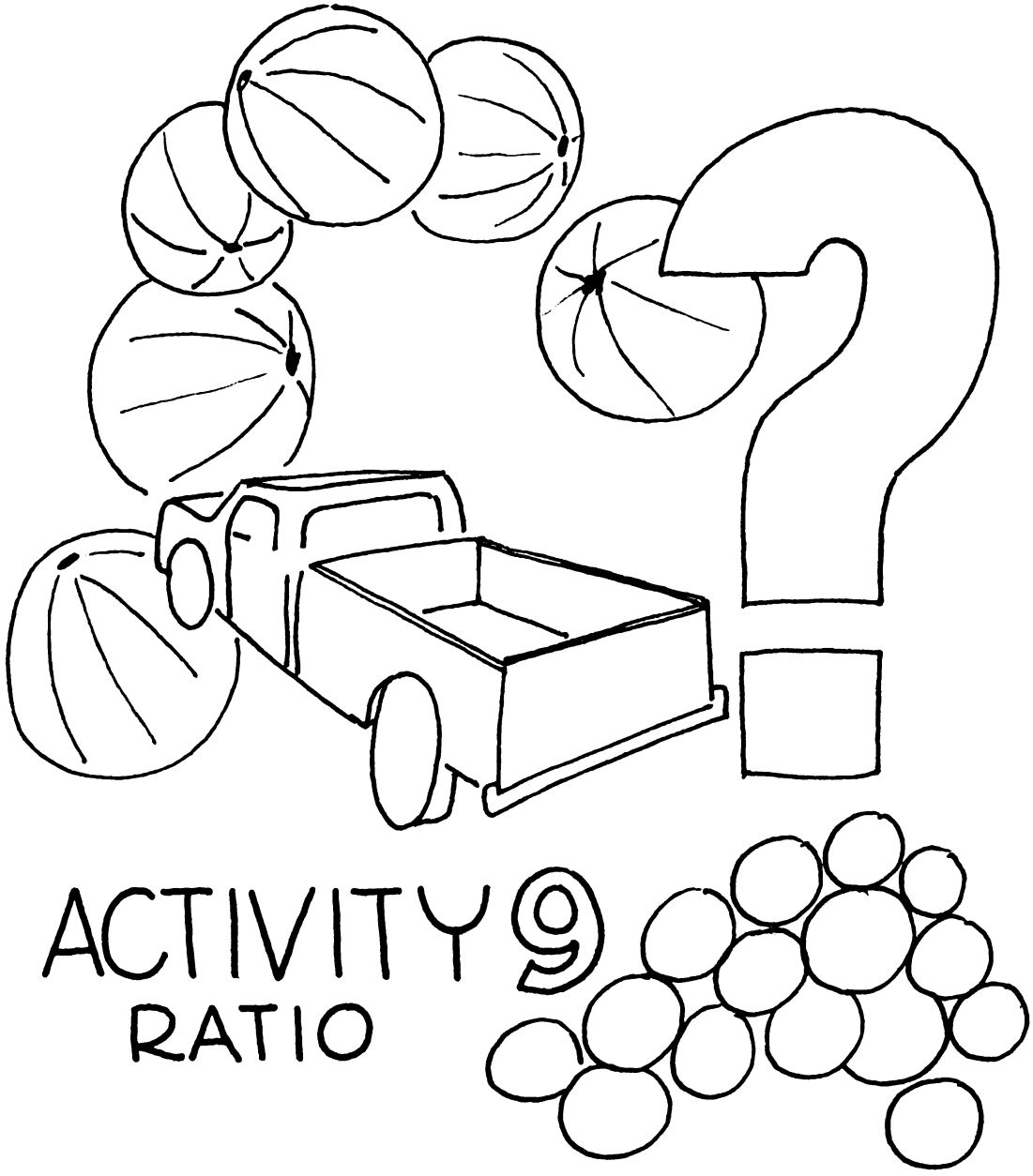
SUMMARY:

What other standard measures could be used to extrapolate beyond the materials and activities that children have been working with.
Help them explore the data. How do the numbers generated by this activity compare to other activities?

EXTRA CHALLENGE:

MAKE A BOTTLE CAP COLLECTION. CAN YOU COLLECT A MILLION OF ANYTHING?

STORY: Using the same pick-up truck that hauled the apples. How could we determine how many melons (cantelopes) the truck is able to carry? (cherries?)



ACTIVITY NINE: RATIO

Teacher Background: The concept of ratio has many aspects that will not be covered here. Let's think of it in very practical ways:

Ratio is a way of expressing a relationship between two sets. Padlocks are shipped with two keys: hence ratio = 1 : 2 or ½ or "n" locks need "2n" keys.

An ordered pair of numbers expressing a ratio such as 1 : 2 may be used to represent a new kind of number, the fraction ½.

Think about buying a new car. Car represents the set represented by "n"; what is the ratio when the other set is represented by : spark plugs, tires, doors, light bulbs, headlights, etc.

If every car is shipped with 5 tires then the ratio is : (1 : 5).

2 cars = 10 tires
3 " = 15 "
4 " = 20 "

Hence the multiple of cars is equivalent to a proportional multiple of tires. In this case multiples of one and five respectively.

BASIC MATERIALS:

5 jars, one gallon each, of rice, navy beans, limas, popcorn and lentils.
paper cups and medicine cups
data recording sheets

[11]Ideas on ratio adapted from: Theresa Denman, "Mathematics, What's With Ratio," The Instructor, v 83, n 6, February, 1974, pp. 42-43.

ACTIVITY NINE: RATIO

CHALLENGE:

> GIVEN FIVE GALLON JARS FULL OF PARTICLES. GIVE OR DETERMINE AN ESTIMATE OF PARTICLES IN JAR "A" USING ONE OF THE METHODS PREVIOUSLY LEARNED.
>
> DEVELOP A STRATEGY FOR ESTIMATING THE QUANTITY IN THE OTHER JARS WITH JUST A SMALL SAMPLE FROM EACH.
>
> EACH GROUP WILL BE GIVEN THREE - FIVE MINUTES TO DISCUSS A STRATEGY AND PRESENT IT TO THE REST OF THE CLASS.

Teacher Talk: You may want to go back to smaller quantities for a short while. Suppose you had two medicine cups, one full of limas and one full of peas. How many does each contain? Develop a ratio. If you had only one lime bean, how many would fill the same amount of space?

Have the children represent the quantities as ratios, then multiples.

	Example:	1 lima = 3 navy beans	
counting by ones		2 " = 6 " "	counting by threes
		3 " = 9 " "	

Have them recognize that the multiples of each whole number form the products of a specific multiplication table.

EXPLORATION:

Data for this exercise will not only include large estimates for the jars. But children should be able to determine the ratios with small quantities. Maybe they would like to represent the ratios like this:

Jar "A" : Jar "B"
or
Quantity in "A" : Quantity in "B"

Someone advanced in math may even bring up the idea if they are represented as fractions of reducing the fractions.

Explore the data. Encourage children to look for patterns and relationships.

ACTIVITY NINE: RATIO

SUMMARY:

What relationships in the classroom may be represented as ratios. The set of classrooms to the set of students or chalkboards, pencils, pencil sharpeners, etc.

EXTRA CHALLENGE:

DEVELOP AND EXPRESS RATIOS. YOUR BODY AS ONE SET AND THINGS ON YOUR BODY OR YOUR POSSESSIONS AS THE OTHER SET(S). HOW MANY CAN BE GENERALIZED TO ALL CHILDREN?

