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A Computer-Assisted, Base-Line Description of the Frequency of Occurrence of Process Science Skills in an Exemplary, Elementary Science Program: Shaumberg Elementary District 54

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A COMPUTER-ASSISTED, BASE-LINE DESCRIPTION OF THE FREQUENCY OF OCCURRENCE OF PROCESS SCIENCE SKILLS IN AN EXEMPLARY, ELEMENTARY SCIENCE PROGRAM: SCHAUMBURG ELEMENTARY DISTRICT 54

by

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VITA

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Mrs. Lipowich is the Facilitator for the Association of Supervision and Curriculum's Network on Designing District Evaluation Instruments for Math and Science Process Skills. She was also the convener and chair of an international Symposium on "Evaluating Process Skills in Science: The Real World and the Ideal World" that was held in April of 1988 at the Annual Meeting of the American Educational Research Association.

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INTRODUCTION

Sputnik sparked the beginning of our exploration into space; Sputnik also sparked a very intensive look into science education in the United States. In 1957 concerned American scientists, educators, and politicians began to devote their time, skills, and dollars to improving secondary and elementary science education. The "alphabet" projects, such as BSCS (Biological Sciences Curriculum Study), SCIS (Science Curriculum Improvement Study), ESS (Elementary Science Study), and SAPA (Science-A Process Approach), emerged from this period in the nineteen-sixties. These projects all involve students in hands-on, problem-solving activities that call for such process science skills as classification, data collection, data organization, data interpretation, inference, and prediction.

In the "ideal science classroom," these activities are still alive and dynamic. In the "ideal science classroom," according to the 1988 National Assessment of Educational Progress' (NAEP) publication, The Science Report Card, students "have abundant opportunities to...design and conduct real experiments and to carry their thinking beyond the information given" (Mullis and Jenkins, 1988, p.16). Like real scientists, such students observe, measure, experiment, predict, infer, and communicate with each other. Such students do exist in school districts in the real world, but these districts are so few in the United States that the National Science Foundation (NSF) and the National Science Teachers Association (NSTA) established a national program, the Search for Excellence in Science Education, to search for such districts and declare them "Exemplary ". (Yager, 1984)

> Responses from students taking the National Science Assessment in 1986
>
> indicate that science instruction continues to be dominated by teacher lectures and textbooks. Meanwhile, activities such as experimentation and use of scientific equipment remain comparatively rare. Less than half of the teachers of students assessed in 1986 reported that they had access to a general purpose laboratory for use in science instruction, thus reducing students' opportunities to engage in 'doing' science (Mullis and Jenkins, 1988, p.101).

The evidence from NAEP's most recent assessment shows that we are not putting into practice what we have learned. Research has shown that "the most effective learners are those who are actively engaged in the learning process and accept responsibility for their own learning" (Mullis and Jenkins, 1988, p.13). The Science Report Card notes that the 'NAEP data support a growing body of literature urging fundamental reforms in science education--reforms in which students learn to use the tools of science to better understand the world that surrounds them" (p.17). Certain state legislatures, including Illinois and California, have now mandated that local school districts teach "process science skills" to their students and evaluate their students' progress.

The Problem

In 1985 the State of Illinois passed an educational reform package that included requirements for local school districts to write down their learning objectives in science; to match these objectives in Grades 3, 6, 8, 10, and 12, to the "areas" in the State of Illinois' State Goals for Learning and Sample Learning Objectives: Biological and Physical Sciences (Illinois State Board of Education Department of School Improvement Services [ISBE], 1986) ; to devise tests to measure whether these "areas" were being met; and to report the results of these tests to the general public. Each district's Learning Assessment Plan for science was to be filed in Springfield, Illinois, by August 31, 1988. Appendix A contains pages 5-8 of the state science goals and their "knowledge and skill" statements. State and local science assessment is to begin in the school year 1989-90 for Grades 3, 6, and 8. Grade 11 is to assess in the following year.

Figure 1 on the next page shows that Illinois's Goal 4 in science meets the NAEP guidelines for the "ideal science classroom" very well--on paper at least. Included as knowledge and skill areas are all of the basic science process skills that are found in the "alphabet" projects. It is now mandated that teachers shall teach these skills, students shall be assessed to see if they have learned these skills, the results of the assessment shall be reported to the public, and the school district shall write a "School Improvement Plan" based upon its evaluation of the assessment.

FIGURE 1
STATE OF ILLINOIS, GOAL 4, PROCESS SKILLS IN SCIENCE

As a result of their schooling, students will have a working knowledge of the processes, techniques, methods, equipment and available technology of science.