ACTIVITY TEN: UNIT CHALLENGE

UNIT CHALLENGE:

> THE SCHOOL IS PLANNING A FAIR!
> WE ARE GOING TO SELL POPCORN!
> IF EVERY CHILD IN THE SCHOOL WERE TO BUY ONE BOX OF POPCORN, HOW MUCH POPPING CORN WOULD WE NEED TO PURCHASE ??

Have the children identify what they need to know to solve this. The following is a list of some of the data needed.

Other questions:
- How many children are there in the school?
- How many popped kernals fill a box?
- How big are the boxes?
- How many kernals in a pound unpopped?
- Does it still weigh a pound popped?
- How much money will be collected?
- How much money will be spent to purchase corn, oil, butter, salt, boxes, and rent the machine?

Have the children develop their own strategies for solving the problem. Pose questions that will help them see what other data they will need.

You may want to try this one out. Have the class make an estimate of what they will need for just their class. Bring it in or have them take this responsibility. This way you can test their theories firsthand.

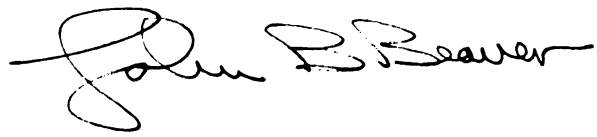
POST-TEST REMINDER

REMINDER: Within one week of completion of the unit the post-tests should be administered.

- See page 16 of this guide for directions on administering these tests.
- Please leave all teacher logs and the end of the unit evaluation in this binder. John Beaver will arrange to pick them up.
- Place the Student and Teacher Perception Forms in the binder as well, for return to the researcher.

Thank you for your assistance. Your help in the development of this unit should prove valuable in guiding future efforts to improve the science curriculum. My thanks to you also for contributing toward my own research project.

Sincerely,



APPENDIX B

OUTLINES OF THE TIME COMMITMENT REQUIRED OF PARTICIPATING TEACHERS AND PROFESSIONAL IMPROVEMENT GOAL FOR TEACHERS

TIME COMMITMENT

The study is a curriculum modification (development) plan. I have taken the ESS unit Peas & Particles and have rewritten it according to an inquiry-script model. The purpose of this rewrite was to clearly establish the objectives of the unit, a means for teaching to those objectives and a way to evaluate the students who have participated in it.

The following is an outline of what is required of you if you agree to participate and the approximate amount of time the study will demand of you. Please keep in mind that all teachers, schools and students participating in the study will remain anonymous. You may use the study in your goals. This unit may be substituted for one of the required ESS physical science units this year, and a letter will be placed, at your request, in your file concerning your work and assistance in the project.

- 2 meetings prior to teaching the unit to familiarize yourself with the teaching model and the study.	1½ hours	0
- Complete Teacher Background Data Form	15 min.	0
- Pre-test students 2 models	1½ hours	I
- Teach ten lessons	10 hours	I
- Complete teacher log after each lesson	1½ hours	0
- Four visits from Science person at your building	3 hours	I
- Complete End of The Unit Evaluation Form	15 min.	0
- Complete Student Perception Form	30 min.	I

- Complete Teacher Perception Form	10 min.	0
- Post-test students 2 models	1½ hours	I

I = In-class time. Total = 13½ hours.

0 = Out-of-class time. Total = 3 hours 45 minutes.

PROFESSIONAL IMPROVEMENT GOAL

- Statement of Goal

Improve the ESS unit Peas & Particles used by the fourth grades through work on a curriculum modification process, including a careful analysis of the intended learning outcomes of the unit, the process for teaching these goals, and a trial of two test models.

Present Status

A rewritten script based on pilot work completed during the 1978-79 school year.

- Plan of Action

1 - Attend and participate in two meetings to analyze the script and the inquiry model it's based on.

2 - Read and evaluate the inquiry-model background and the script.

3 - Utilize the school's video-tape equipment to record and analyze four of the ten lessons of the unit with the science-math teacher in a post-lesson interview.

4 - Complete logs of each lesson as an analysis thereof.

5 - Complete an end of the unit evaluation report of the entire process.

6 - Administer student perception instrument and complete a teacher perception form.

7 - Administer two forms of a student test pre- and post-instructional and conduct interviews of selected students.

- Standard of Achievement

Through the use of the above mentioned procedures the unit will be analyzed toward further revision and the development of a model for revising other science units.

APPENDIX C

ACTIVITY CATEGORIES INDEX (ACI)
OBSERVER TRAINING

ACTIVITY CATEGORIES: AN INSTRUMENT FOR QUANTITATIVELY RECORDING ACTIVITIES IN A SCIENCE CLASS*

TRAINING:

Training in the use of the Activity Categories Index (ACI) is expected to occur in the following steps and time frame. For this study two associate observers will be trained to use the activity categories. Each observer will make one-third of the observations.

Step 1: At the first training meeting the two associate observers will be given copies of the categories, ground rules and a recording sheet and will be told how these are to be used in the science class. They will be told that in order to use the categories they must memorize the categories and ground rules. A suggested procedure will be to practice rating their own classes.

Step 2: At the second meeting the associate observers and the investigator will discuss any problems and then will practice coding with an audio tape of a science lesson. They will code together, stopping the tape occasionally to discuss any problems in coding.

Step 3: During the final week of training the observers will observe three science classes to standardize the performance of all three observers. During the first of these sessions observers will be seated together so that they can see how their decisions compare. During the last two meetings they will separate and will not be able to see each other's recording sheet. After the observation period the observers will meet to discuss discrepancies in coding.

Step 4: Observers will code an elementary science class independently of one another and an interrater reliability will be established before the study begins.

The Categories

Six categories describe activities considered to be indirect activities. These are open-ended laboratory experiences, structured laboratory experiences, group projects, student demonstrations, student library research and student talking. During these activities the teacher acts as a coordinator of learning experiences. Emphasis is on student participation.

The first two categories describe laboratory experiences; open-ended laboratory experiences (category No. 1) and structured laboratory experiences (category No. 2).

The major difference between open-ended and structured laboratory experiences is the amount of freedom granted to students. In a structured laboratory experience students have little or no freedom. The procedure is carefully outlined and students are not asked to make any analysis or interpretation of the data. They are only required to make observations. The following examples are structured laboratory experiences:

> Example 1: Students are told that foods which contain starch are turned blue by the addition of iodine solution. They are given iodine solution and several foods, told to add a drop of iodine solution to each food and asked to write the names of foods which turn blue or contain starch.
>
> Example 2: Students are told to plant four seeds. They must give one seed water, sunlight and dirt; the second, only sunlight and water; the third, only sunlight and dirt; and the fourth, only water and dirt. Students are asked to describe what happens.

In both cases the procedure was specified and students were only required to make observations. They were not asked to explain or draw conclusions from the data.

In open-ended laboratory experiences students are presented one or more problems. They may or may not be asked to determine a procedure but are asked to analyze or interpret the results. The following examples are open-ended laboratory experiences:

> Example 1: Students are given three chemicals; iodine solution, water with blue food coloring and water with green food coloring, and several foods. They are told potatoes contain starch and are asked to tell all they can about the foods. Students are also asked to tell what they do and give reasons for their statements about the foods.
>
> Example 2: Students are asked, "What do plants need to grow?" "How much do they need?" The students are required to plan and carry out experiments to answer the questions. They must describe what they do and give reasons for any conclusions they may make.

In these examples students not only analyze or interpret their observations, but also plan their own procedures.

Three categories describe children working individually or in small groups on a project, demonstration or report. Students are often granted class time to prepare science

fair projects or demonstrations for the class. The category entitled "group projects" (No. 3) is recorded when students are preparing projects or demonstrations. When a demonstration, project or oral report on a project is being presented to the class by a student or group of students, the category entitled "student demonstrations" (No. 4) is recorded. If the study of weather at the elementary school level projects are often prepared and demonstrated. Students make instruments to measure wind velocity, air pressure and precipitation or wind direction and demonstrate them to the class. Many teachers have students prepare and present oral or written reports on various animals. The category "student library research" (No. 5) is recorded when students are working with reference materials to prepare a report or when students are presenting their reports to the class.

Categories entitled "workbook work" (No. 8), "teacher demonstration" (No. 9) and "lecture" (No. 10) are classified as direct activities. During these activities the teacher imparts knowledge verbally or with some device.

The workbook work category is used to describe situations in which students are filling out workbooks, working homework problems, writing answers to questions, copying pictures or coloring pictures. This category is classified direct because teachers usually ask questions which require students to search for an answer in the textbook or have students color a sketch of some picture hanging in the front of the room. This is just another way of imparting information to the students. They are given little freedom to express themselves to analyze or interpret information. However, if questions are judged by the observer to be thought provoking, a notation is made in the margin of the coding sheet.

Modern technology has provided teachers with instructional aids, audio-visual devices and other media which provide teachers with efficient and enjoyable ways to present information. Included as instructional aids are television, films, filmstrips, phonograph records, tape recordings and radio. Category No. 9, "Teacher Demonstrations," is recorded when the teacher is using instructional aids. This category is also recorded while the teacher is demonstrating. The following example will illustrate when the category was used. During the study a teacher heated a Coke bottle capped with a balloon "to prove that air expands when heated." Several times films or filmstrips were used.

If properly used, instructional aids or a demonstration will arouse student curiosity and provoke discussion or

investigation. Situations where instructional aids are used to simulate inquiry will be short and interrupted by situations which can be classified into an indirect activity category. Unfortunately, demonstrations are seldom used to stimulate inquiry. The teacher rushes through the film, filmstrip or demonstration and only asks a question to make sure students are paying attention. The teacher seldom stops the film, filmstrip or demonstration and asks, "What do you think is going to happen?" and "Why do you think it happened?" If he did stop, asked questions and allowed students to express their views, "student talking" (category No. 6) and probably "teacher questioning" (category No. 7) would be recorded more than "teacher demonstrations" (category No. 9).

The category entitled lecture (No. 10) is recorded when the teacher reads aloud, expresses his views, gives directions, makes an assignment, or asks a rhetorical question. The student listens and only interrupts if he does not understand what the teacher is saying. If the teacher writes on the blackboard or overhead projector, the interval is still classified as lecture. These instructional aids are not considered "teacher demonstrations." Students reading the text, aloud or silently, and lulls during a lecture for students to write notes are also classified as lecture. This category describes those activities in which students receive information or directions from the teacher or textbook.

The teacher questioning category (No. 7) is recorded when students are asked a question by the teacher. This category could be considered direct since it describes situations in which students are not participating. However, the teacher is not imparting information but is attempting to elicit student talk. Not classifying this category direct or indirect when calculating the activity ratio has implications which were discussed in the description of instruments, Chapter III.

"General havoc" (No. 11) is the category used to describe intervals of time when the class is interrupted. These non-teaching activities include students settling down or cleaning up, announcements, on the public address system, visitors at the door, fire drills, handing out homework or materials, moving from one classroom location to another, etc. Periods of silence while the teacher gets the materials ready, erases the board or does some other menial task are also classified as "general havoc."

Use of the Activity Categories

In the classroom the observer uses a stopwatch and a notebook. The notebook has a copy of the categories and the

ground rules attached to the inside left cover and a recording sheet on the right side. Before class, in the spaces provided at the top of the sheet, the observer writes his name, the teacher's name, the date and the time. Spaces on the recording sheet are provided for the observer to record a series of numbers. The spaces, small squares, are arranged in groups of twelve. Twelve squares are filled every minute; each square corresponds to a five-second interval of time.

When the lesson begins, or just before it begins, the stopwatch is started. It runs continuously throughout the science lesson. Every five seconds the observer notes a single numeral which designates one of the eleven categories. The activity which occurs during the five-second determines which category is chosen and hence which number is recorded. If the teacher was asking a question, the observer records a 7, "teacher questioning." If a student was giving a report, the observer records a 5 to indicate the category entitled "student library research." If the students were cleaning up after a laboratory experiment, the observer records an 11, "general havoc." A series of numbers is obtained. This series of numbers tells what type of activities occurred as well as the order in which they occurred.

Ground Rules

Several ground rules were developed to clarify use of the instrument. Many times two or more activities occur simultaneously or sequentially in the same five-second interval. Since only one number is recorded, only one category is chosen. Two ground rules are provided for the simultaneous or sequential occurrence of two or more activities in the same time interval. When activities occur simultaneously, the observer chooses the category with the lowest number (rule 1). For example, the teacher is talking during a film. If the teacher is lecturing or telling students (category No. 10), the observer records No. 9 (teacher demonstration). If the teacher is asking a question, the observer records No. 7 (teacher questioning). When activities occur sequentially in the same five-second interval, the observer chooses the category which describes the activity occupying the major portion of the interval (rule 2). If this is not possible, the observer chooses the category with the lowest number. For example, the teacher ends his question in an interval and a student begins to talk immediately. If the student talk occupied the greatest portion of the five-second interval, the observer records No. 6 (student talk). If the question occupied the greatest portion, the observer records No. 7 (teacher questioning). If both activities occupied the same

portion, the observer chooses the category entitled student talk because its numerical designation is lowest (No. 6).

Periods of silence during a lecture or following a question are also classified (rule 3). The lull in a lecture for purposes of notetaking or allowing the information to sink in is coded as part of the lecture. The lull following a teacher's question is categorized "teacher questioning" (category No. 7).

Occasionally activities not described by a category will occur. To provide for such situations, it was necessary to add ground rules. The general rule for intervals which cannot be assigned a number is (rule 4). The interval is left blank, and the observer writes a description of the activity in the margin of the recording sheet.

Fieldtrips are classified "student library research," category No. 5 (rule 5). Fieldtrips may range from a trip to another class where an exhibit is displayed to a trip to an industrial concern in another city. The travel time is categorized "general havoc" (category No. 11). Tests are not classified. The observer records a "T" to denote test (rule 6). Laboratory activities with non-verbal directions are coded "L" until the directions can be examined (rule 7). Usually the teacher gives a copy of the directions to the observer. Guest speakers are not recorded; the interval is left blank and "guest speaker" is written across the intervals (rule 9).

Ground rule (No. 8) provides for workbook materials which are thought-provoking rather than "look-up-the-answer" type. The observer makes a marginal notation when the materials require students to analyze or interpret rather than hunt for answers.

After class the observer writes the subject-matter topic which was studied in the space at the top of the form. This information can be used to determine if effects due to subject matter occurred. Perhaps teachers use certain categories of activities when teaching one subject-matter area and other categories of activities when teaching other subject matter areas. Data should be available to measure effects due to subject matter.

On the reverse side of the recording sheet the observer also makes subjective comments about classroom atmosphere. When applicable, he writes a concise phrase to answer the following three questions:

1. In general, what types of questions did teachers ask? Recall? Thought-provoking?

2. Did the teacher have sufficient knowledge of the subject matter? Were students interested?
3. Was the class structured or unstructured; i.e., did students have the opportunity to inquire or were their questions overlooked?

* Activity Categories Index (ACI), Harrie J. Caldwell.

GROUND RULES*

1. When two activities occur simultaneously in a five-second interval, observers choose the category with the smallest number. For example, a teacher may be talking while showing a filmstrip (No. 9). If the teacher is telling the students (No. 10), observers record a 9. If the teacher is asking a question (No. 7), observers record a 7.