The following knowledge and skills are related to this State Goal for Learning:

A Observation
B Classification
C Inference
D Prediction
E Measurement
F Communication
G Data collection, organization, and interpretation
H Operational definition development
I Question and hypothesis formulation
J Experimentation
K Model formulation
L Results verification
M Scientific equipment use

The assessment, or testing, of this goal, however, poses a very different and difficult problem. Traditionally, measurement of the process skills, if done at all, has been done by performance tests. Either a student "performs" the skill and turns in a product to which the teacher can apply some kind of "uniform grading standard", or the teacher observes the student actually performing the skill and, using a checklist with pre-determined standards of uniform scoring, notes the extent to which the student has achieved the skill.

This description of performance testing is mostly theoretical, at least at the elementary level. Elementary teachers simply do not have the preparation time needed to set up a performance test, or a "practical", unless they come in very early before school or stay very late after school.

There are some junior high teachers and some high school teachers who do present students with "practical" tests. The "practicals", at the junior and senior high schools, though, are generally designed to separate the A students from the B and so on down the scale. They are not the kind of criterion referenced measurement instruments that could be used to show that all students have achieved the desired skills. The intent of the reform package in Illinois is to see that all students achieve this success in the skills defined by the State Goals.

Just what are the "desired skills"? In Illinois, the mandated skills were set down on paper by a committee of science education experts in a "verb" format to emphasize the concept that "science is doing". Figure 1, taken from the final, published version, lists the skills in "noun format".

The differences between noun and verb are minor compared to the differences that occur when one sits down with a committee of teachers and administrators to try to reach concensus on just what each process skill involves. From project to project, from district to district, and from teacher to teacher, there is no commonly understood or agreed upon national or international standard of operational definitions for the process skills in science. R. W. Tyler suggested very succinctly and correctly that it's almost as if we lacked a "common language" upon which to proceed (personal communication, March, 1988).

How, then, can local districts fulfill the mandated requirements for assessment that begin in Illinois in the1989-90 school year? How can student achievement in activities in science skills be measured validly, reliably, and efficiently at the local district level?

In terms of efficiency, experts are beginning to develop and validate paper and pencil tests that purport to measure the science process skills. However, even "the most recent NAEP science assessments did not include measures of students' ability to 'do' science--that is, their ability to use laboratory equipment and appy higher-order thinking skills in experimental situations" (Mullis and Jenkins, 1988, p. 21). NAEP did do a pilot study of hands-on activities in 1986 that was basically in the form of a "practical", or a performance test. Learning by Doing: A Manual for Teaching and Assessing Higher-Order Thinking in Science and Mathematics describes this pilot study, but does not give enough guidance to allow a district to reproduce the results (National Assessment of Educational Progress [NAEP], 1987).

If one puts performance testing aside as not being practical, in terms of efficiency, to do with hundreds of students, then the whole issue of construct validity needs to be addressed. Construct validity refers to whether a given item actually does measure a given objective. The base question here is whether paper and pencil forced-choice tests can be used to measure what are normally considered to be performance skills.

The states that mandate testing are accepting face validity for test items professing to measure science process skills. Face validity means that if "expert educators" say that a given test item "measures" a given objective, then that test item does, indeed, measure that given objective.

Student achievement, in activities in all the science skills mandated in Illinois, and elsewhere, cannot be measured validly, reliably, and efficiently, at this time. However, it is possible to measure evidenced student participation in the process science skills as students work in a classroom. If one then has a "common language" of operational definitions for what the process science skills are, a computer's assistance for efficiency in tabulating results, and a very simple microphone set-up, one can obtain a valid, reliable, and efficient measurement of participation in the process science skills at the local district level.

The Purpose

The purpose of this study is to establish a quantitative base-line of the frequency of occurrence of process science skills in Illinois's Schaumburg Elementary School District 54, a district that has been declared "Exemplary" by both the National Science Foundation (NSF) and the National Science Teachers Association (NSTA) under the Search for Excellence in Science Education (SESE) program (Penick, 1983). The district's science curriculum is also housed in the Smithsonian Institute in Washington, D.C., as an example of an outstanding, elementary science curriculum. Schaumburg Elementary School District 54 is also the largest elementary school district in the state of Illinois.

The question of what might be a base-line is exceptionally important at this time, at the local, state, national, and international level. Many states in the United States have mandated that process science skills be taught. These states have also mandated that student achievement in the process science skills be measured and publicly reported. Yet, science educators do not, at this time, have nationally standardized, valid, reliable, and efficient instruments to assess all of the process science skills that have been mandated to be taught.