2. When two or more activities occur sequentially within a five-second interval, observers choose the activity which occupied the major portion. If this is not possible, observers choose the category with the lowest number.

3. Lulls in a lecture for purposes of notetaking (No. 10). If the lull occurs following a teacher's question, it is recorded as a question (No. 7).

4. If an interval cannot be assigned a number, it is left blank. The situation should be explained in the margin as soon as possible.

5. Field trips are classified "student library research," category 5. The travel time is categorized "general havoc" (category No. 11).

6. A test is coded as "T".

7. Laboratory experiments: If a distinction between categories 1 and 2 cannot be made because the directions are nonverbal, then an "L" will be used until the directions can be examined. While students are predominantly reading directions, consider this as category 10, directions.

8. When category No. 8 is applicable, the observer should check the materials. If the materials are thought-provoking rather than "look-up-the-answer" type, the observer will note this on the reverse side of the sheet.

9. Guest speakers are not recorded. "Guest speaker" is written across the blank intervals.

* Activity Categories Index (ACI), Harrie J. Caldwell.

A C I *

STUDENT-CENTERED ACTIVITIES	1.	LABORATORY EXPERIENCES: OPEN-ENDED	Students are presented a problem to be solved by experimentation. The procedure may or may not be given. They are required to make observations and analyze or interpret their findings.
	2.	LABORATORY EXPERIENCES: Structured	Students are presented a laboratory experiment with a structured procedure. They are not required to analyze or interpret their data. They are asked to make observations.
	3.	GROUP PROJECTS	One or more groups of students are working on a science project during the class period. Some may work individually (not written projects).
	4.	STUDENT DEMONSTRATIONS	A student or a group of students demonstrate a science experiment or project which they have prepared. (Oral report on science project would be included.)
	5.	STUDENT LIBRARY RESEARCH	a) A student or group of students give an oral report they have prepared based on reference material. b) The class works with reference materials for the purposes of writing or making reports.
	6.	STUDENT SPEAKING	The student contributes verbally by asking a question, answering a question or simply volunteering information.
	7.	TEACHER QUESTIONING	Students are asked a question by the teacher.
STUDENT-CENTERED ACTIVITIES	8.	WORKBOOK WORK	Students work in class on workbooks, homework, questions from the text, art type work, etc.
	9.	TEACHER DEMONSTRATIONS	The teacher presents material by film, filmstrip, record, T.V., radio, demonstration, etc.

A C I *
Continued

STUDENT-CENTERED ACTIVITIES	10. LECTURE	The teacher reads aloud, expresses his views, gives directions, makes an assignment or asks rhetorical questions. Students are expected to listen. They may interrupt only when they don't understand. Student reading in the text is also included in this category.
	11. GENERAL HAVOC	The class may be cleaning up, settling down or doing nothing. In general, this category should be used sparingly.

* Activity Categories Index (ACI), Harrie J. Caldwell.

1.	LABORATORY EXPERIENCES: OPEN-ENDED
2.	LABORATORY EXPERIENCES: STRUCTURED
3.	GROUP PROJECTS
4.	STUDENT DEMONSTRATIONS
5.	STUDENT LIBRARY RESEARCH, REPORTING, ETC.
6.	STUDENT SPEAKING
7.	TEACHER QUESTIONING
8.	WORKBOOK WORK
9.	TEACHER DEMONSTRATIONS
10.	LECTURE
11.	GENERAL HAVOC

GROUND RULES

1.	SIMULTANEOUS ACTIVITIES — CHOOSE LOWER NUMBER
2.	SEQUENTIALLY OCCURRING ACTIVITIES — CHOOSE ONE TAKING MAJOR PORTION — IF NOT POSSIBLE CHOOSE LOWER NUMBER
3.	LULLS FOR NOTETAKING IN LECTURE — RECORD NO. 10
4.	LULLS AFTER QUESTION — RECORD NO. 7
5.	IF INTERVAL CAN'T BE CODED, LEAVE BLANK AND EXPLAIN IN MARGIN AS SOON AS POSSIBLE.
6.	A TEST IS CODED "T".
7.	IF DISTINCTION BETWEEN 1 AND 2 CAN'T BE MADE, RECORD "L" UNTIL YOU CAN DECIDE.
8.	WHEN CATEGORY 8 IS APPLICABLE, CHECK MATERIALS. IF THOUGHT-PROVOKING, NOTE.
9.	GUEST SPEAKERS ARE NOT RECORDED. WRITE GUEST SPEAKERS ACROSS THE INTERVALS.

TEACHER NUMBER:_____ SCIENCE TOPIC:_____

TIME:_____ DATE:_____ OBSERVER:_____

| | | |

APPENDIX D

STUDENT PERCEPTION FORM

Class Code #____

Science Activities - Student's Perceptions

Think about the science lesson. Read each question below and check the answer you think best for each question. There are no right or wrong answers.

1. During the science period, the class
   a. mostly listened to the teacher ___
   b. mostly watched the teacher or a boy or girl do experiments ___
   c. mostly worked with equipment ___

2. Most of the talking was done
   a. by the teacher ___
   b. by a few boys or girls ___
   c. by many boys or girls ___

3. Most of the experiments were done
   a. by the teacher ___
   b. by a few boys or girls ___
   c. by many boys or girls ___

4. I got to talk about science
   a. not at all ___
   b. not as much as I wanted to ___
   c. as much as I wanted to ___

5. I got to work with the science equipment
   a. hardly at all ___
   b. about half the time ___
   c. most of the time ___

6. When I worked with the science equipment, I mostly did experiments
   a. planned by the teacher ___
   b. planned by the book ___
   c. planned by the group ___

7. It is all right to help other students with science
   a. not at all ___
   b. sometimes ___
   c. most of the time ___

8. When my teacher told me or asked me something, it was
   a. usually about my work ___
   b. usually about the way I acted ___
   c. usually about other things ___

9. During the science periods, I understood
   a. most of the time ___
   b. about half the time ___
   c. hardly at all ___

10. What is your favorite subject? Write a number 1 in front of your first choice, a number 2 in front of your second choice, a number 3 in front of your third choice, a number 4 in front of your fourth choice, and a number 5 in front of your fifth choice.

    _____Arithmetic

    _____Language Arts

    _____Reading

    _____Science

    _____Social Studies

(Student's Perception Form developed by the Science Curriculum Improvement Study, University of California, Berkeley)

APPENDIX E

TEACHER PERCEPTION FORM

Science Activities - Teacher's Perceptions

Think about the science lesson you have just concluded. Would you please respond to each item in terms of how you feel the children, as a total group, will respond. There are no right or wrong answers for either the children or the teachers; it merely represents one sample of one lesson.

1. During the science period, the class

   a. mostly listened to the teacher ___
   b. mostly watched the teacher or a boy or girl do experiments ___
   c. mostly worked with equipment ___

2. Most of the talking was done

   a. by the teacher ___
   b. by a few boys and girls ___
   c. by many boys and girls ___

3. Most of the experiments were done

   a. by the teacher ___
   b. by a few boys and girls ___
   c. by many boys and girls ___

4. I got to talk about science

   a. not at all ___
   b. about half the time ___
   c. most of the time ___

5. I got to work with the science equipment

   a. hardly at all ___
   b. about half the time ___
   c. most of the time ___

6. When I worked with the science equipment, I mostly did experiments

   a. planned by the teacher ___
   b. planned by the book ___
   c. planned by the group ___

7. It is all right to help other students in science

   a. not at all ___
   b. sometimes ___
   c. most of the time ___

8. When my teacher told me or asked me something, it was

   a. usually about my work ___
   b. usually about the way I acted ___
   c. usually about other things ___

9. During the science periods, I understood

   a. most of the time ___
   b. about half the time ___
   c. hardly at all ___

10. What is your favorite subject? Write a number 1 in front of your first choice, a number 2 in front of your second choice, a number 3 in front of your third choice, a number 4 in front of your fourth choice, and a number 5 in front of your fifth choice.

_____Arithmetic

_____Language Arts

_____Reading

_____Science

_____Social Studies

(Student's Perception Form developed by the Science Curriculum Improvement Study, University of California, Berkeley)

APPENDIX F

TEACHER BACKGROUND DATA FORM

TEACHERS' BACKGROUND DATA SHEET

The following information is necessary for a complete analysis of the data collected for this study. IT WILL NOT BE USED IN ANY OTHER WAY and the responses you provide will not be seen by anyone other than the researcher. No teachers, administrators, or schools will be identified in the report of this study, thus complete anonymity will be guaranteed to persons cooperating with this study.

Please answer the following questions by checking the appropriate responses:

---

1. Sex: male_____ female_____

2. Age (last birthday):
   less than 25___; 25-30___; 31-40___; 41-50___; more than 50___.

3. Total years teaching experience: (count this year)
   _____1 _____3 _____7-10 _____more than 15
   _____2 _____4-6 _____11-15

4. How many years have you taught in this school: (count this year)
   _____1 _____3 _____7-10 _____more than 15
   _____2 _____4-6 _____11-15

5. Total number of academic hours completed:
   _____Bachelor's degree
   _____Bachelor's degree + 15 hours
   _____Bachelor's degree + 30 hours
   _____Master's degree
   _____Master's degree + 15 hours
   _____Master's degree + 30 hours
   _____Master's degree + 45 hours
   _____Master's degree + 60 hours

6. Indicate the approximate number of pupils that attend your school:
   _____under 300 _____301-500 _____501-750
   _____more than 750

7. If you are using textbook materials, please indicate the series (if more than one please list others).
   _____
   _____

8. Have you taught the unit Peas & Particles other years? _____yes _____no

9. How many times have you taught the unit Peas & Particles?
_____once _____twice _____three times _____four times
_____five times _____more than five times

10. On the average, how many science lessons do you teach a week?

_____1 _____2 _____3 _____4 _____5

11. Indicate the average number of minutes per lesson.

_____less than 20 _____31-45 _____more than 60

12. Number of semester hours of college training in:

	0	3-6	7-12	13-15	15+
Biological Science					
Physical Science					
Chemistry					
Earth Science & Geology					
Methods of Teaching Science					

13. Have you participated in any special training activities (in addition to your courses reported under item #12) related to the teaching of elementary school science?

Yes_____(if yes, please complete item #14 below)
No _____

14. Type of training program and/or activities:

Type of Activities	No. of Sessions	Length of Sessions	Conducted by?
Local-School Workshop			
Science conference			
Summer workshop			
College course			
Other: _____ Specify			

APPENDIX G

END OF THE UNIT EVALUATION FORM AND CLASSROOM LOG

End of the Unit Evaluation of Peas & Particles

1. How would you rate concepts presented in the unit?
   _____too difficult _____difficult _____satisfactory
   _____easy _____too easy

2. How would you rate process skills presented in the unit?
   _____too difficult _____difficult _____satisfactory
   _____easy _____too easy

3. How would you rate the content presented in the unit?
   _____too difficult _____difficult _____satisfactory
   _____easy _____too easy

4. What percent of the time was usually devoted to exploration or lab work in each lesson?
   ___0 ___20 ___30 ___40 ___50 ___60 ___70 ___80 ___90

5. Do you think more time should be devoted to lab time in the future? _____yes _____no

6. Rate student attitude for the entire unit.
   _____very enthusiastic
   _____moderate enthusiasm
   _____average enthusiasm and interest
   _____somewhat uninterested
   _____very uninterested

7. Generally speaking do you think that the children experienced more success with the scripted unit than the same unit as it was taught? ___yes ___no If no, please comment _____

8. Do you think that this unit belongs at the fourth grade level? _____yes _____no

9. If no, what grade level would you recommend?
   _____2 _____3 _____5 _____6

10. Did you cover all the activities? _____yes _____no

11. If no, please check the activities you did not cover.
    ___1 ___2 ___3 ___4 ___5 ___6 ___7 ___8 ___9 ___10 __11

12. If you had to eliminate one activity which one would it be? Activity number _____

13. Which activity did children enjoy most?
    Activity number_____

14. Which activity did you enjoy most? Activity number____

15. Which activity did the children enjoy the least?
Activity number_____

16. Which activity did you enjoy the least?
Activity number_____

17. Did you generally have enough materials to assist you in teaching? _____yes _____no

18. Did you generally have sufficient time to complete an activity? _____yes _____no

19. Did you have enough time to complete the unit?
_____yes _____no

COMMENTS:

Classroom Log

Teacher _____ Time_____ Date_____

Activity number_____

Note the approximate amount of time spent on:

Launching Activity_____

Exploration_____

Summary_____

Note any significant discoveries made by children in today's lesson: _____

_____

Note any significant strategies developed by the children in the activity:_____

_____

List any deviations from the script:

_____

_____

_____

Reasons for deviations:_____

_____

_____

Please rate your students on attitude toward today's science class:_____

_____very enthusiastic

_____moderate enthusiasm

_____average enthusiasm and interest

_____somewhat uninterested

_____very uninterested

APPENDIX H

STUDENT UNIT-ACHIEVEMENT TEST FOR THE PEAS & PARTICLES UNIT (FORM A & FORM B)

FORM A

DIRECTIONS: The teacher is going to show you some pictures of objects. You will have five seconds to look at the objects and estimate how many there are in the picture. Circle the letter next to the best estimate.

EXAMPLE: Jars

A - 8
B - 10
C - 12
D - 14

---

1) Bologna

A - 25
B - 30
C - 35

---

2) Can Tops

A - 60
B - 80
C - 100
D - 120

---

3) Soda Pop

A - 50
B - 100
C - 150

---

4) Bricks

A - 60
B - 70
C - 80
D - 90

---

5) Paint

A - 30
B - 35
C - 40
D - 45

DATE_____

PEAS & PARTICLES EVALUATION

DIRECTIONS: READ EACH ITEM CAREFULLY. CIRCLE THE LETTER NEXT TO THE ANSWER YOU THINK IS CORRECT.

---

6) Find the numeral that shows one million.

A - 1,000
B - 1,000,000
C - 1,000,000,000
D - 1,000,000,000,000

---

7) Which of the following is the rule for finding the area of a rectangle?

A - Add length and width
B - Sum the four sides
C - Multiply length times width
D - Multiply the four sides together

---

8) Pencils are sold to the school store by the dozen. If the store needed 137 pencils, how many dozen would they have to buy?

A - 12 dozen
B - 13 dozen
C - 14 dozen
D - 15 dozen

---

9) To estimate the sum 356 and 503 to the nearest hundred, you can add

A - 300 and 500
B - 350 and 500
C - 400 and 500
D - 400 and 600

---

10) Which of the following numerals shows 13,628 rounded to the nearest ten?

A - 13,600
B - 13,610
C - 13,620
D - 13,630

---

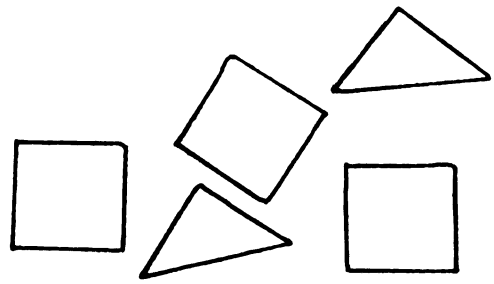
11) Which is the best way to show the ratio of triangles to squares in the drawing below?