Even though science educators do not, at this time, have the necessary instruments to measure process science skills, there is still a need to determine whether these skills are indeed taking place within a given classroom. Many districts in states that have mandated reform in science education are looking at their science programs and trying to determine the materials and methods needed to bring their districts closer to a process science program. Both time and money will be spent in the attempt to improve science education within the district, and some method of establishing a base-line of the current state of process science education is badly needed. One cannot determine if one's methods are effective if one cannot see where one has been in the past and where one is in the present.

The specific aim of this study is to determine the extent to which fourth grade students in Schaumburg Elementary School District 54 are demonstrating the skills and general knowledge in process science listed under Goal 4 of the Illinois State Goals for Learning in the Biological and Physical Sciences (Figure 1 and Appendix A).

Appendix B is a detailed listing of the Grade 4 Science Objectives classified according to the State of Illinois' State Goals for Learning in the Biological and Physical Sciences. The listing document was produced by this investigator, under the direction of Larry Small, in 1986-87, using a draft copy of the State Goals for Learning. Figure 2 illustrates the format of Appendix B. Note that the process skills were still in the "verb format" at that time. What are now called "skill and knowledge statements" were called "outcomes" in the draft version.

FIGURE 2
EXAMPLE OF SCHAUMBURG DISTRICT 54'S PROCESS SCIENCE OBJECTIVES, GRADE 4, CLASSIFIED ACCORDING TO THE STATE OF ILLINOIS' GOAL 4
(Draft Copy)

OUTCOME G: Collect, organize and interpret data.

GRADE:	UNIT	L.OBJ.:
4	Small Things	Draw pictures of what is observed.
4	Small Things	Record finding on activity sheets
4	Small Things	Compile a notebook of activity sheets and observations.
4	Small Things	Compare cells from different parts of different plants.

Secondary aims of this study are: (1) to produce a set of understandable, teacher-written, operational definitions of the process science skills mandated by the State of Illinois; (2) to develop an inexpensive, relatively simple , computer-assisted method of counting the frequency of occurrence of process science skills within a given classroom; and (3) to match student and teacher verbalizations from fourth grade classes in Schaumburg Elementary School District 54 to the twelve, Illinois, process science skills in Goal 4 to determine the extent to which students are evidencing use of these skills in their science lesson activities.

It is hoped that teachers, administrators, and/or researchers will be able to use the method developed herein to compare the frequency of occurrence of process science skills within a given fourth grade classroom to that of the fourth graders in Schaumburg's exemplary, elementary science programs. It is further hoped that teachers, administrators, and/or researchers might use the base-line herein to compare the frequency of occurrence of process science skills at other grade levels to that of the Schaumburg fourth graders.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Computer and hand searches of the related literature were conducted in order to find out whether or not any national or international studies had been undertaken previously to measure students' achievement in performing the process skills in science, on a skill by skill basis, as listed by the State of Illinois in its State Goals for Learning and Sample Learning Objectives: Biological and Physical Sciences (ISBE, 1986). See Figure 1 and Appendix A. The resources used were: Dissertation Abstracts International; Educational Resources Information Center (ERIC); the Education Index; and the Current Index to Journals in Education. Schaumburg Elementary School District 54's Science Resource Center and Teachers' Resource Library also provided resources of current literature as well as relevant out-of-print materials. Only two studies were discovered that came close to meeting the given criteria: those of the National Assessment of Educational Progress' (NAEP) five National Science Assessments in the United States in 1970, 1973, 1977, 1982, and 1986 (Mullis and Jenkins, 1988) , and the Hacker Science Lesson Analysis System (SLAS) studies of the 1980's (Hacker, 1984) in Australia. Both of these studies were of national groups of students over multiple grade levels, and both of these studies attempted measures of student performance of hands-on, process science on a skill by skill basis. In terms of the commonality of number and definition of process skills, both studies had enough over-lap with the Illinois skills to be useful. The NAEP instruments involved paper and pencil forced choice questions that were well supplemented with graphics, as well as performance tests with a written product in a 1986 pilot study of hands-on activities (NAEP, 1987) . The Hacker study involved performance observations by trained staff with very high inter- and intra-rater reliability. (See Appendix C for the categories Hacker used.) Both studies were funded and supported by national bodies.