A - 3 : 2

B - $\frac{2}{3}$

C - 2 : 2

D - $\frac{3}{2}$



12) In which situation would using an estimate or rounded-off quantity be all right?

A - people at a school assembly
B - cupcakes needed for a class party
C - desks needed in a classroom
D - seats on an airline

13) Which of the following shows 19,231 rounded to the nearest ten?

A - 19,200
B - 19,220
C - 19,230
D - 19,300

14) There are about twenty-five students in each of five classes in the fourth grade of the Red River School. Which of the following is the best estimate of the number of students in the fourth grade at this school?

A - 100
B - 200
C - 300
D - 400

15) You are using the sampling method to estimate the number of acorns in a jar. Which of the following is a variable?

A - Number of trials completed
B - Number of buttons in each handful
C - The size of the jar
D - Number of buttons in the jar

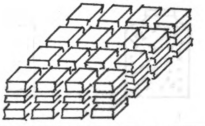
16) Look at the drawing of tiles. How many tiles are stacked up here?

A - 16

B - 32

C - 48

D - 50



---

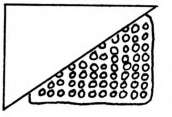
17) Some of the marbles in the drawing below have been covered? Assume the tray is full, how many marbles are there in all?

A - 18

B - 70

C - 77

D - 88



---

18) If you rip a piece of paper in half, and then rip these pieces in half again, and finally rip these pieces in half a third time, how many pieces do you end up with?

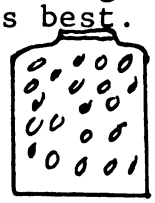
A - 6
B - 8
C - 12
D - 16

---

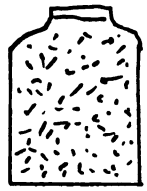
19) Which of the following numerals shows 11,843 rounded to the nearest hundred?

A - 11,000
B - 11,800
C - 11,840
D - 11,850

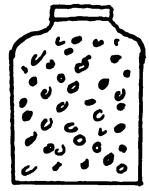
DIRECTIONS: The next four questions will be about the drawing below. Read each item carefully, look at the drawing, and circle the letter next to the answer you think is best.



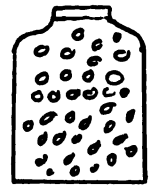
1 gallon lima beans



1 gallon rice



1 gallon corn



1 gallon peas

---

20) Which jar contains the least number of particles?

A - lima beans
B - rice
C - corn
D - peas

---

21) Which jar contains the second greatest number of particles?

A - lima beans
B - rice
C - corn
D - peas

---

22) Which jar contains the most particles?

A - lima beans
B - rice
C - corn
D - peas

---

23) Which jar contains the third greatest number of particles?

A - lima beans
B - rice
C - corn
D - peas

---

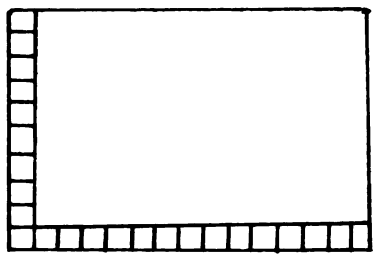
24) A new tile floor is being put in a room. The drawing shows that fifteen tiles fit along one wall. Ten tiles fit along another wall. How many tiles were needed to cover the whole floor?

A - 25

B - 50

C - 150

D - 300



---

25) In which situation below would an exact quantity be necessary?

A - bricks needed to build a school
B - light bulbs needed for a school
C - pencils ordered for a school store
D - textbooks needed for a class

---

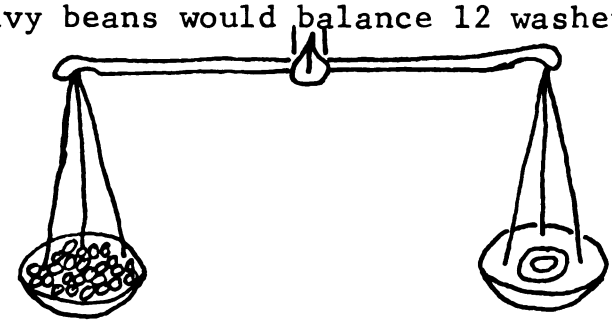
26) Look at the balance below. One washer balanced 45 navy beans. How many navy beans would balance 12 washers?

A - 480

B - 500

C - 540

D - 600



---

27) Which of the following estimation techniques is the most accurate?

A - counting by area
B - counting by fives
C - guessing the quantity
D - counting by volume

---

28) What is the rule for counting by volume?

A - add the number of particles along each side together
B - add the number along the side to the number along the width
C - multiply the number along the side times the width
D - multiply the number along the side times the width times the number of layers

---

29) Look at the drawing of the spring scale. Five peas weigh 1 g. About how many peas are in the cup now?



A - 100
B - 150
C - 200
D - 250

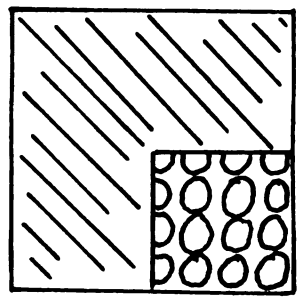
---

30) The ratio of lima beans to corn is 1 : 6. A jar holds 2500 lima beans. How much corn would a jar the same size hold?

A - 2500
B - 5000
C - 10,000
D - 15,000

---

31) Look at the drawing of the geoboard below. Count the objects in the uncovered part and estimate the total number of objects on the board. The board is totally covered one layer deep.



A - 30

B - 35

C - 48

D - 49

---

32) Chris halved a pile of rice several times. He ended up with 32 piles of rice. How many times did he halve the original pile of rice?

A - 2
B - 3
C - 4
D - 5

---

33) Which of the following shows another name for 2000?

A - $2\ (10)^1$
B - $2\ (10)^2$
C - $2\ (10)^3$
D - $2\ (10)^4$

DIRECTIONS: Use the information below to answer the next three questions.

INFORMATION: Hidden Valley School District

6 school buildings

30 classrooms in each building

25 children in each classroom

---

34) About how many children attend the Hidden Valley Schools?

A - 750
B - 1,500
C - 3,000
D - 4,500

---

35) About how many children are there in each building?

A - 150
B - 180
C - 750
D - 1000

---

36) About one-half of the children in the district buy milk each day. About how many cartons of milk are sold each day?

A - 2,250
B - 4,500
C - 9,000
D - 9,500

FORM B

DIRECTIONS: The teacher is going to show you some pictures of objects. You will have five seconds to look at the objects and estimate how many there are in the picture. Circle the letter next to the best estimate.

EXAMPLE: Jars

A - 8
B - 10
C - 12
D - 14

---

1) Bologna

A - 25
B - 30
C - 35

---

2) Paint

A - 30
B - 35
C - 40
D - 45

---

3) Bricks

A - 60
B - 70
C - 80
D - 90

---

4) Soda Pop

A - 50
B - 100
C - 150

---

5) Can Tops

A - 60
B - 80
C - 100
D - 120

Date_____

PEAS & PARTICLES EVALUATION B

DIRECTIONS: READ EACH ITEM CAREFULLY. CIRCLE THE LETTER NEXT TO THE ANSWER YOU THINK IS CORRECT.

---

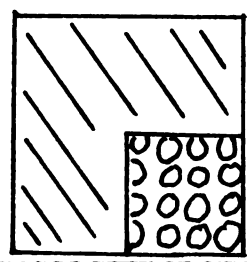
6) Look at the drawing of the geoboard below. Count the objects in the uncovered part and estimate the total number of objects on the board. The board is totally covered one layer deep.