Post-Sputnik Science Education

Sputnik may have sparked off the beginning of our exploration into space, but it also sparked off a very intensive, national look at and funding of science education projects in the United States. As a result of Sputnik, funding was made available to develop the "alphabet" projects, such as the Elementary Science Study, (ESS), the Science Curriculum Improvement Study (SCIS), and Science--A Process Approach (S-APA). All of these projects involve students in hands-on, problem-solving, process science activities.

ESS was developed by the Educational Development Center, formerly known as Educational Services Incorporated. ESS has approximately 56 independent units that are not specific to any one grade level. The units include life and physical science and begin with a problem, go on to an open-ended exploration that includes hands-on activities, and then conclude with a discussion that is meant to bring together the students' experiences. Evaluation is basically informal observation of students while they are working.

SCIS was developed by Robert Karplus and a team of educators, scientists, and psychologists at Lawrence Hall of Science at the University of California, Berkeley. The program is based upon interrelated scientific concepts, such as "matter", "organism", and "interaction"; process-oriented concepts, such as "property", "variable", and "system"; and attitudes, such as "curiosity", " inventiveness", "critical thinking," and "persistence" (Knott, Lawson, Karplus, Thier, and Montgomery, 1978). Process is also addressed in the SCIS program beginning with an exploration of new and interesting materials, a chance to explore and "discover" a new concept, and a culminating activity to begin to apply the new concept to different situations. Evaluation is to be done by teacher observation of students during their activities and through examination of students' work in their Student Record Books.

The development of S-APA was directed by the Commission on Science Education of the American Association for the Advancement of Science (AAAS). In contrast to both ESS and SCIS, S-APA's content was highly structured into units called modules, or "mods", that were designed specifically to teach individual science processes in a developmental manner. Thus, there are "Observation" mods, "Operational Definition" mods, and "Classification" mods --at different grade levels--all building upon discrete process skills. S-APA defines eight basic and six advanced science processes. Each process is broken down into separate steps for instruction, and all of the processes are operationally-described by student behavior. S-APA, like SCIS, is sequenced hierarchically. Life, physical, and earth sciences are included in the content. Evaluations for each of the mods is provided for use with both individual students and/or whole classes. (Science-A Process Approach [S-APA], 1965)

Smeroglio and Honigman's study, published in 1973, (cited in Bredderman, 1982) noted that these new post-Sputnik programs all have the following characteristics:

1. They are jointly developed by practicing teachers, scientists, administrators, and psychologists.

2. They have been extensively field tested on students and have been revised after the field testing.

3. Developmental cognitive growth of children is a part of the projects' guidelines.

4. The programs are all activity oriented involving students directly in psychomotor endeavors.

5. The programs are not text book oriented. They do provide manuals and guidelines for the teachers, however, and SCIS provides manuals, or record books, in which the students can record data they've gathered.

6. The programs come with the necessary materials needed for experimentation provided in boxes called "kits".

7. The programs all have an in-service qualification component for the teachers.

8. The programs are process skill oriented.

Hands-on activities like those described above have been linked to success in increasing the participation of minorities and females in science careers (National Science Board Commission on Precollege Education in Mathematics, Science, and Technology, 1983). NAEP has also found that "seventh- and eleventh-grade students who reported classroom activities that were challenging and participatory were likely to have higher science proficiency" (Mullis and Jenkins, Eds., 1988, p. 97). Whether the students had higher proficiency to begin with and thus were placed in more challenging, interesting classes, or whether the classes resulted in higher proficiency cannot be determined without further research into the question.

However, in spite of the renewed interest in science in the 1960's, in the 1970's, enrollment in secondary school science courses continued to drop. The new curriculum studies took some of the blame and were perceived to have been inadequate for the job. In actuality "none of the new K-12 curricula ever succeeded in getting a nationwide adoption of more than 25 percent" (Shymansky, 1982). Added costs, difficulty in securing and maintaining materials, additional time required for preparation of activities, and resistance from some teachers who had not been given an opportunity to help select the new programs: all contributed to a decline in the use of process science materials and a "back-to-basics" request for more traditional, textbook programs.

The Search for Excellence

In 1978 the National Science Foundation funded Project Synthesis to summarize and analyze twenty years of research on what ought to be happening in pre-college science classrooms. Five teams of nationally recognized science educators came up with a three part analysis: they established what should be happening in K-12 science classrooms; they compared this to what was actually happening; and they made recommendations on how to narrow the differences between the "Desired States" and the "Actual States". The timing was perfect for Project Synthesis. Four major works had just been finished, and Project Synthesis was able to draw upon all four: the National Assessment of Educational Progress's Science: 3rd Assessment (National Assessment, 1978); Ohio State University's The Status of Pre-College Science, Mathematics, and Social Science Education: 1955-1975 (Helgeson, et al., 1977); the University of Illinois's Case Studies in Science Education (Stake & Easley, 1978); and the Center for Educational Research and Evaluation's Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education (Weiss, 1978).

Project Synthesis's report painted a very bleak picture of elementary school science twenty years after Sputnik. The Search for Excellence in Science Education (SESE) began, in 1982, an effort to find and identify the exception(s) to this bleak picture. Jointly sponsored by the National Science Foundation and the National Science Teachers Association, SESE asked science consultants in each of the fifty states to identify and nominate districts whose science programs most closely matched the criteria of the "Desired States" in Project Synthesis. Twelve elementary programs were selected as meeting that criteria. The twelve are described in detail in the NSTA monograph Elementary Science in the Focus on Excellence series (Penick, 1983). One of the twelve programs selected was the K-8 science program in District 54 in Schaumburg, Illinois.

The Schaumburg program is a teacher-written, teacher-piloted, teacher-inserviced, hands-on, process science curriculum. Its units are based primarily on ESS and SCIS units that are now in the public domain. Groups of teachers from within the district meet during the summer and the school-year to write units that go one step beyond the "alphabet kits" by incorporating local environments, interests, and needs (Small, 1988).

Evaluation and Process Science

Science education objectives vary: from expert to expert, from project to project, from state to state, and from district to district. L. Klopfer (Klopfer, 1971, p. 561) writes that "it is...not possible at present to state one set of objectives to which all teachers of science at each educational level would subscribe." Klopfer notes that in the seventies, the "most serious problem of evaluation in science is the disparity between the methods and techniques which are available to the science teacher and what generally happens in the science classroom." (637) Klopfer also notes that without detailed descriptions of the behaviors involved, one cannot begin to evaluate performance. He goes on to state that: "In comparison with the techniques already at hand for testing and evaluating in the cognitive domain, the means of evaluation in the affective domain and in scientific literacy are flaccid and unsophisticated." (638)

L. Henkin and R B. Davis, in Testing, Teaching and Learning, note that "Mathematical understanding of a given phenomenon involves not merely knowing the facts involved, but also possessing insight into 'why' that facts are as they are." (in Tyler & White (Chairmen), 1978, p.90)Mathematics is often spoken of as the language of science, and the process skills in both subjects are similar. Telling "why" something happened may be "inferring". The authors note that "To test for understanding of the kind just described, it is natural to ask for an explanation." (p. 91) Henkin and Davis have also noted that (1) the student may not be able to articulate an explanation and (2) the explanation may not be an inference; it may simply be recall of a prior explanation from a teacher or a book that the student is simply repeating, but does not really understand. In the Appendix to this article, the authors give an extreme, but cogent example:

> "To take an extreme example, we encountered a student who could not respond properly to the request 'Can you write down an example of a quadratic equation', yet who was able to use without hesitation two of the standard algorithms to obtain the correct roots of q.e.'s that were given to her, and was familiar with the term 'quadratic formula.' It is a fair inference that the term 'quadratic equation' was mentioned in this student's class when the topic was first considered, but it was not a term actively employed in

subsequent class work, and hence did not remain a part of her active vocabulary." (p. 97)

R. Taylor, in 1978, in commenting on the minimum competency programs set in place in the seventies, states that "Initial minimum competency programs were often hastily conceived and implemented with the naive assumptions that higher achievement could be legislated, that no special funds were needed for testing and remediation programs, and that suitable tests were readily available." (in Tyler & White (Chairmen), 1978, p.98) In 1988, ten years later, three of those issues are still very much alive: can higher achievement be legislated? can testing and remediation be done without special funds? and are suitable tests readily available to test what has been mandated be tested?

J. Schwartz and E. F. Taylor describe "Project TORQUE", an assessment project that is concerned with alternatives to the present assessment models in the elementary schools. Project TORQUE's materials are criterion-referenced and can be used for both teaching and assessing--for formative and summative evaluation. The "tests are designed and validated by observing children perform on specially designed games and in 'real life' activities." (p. 261) One of the Project TORQUE packages involves measurement, which, in Illinois, is a "skill" in science and a "goal" in mathematics. The TORQUE measurement tests have been validated for construct validity using children's performance in real-life activities and correlating that performance with the children's performance on the pencil and paper tasks.