A - 30

B - 35

C - 48

D - 49



---

7) Which of the following numerals shows 11,843 rounded to the nearest hundred?

A - 11,000
B - 11,800
C - 11,840
D - 11,850

---

8) Which of the following numerals shows 13,628 rounded to the nearest ten?

A - 13,600
B - 13,610
C - 13,620
D - 13,630

---

9) In which situation below would an exact quantity be necessary?

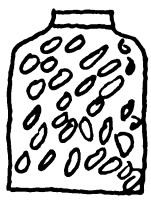
A - bricks needed to build a school
B - light bulbs needed for a school
C - pencils ordered for a school store
D - textbooks needed for a class

---

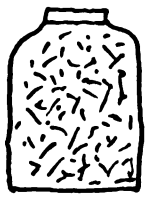
10) The ratio of lima beans to corn is 1 : 6. A jar holds 2500 lima beans. How much corn would a jar the same size hold?

A - 2500
B - 5000
C - 10,000
D - 15,000

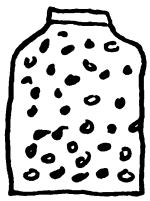
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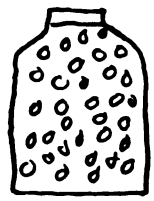
1 gallon lima beans



1 gallon rice



1 gallon corn



1 gallon peas

---

11) Which jar contains the most particles?

A - lima beans
B - rice
C - corn
D - peas

---

12) Which jar contains the least number of particles?

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13) Which jar contains the second greatest number of particles?

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B - rice
C - corn
D - peas

---

14) Which jar contains the third greatest number of particles?

A - lima beans
B - rice
C - corn
D - peas

---

15) Find the numeral that shows one million.

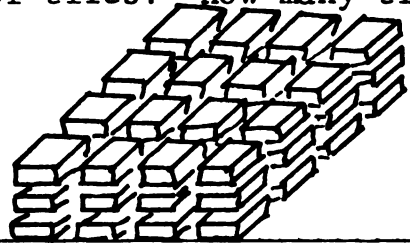
A - 1,000
B - 1,000,000
C - 1,000,000,000
D - 1,000,000,000,000

16) There are about twenty-five students in each of five classes in the fourth grade of the Red River School. Which of the following is the best estimate of the number of students in the fourth grade at this school?

A - 100
B - 200
C - 300
D - 400

---

17) Look at the drawing of tiles. How many tiles are stacked up here?



A - 16
B - 32
C - 48
D - 50

---

18) Which of the following estimation techniques is the most accurate?

A - counting by area
B - counting by fives
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---

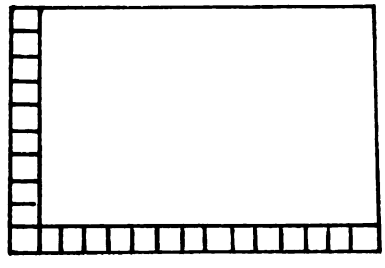
19) A new tile floor is being put in a room. The drawing shows that fifteen tiles fit along one wall. Ten tiles fit along another wall. How many tiles are needed to cover the whole floor?

A - 25

B - 50

C - 150

D - 300



---

20) You are using the sampling method to estimate the number of buttons in a jar. Which of the following is a variable?

A - Number of trials completed
B - Number of buttons in each handful
C - The size of the jar
D - Number of buttons in the jar

DIRECTIONS: Use the information below to answer the next three questions.

INFORMATION: Hidden Valley School District

6 Schools

30 Classrooms in each building

25 Children in each classroom

---

21) About how many children attend the Hidden Valley Schools?

A - 750
B - 1,500
C - 3,000
D - 4,500

---

22) About one-half of the children in the district buy milk dach day. About how many cartons of milk are sold each day?

A - 2,250
B - 4,500
C - 9,000
D - 9,500

---

23) About how many children are there in each building?

A - 150
B - 180
C - 750
D - 1000

---

24) Look at the drawing of the spring scale. Five peas weigh 1 g. About how many peas are in the cup now?



A - 100
B - 150
C - 200
D - 250

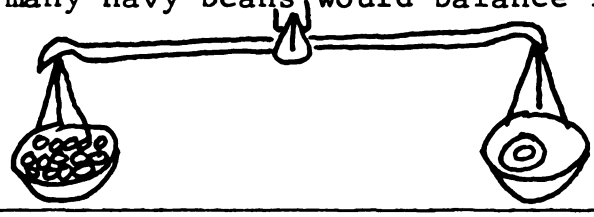
25) In which situation would using an estimate or rounded-off quantity be all right?

A - people at a school assembly
B - cupcakes needed for a class party
C - desks needed in a classroom
D - seats on an airline

---

26) Look at the balance below. One washer balanced 45 navy beans. How many navy beans would balance 12 washers?

A - 480
B - 500
C - 540
D - 600



---

27) What is the rule for counting by volume?

A - add the number of particles along each side together
B - add the number along the side to the number along the width
C - multiply the number along the side times the width
D - multiply the number along the side times the width times the number of layers

---

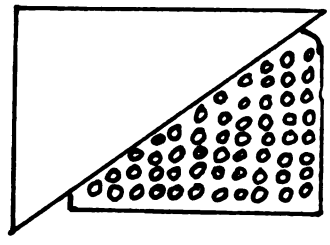
28) Some of the marbles in the drawing below have been covered. Assume the tray is full; how many marbles are there in all?

A - 18

B - 70

C - 77

D - 88



---

29) Which of the following shows another name for 2000?

A - $2\ (10)^1$
B - $2\ (10)^2$
C - $2\ (10)^3$
D - $2\ (10)^4$

30) Which of the following shows 19,231 to the nearest ten?

A - 19,200
B - 19,220
C - 19,230
D - 19,300

---

31) If you rip a piece of paper in half, and then rip these pieces in half again, and finally rip these pieces in half a third time, how many pieces do you end up with?

A - 6
B - 8
C - 12
D - 16

---

32) Chris halved a pile of rice several times. He ended up with thirty-two piles of rice. How many times did he halve the original pile of rice?

A - 2
B - 3
C - 4
D - 5

---

33) Which of the following is the rule for finding the area of a rectangle?

A - add length and width
B - sum the four sides
C - multiply length times width
D - multiply the four sides together

---

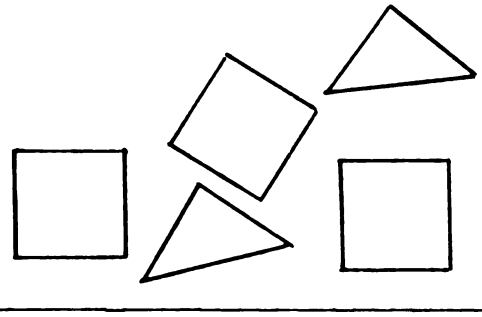
34) Which is the best way to show the ratio of triangles to squares in the drawing below?

A - 3 : 2

B - $\frac{2}{3}$

C - 2 : 2

D - $\frac{3}{2}$



---

35) To estimate the sum 356 and 503 to the nearest hundred, you can add

A - 300 and 500
B - 350 and 500
C - 400 and 500
D - 400 and 600

---

36) Pencils are sold to the school store by the dozen. If the store needed 137 pencils, how many dozen would they have to buy?

A - 12 dozen
B - 13 dozen
C - 14 dozen
D - 15 dozen

APPENDIX I

STUDENT TASK-INTERVIEW TEST

TASK-INTERVIEW TEST

The following questions will be posed to children. You will record their responses on a response sheet. Give children adequate time to answer each question. Do not give them clues. Just read the questions as printed. You will need a pencil for yourself and the child should have one available to him. The only other materials will be the set of questions, a response sheet, and a jar of buttons.