In assessing performance, once again, the question remains as to whether forced choice tests have construct validity. N. Frederiksen discusses "alternatives to multiple-choice tests". (in Tyler & White (Chairmen), 1978, p.186) He notes that "real-life problems do not ordinarily appear in multiple-choice form with all the options clearly presented." (p.188)

"Multiple-choice tests can no doubt measure much of the knowledge and some of the skills involved in the process, but they will certainly not reflect the whole problem-solving procedure. I believe we should develop testing procedures that will assess

> aspects of the thinking process not adequately dealt with by multiple-choice tests...There may be many important dimensions of performance other than the number of correct answers." (pp. 188-189)

Klopfer, in his section on "materials that would be helpful to those designing evaluation instruments for science" mentions Bloom's and Krathwohl's taxonomies of cognitive and affective domains and states that both books have "helped to improve the precision of communication among educators concerned with evaluation." (p. 635) It is particularly telling to note that although Klopfer praises Bloom's classification, nonetheless, Klopfer <u>uses a different classification</u> for student behaviors in measuring science. The categories used in Hacker's work in Australia "might be regarded as a condensed version of Klopfer's (1971) behaviours or as a version of the categories of Eggleston et al. (1975), expanded to include behaviours likely to occur in primary school science lessons." (Hacker, 1984, p. 140) Since there is no common language or standard in the evaluation of process science skills, each research group comes up with its own "dialect", thus compounding the already inherent difficulties of assessment.

<u>State-Mandated Reforms in Science Education</u>

In the 1980's there has been a major attempt to set forth statewide sets of goals and objectives as part of a move toward accountability in education. State legislatures are mandating reforms in education. They are stating that school districts must publicly state their objectives, evaluate their students' meeting of those objectives, publicly report their results, and devise school improvement plans based on this process. In accordance with the National Science Teachers Association's recommendations in <u>Science/Technology/Society: Science Education for the 1980's</u> (Penick and Meinhard-Pellens, 1984), some states are mandating, in their reform packages, the teaching of "process" science as a part of the total science program.

This ideal-world mandate, however, poses a major problem: the instruments to evaluate "process" science are still very much "state-of-the-art". The state of the real-world, at this time, is that educators do not have nationally recognized, valid, reliable, and efficient (paper and pencil) instruments to assess all of the process science skills that states have mandated be taught and tested. Educational researchers, policy makers, and practitioners are now in the process of dealing with this real-world problem of science assessment of process skills at the district, state, regional, national, and international level. Some researchers and policy makers in different states and countries have been working in the area of assessing process science skills for many years. The products of their research and experience can help other educators begin to translate research into practice.

R.Tyler and S.H. White, in their Chairmen's Report in Testing, Teaching and Learning, note that:

> "Not only a student's answer, but also the efficiency of the solution strategy are of interest. Easily-graded standardized tests for these more complex problem solving procedures have been difficult or impossible to devise, so that a very important class of educational objectives has been left untested and thus undervalued." (p. 16)

One pair of researchers, M.Padilla and D. McKenzie, at the University of Georgia, have addressed the question of whether one can assess this kind of performance activity with paper and pencil, forced choice items. Padilla and McKenzie have been working on the construct validity of paper and pencil items for measuring various graphing skills. They have triangulated their "Test of Graphing in Science (TOGS Test) by having 69 students do a real graphing task, on paper with pencil. The correlation between the students' actual graphing tasks and their scores on the TOGS Test was .73. "This indicates a reasonable degree of criterion validity for TOGS" (Padilla, 1988, p. 7). M. Padilla and M. Twiest are currently getting ready to present work on the construct validation of the Test of Basic Process Skills (BAPS Test), an elementary, paper and pencil test that covers the process skills of:

observation, inference, prediction, measurement, communication, and classification. Original attempts to obtain a construct validity for this test were "confusing and disappointing" (p. 8), but more recent efforts using a different approach have been more successful (personal communication, August, 1988).

M. Padilla, in his paper "Testing for Higher Order Understanding in Science", cites John Bransford's work and stresses the need to identify and define the problem in any kind of problem solving (Padilla, 1988). This identification and definition process is needed within any group discussing any problem. Researchers, administrators, teachers, and students within a given group need to have a common language if they are to discuss a common problem.

This concept of using a common language is one of the most critical concepts in assessing science process skills. Padilla uses the definitions from Science - A Process Approach (S-APA, 1965). Allen Olson, Director of the Northwest Evaluation Association's Science Curriculum and Assessment Project, supplies the operational definitions used for the Project's "Concepts" and "Processes" with the items in the Project's Item Bank (Olson, 1988). Larry Small supplies operational definitions for the science processes assessed in his district, Schaumburg Community Consolidated District #54 in Schaumburg, Illinois (Small, 1988). Roger Hacker operationally defined each process science category in the Science Lesson Analysis System (SLAS) (Hacker, 1984). In supplying operational definitions with their assessment instruments, Padilla, Olson, Small, and Hacker make it possible for others to understand and utilize their work.

One of the major problems of writing or collecting process science assessment items is the question of content versus process. Ralph W. Tyler has stated that a behavioral objective needs to be content specific and grade level specific (personal communication, March, 1988).

Oregon's project allows for both content and process by having separate "content categories," "process categories", and "concept categories". The basic question, however, remains: "Can one really assess process without content?"

In setting up situational questions, the "set-up" of the question can become very "wordy", and the item may end up having a very heavy "test of reading ability" component. Padilla comments on this question of reading difficulty and the steps taken to counteract the difficulty in the construction of the Middle Grades Integrated Process Skill Test (MIPT), intended for students in Grades 6-9 (Padilla, 1988). Students in a given grade in a given district might well be reading below grade level. Where an assessment's purpose is to show that all students are achieving a given process skill, reading level is definitely a factor to consider.

One of the major issues still to be answered is whether a paper and pencil test can really test process skills. Is the process being tested, or is recognition or recall of the process being tested when a student has to choose between "given" responses? Yet, to observe a student going through a process, to question that student about that process, to uniformly decide whether the student has "successfully" gone through the process requires more staff training, hours, and dollars than most local districts or states can afford to, or are willing to, spend. This "observational" process of evaluation is not "efficient" with large numbers of students. The question then becomes, is there a process of evaluation that is efficient, and is also valid and reliable? Norman Stenzel suggests that computer-based strategies have "a good chance to be more valid" than paper and pencil tests "in respect to the dynamics of processes" (Stenzel, 1988). Stenzel also points out another very critical issue: what is "new" for one student may well be "recall" for another student. This issue of a student's prior knowledge is one of the most difficult to ascertain and cannot easily be addressed in a paper and pencil, multiple choice format. One student may truly be "predicting", while another, giving an identical surface response, may be "recalling".

The question of construct validity is always prime. Is the item measuring what it purports to measure, or is it measuring some other attribute? Validity is measured most often by "experts" who match assessment items to assessment objectives, or to skill and knowledge statements, giving a face validity. However, Padilla has attempted to establish construct validity. The Georgia group has correlated the Test of Graphing in Science (TOGS) (McKenzie and Padilla, 1986) to a "pencil and paper graphing task" and obtained a correlation of .73 with 69 students (Padilla, 1988). Cronin, Padilla, and Twiest undertook a validity study of their Test of Basic Process Skills (BAPS) using an interview technique with 32 students, but got very mixed results. They are currently reassessing BAPS with a new, different interview instrument. Padilla notes the importance of developing individual interview and station study items to validate paper and pencil items. The difficulty of what these researchers are attempting is immense, but their example and methodology can be enormously helpful to others. In the ideal-world, every researcher developing an instrument for assessment would show construct validity. In the real-world, one is fortunate to have "experts" to grant face validity.

In the real-world, the local district, charged with developing a local assessment instrument to assess its local objectives, has the most difficult task. Larry Small put together a team in Schaumburg Elementary District #54, Schaumburg, Illinois, to develop assessment instruments for process science skills in Grades 3, 6, and 8, as mandated by the State of Illinois. Their model of cooperation: with university level researchers, such as Padilla, in Georgia, and John Staver, in Illinois; with Illinois State Board of Education evaluation personnel, such as Norman Stenzel; with district testing experts such as Joyce Zitnan, Fred Tarnow, Marianne Zito, Mary Kelly, and the many, expert, process science teachers in Schaumburg District 54 and Hinsdale Elementary School District 181; is a model other large districts could follow.

The Oregon Project is able to provide valuable resources to any group that would like to develop its own assessment instrument; its Item Development and Review Process set up excellent methods of procedure. Smaller districts, without "test experts" are getting assistance with some of these procedures by banding together and working with such groups as state Educational Service Centers.