"Before you begin, tell the child to take his time in answering the questions. Tell him that you are going to keep a record of his answers and that there are several answers to some of the questions. He may use pencil and paper if he needs to help explain. He will not have to make any arithmetic calculations, but he will be asked to explain how he might solve a problem. The interview should only be five to ten minutes long."

The Questions:

(1) "What is the difference between an estimation and a guess?"

(2) "Explain how you would estimate the number of buttons in this jar?"

"Can you tell me about another method?"

"Are there any other methods that can be used to estimate the number of buttons in the jar?"

To Teacher: Have the child describe as many methods as possible. When he says he can't think of any more, go on.

(3) "Which of the methods you just described would probably be the easiest and fastest for solving the problem?" "Why?"

(4) "How could you estimate the number of blades of grass on a lawn?"

TASK-INTERVIEW RESPONSE SHEET

(1) ____complete answer ____partial answer ____no answer

Comments: _____

_____

(2) ____partial explanation ____complete explanation
counting method: _____

____partial explanation ____complete explanation
counting method: _____

____partial explanation ____complete explanation
counting method: _____

____partial explanation ____complete explanation
counting method: _____

____partial explanation ____complete explanation
counting method: _____

____partial explanation ____complete explanation
counting method: _____

____partial explanation ____complete explanation
counting method: _____

____partial explanation ____complete explanation
counting method: _____

____partial explanation ____complete explanation
counting method: _____

Comments: _____

_____

(3) ____complete answer ____partial answer ____no answer
counting method: _____
Comments: _____

_____

_____

_____

_____

APPENDIX J

ITEM ANALYSIS INFORMATION FOR THE UNIT-ACHIEVEMENT TEST PRE- AND POST-TEST

Pre- and Post-Test Item Analysis Information For The Unit-Achievement Test Including Discrimination, Difficulty, and Test Values For Each Item

Item Number		Discrimination		Difficulty		Test Values	
Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	1	.05	.18	27%	25%	1.32	.74
2	5	.29	.15	34%	31%	.45	.58
3	4	.25	.35	25%	18%	.57	.37
4	3	.25	.15	30%	28%	.57	.84
5	2	.27	.05	38%	40%	.49	2.83
6	15	.33	.27	15%	12%	.42	.29
7	33	.09	.34	41%	32%	.76	.38
8	36	.27	.31	37%	29%	.37	.33
9	35	.24	.39	35%	32%	.48	.29
10	8	.37	.33	29%	17%	.37	.31
11	34	-.05	.17	37%	37%	-2.51	.79
12	25	.31	.32	36%	34%	.35	.35
13	30	.49	.26	13%	10%	.37	.25
14	16	.49	.43	25%	23%	.31	.26
15	20	.04	.66	48%	27%	2.09	.32
16	17	.44	.29	16%	12%	.33	.35
17	28	.51	.43	24%	20%	.31	.35
18	31	.29	.17	37%	33%	.35	.61
19	7	.51	.47	26%	19%	.28	.24
20	12	.52	.44	37%	14%	.22	.23
21	13	.35	.24	34%	26%	.34	.50
22	11	.45	.44	36%	14%	.26	.23
23	14	.37	.32	39%	29%	.30	.44
24	19	.44	.32	26%	15%	.36	.32
25	9	.21	.26	40%	39%	.52	.34
26	26	.21	.46	40%	31%	.37	.28
27	18	.20	.12	36%	38%	.94	.77
28	27	.05	.35	46%	32%	.73	.33
29	24	.11	.35	42%	34%	.33	.26
30	10	.11	.55	48%	30%	.28	.21
31	6	.41	.49	36%	28%	.36	.27
32	32	.27	.34	37%	34%	.42	.33
33	29	-.04	.27	49%	37%	-1.93	.34
34	21	.40	.60	42%	31%	.20	.20
35	23	.21	.51	40%	27%	.54	.25
36	22	.28	.40	24%	14%	.52	.23

APPENDIX K

STUDENT AND TEACHER PERCEPTION FORM DATA

N = 272 Class Code #___

Science Activities - Student's Perceptions

Think about the science lesson. Read each question below and check the answer you think best for each question. There are no right or wrong answers.

1. During the science period, the class
   a. mostly listened to the teacher 59
   b. mostly watched the teacher or a boy or girl do experiments 43
   c. mostly worked with equipment 170

2. Most of the talking was done
   a. by the teacher 133
   b. by a few boys or girls 50
   c. by many boys or girls 89

3. Most of the experiments were done
   a. by the teacher 17
   b. by a few boys and girls 26
   c. by many boys and girls 229

4. I got to talk about science
   a. not at all 59
   b. not as much as I wanted to 99
   c. as much as I wanted to 114

5. I got to work with the science equipment
   a. hardly at all 12
   b. about half the time 85
   c. most of the time 175

6. When I worked with the science equipment, I mostly did experiments
   a. planned by the teacher 135
   b. planned by the book 21
   c. planned by my group 95
   d. planned by the class 21

7. It is all right to help other students with science
   a. not at all 4
   b. sometimes 203
   c. most of the time 65

8. When my teacher told me or asked me something, it was
   a. usually about my work 188
   b. usually about the way I acted 24
   c. usually about other things 60

9. During the science periods I understood
   a. most of the time 183
   b. about half the time 78
   c. hardly at all 11

10. What is your favorite subject? Write a number 1 in front of your first choice, a number 2 in front of your second choice, a number 3 in front of your third choice, a number 4 in front of your fourth choice, and a number 5 in front of your fifth choice.

101 Arithmetic

17 Language Arts

71 Reading

58 Science

25 Social Studies

(Student's Perception Form developed by the Science Curriculum Improvement Study, University of California, Berkeley)

N = 12 Code #_____

Science Activities - Teacher's Perceptions

Think about the science lesson you have just concluded. Would you please respond to each item in terms of how you feel the children, as a total group, will respond. There are no right or wrong answers for either the children or the teacher; it merely represents one sample of one lesson.

1. During the science period, the class
   a. mostly listened to the teacher 2
   b. mostly watched the teacher or a boy or girl do experiments 1
   c. mostly worked with equipment 9

2. Most of the talking was done
   a. by the teacher 6
   b. by a few boys and girls 3
   c. by many boys and girls 3

3. Most of the experiments were done
   a. by the teacher 0
   b. by a few boys and girls 1
   c. by many boys and girls 11

4. I got to talk about science
   a. not at all 1
   b. about half the time 9
   c. most of the time 2

5. I got to work with the science equipment
   a. hardly at all 2
   b. about half the time 2
   c. most of the time 8

6. When I worked with the science equipment, I mostly did experiments
   a. planned by the teacher 8
   b. planned by the book 2
   c. planned by the group 2
   d. planned by the class 0

7. It is all right to help other students in science
   a. not at all 0
   b. sometimes 6
   c. most of the time 6

8. When my teacher told me or asked me something, it was
   a. usually about my work 11
   b. usually about the way I acted 1
   c. usually about other things 0

9. During the science periods, I understood
   a. most of the time 5
   b. about half the time 6
   c. hardly at all 1

10)What is your favorite subject?
Write a number 1 in front of your first choice, a number 2 in front of your second choice, a number 3 in front of your third choice, a number 4 in front of your fourth choice, and a number 5 in front of your fifth choice.

__5__ Arithmetic

__0__ Language Arts

__3__ Reading

__0__ Science

__3__ Social Studies

(Student's Perception Form developed by the Science Curriculum Improvement Study, University of California, Berkeley)

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