One of the largest studies done of process science skills was done in Australia; the study was first done in science and then its methodology was extended into social studies. The methodology is far different from the paper and pencil forms discussed elsewhere in this grouping of studies. The methodology is that of observers entering actual classrooms and observing, classifying, and recording interactions between and among students and teachers. The "SLAS data can be used to confirm the extent to which students are afforded the opportunity to develop, practice and refine emergent intellectual abilities in science classrooms" (Carter & Hacker, 1988). What is particularly striking, however, is that Carter's and Hacker's "intellectual abilities practiced" in Australia are "science process skills" in the United States. Carter and Hacker also record non-verbal interactions with science materials and multi-media materials. Since a user's manual and a full observer training program were developed with the SLAS, one could "transport" the system to the United States and see how American interactions correlated with Australian.

Need for This Study

The March, 1988, ASCD Update asks the following questions in its "Issues" section: "Do current testing programs do an adequate job of assessing student thinking?" and "If not, what progress is being made to improve them?" (O'Neil, 1988, pp. 4-5) The six experts responding to the questions are: Peter Kneedler, a research and evaluation consultant in the California State Department of Education; William Corbett, Principal of The James Russell Lowell School in Watertown, Massachusetts; Bena Kallick, an independent consultant for the

Connecticut State Department of Education; Robert Marzano, Director of Research at the Mid-Continent Regional Educational Laboratory; Kenneth Haskins, former Head of the Harvard Principals' Center; and Richard Wallace, Superintendent of Schools, in Pittsburgh, Pennsylvania.

"Student thinking" is very much a part of "process science skills"; one should not be doing any of the skills without first engaging in some kinds of mental processes. The educators above responding to the two questions of the "Issue" note six major points:

1. No adequate instruments currently exist at the national level that do an adequate job of assessing the process of thinking in a reliable, valid, and efficient way.
2. One of the major reasons no such instrument exists is because educators and psychometricians have not yet come to major agreement on just what "thinking" is.
3. There is a great need at this time to precisely define what these process skills are so that we can both teach them and evaluate them.
4. Current tests do not cause students to generate responses; they cause them to react to several offered choices.
5. The best method educators have to evaluate process, at this time, is through practical exercises done within the classroom over time.
6. Even though educators do not have adequate instrumentation to measure process at this time, it is still important for states to mandate that thinking be taught and assessed. (pp. 4-5)

The general concensus of the group is that continued attempts to teach thinking skills and measure them will improve process assessment instruments, improve the definitions of thinking skills, and improve educational outcomes.

T. Bredderman, in his meta-analysis of controlled studies on the effects of activity -based elementary science programs on student outcomes and classroom practices, used the following list of "science processes" (p. 12, 1982):

analyzing
predicting
manipulating variables
problem solving
inferring
explaining from data
identifying variables
describing change and interaction based on observations
measuring
constructing histograms
observing properties and reporting on them.

The study, however, does not give "operational definitions" for each process. Thus, "analyzing" may well have one meaning for an elementary teacher and quite another meaning for a secondary teacher.

The California Assessment Program of the California State Department of Education, in its Survey of Academic Skills: Grade 8 Science Rationale and Content, Draft Copy, gives operational definitions for seven science processes (California State Department of Education, 1988, pp.55-56). Their assessment matrix then places the seven processes into three content areas: biological, earth, and physical. California's seven processes are:

observing
communicating
comparing
organizing
relating
inferring
applying.

With operational definitions given, other groups have at least a basic idea of whether they're speaking that "common language" needed for communication to take place.

A. Olson and S. Smoyer (1988, p. 4) list the 15 processes and 29 concepts that serve as the framework for the Science Curriculum and Assessment Project set up by the Northwest Evaluation Association. The processes and concepts,operationally defined in Appendix B (pp. 17-20), are listed below:

Science Concepts		Scientific Processes
Cause-Effect	Change	Classifying
Cycle	Energy-Matter	Communicating
Entropy	Equilibrium	Controlling Variables
Evolution	Field	Defining Operationally
Force	Fundamental Entities	Designing Experiments
Gradient	Interaction	Formulating Models
Invariance	Model	Hypothesizing
Order	Organism	Inferring
Perception	Probability	Interpreting Data
Population	Quantification	Measuring
Replication	Resonance	Observing
Scale	Significance	Predicting
Symmetry	System	Questioning
Theory	Time-Space	Using Numbers
Validation		Relating Time-Space

R. W. Tyler writes: "Education is a process of changing the behavior patterns of people. This is using behavior in the broad sense to include thinking and feeling as well as overt action" (Tyler, 1949). In Michigan (Michigan State Board of Education,1985, p. 59) and Anchorage, Alaska (Anchorage School District, date unknown), dimensions of feeling are added which are not present in the objectives for the State of Illinois: the dimensions of "attitudes and values". What is the relationship of these "attitudes" to "process" skills? Is Alaska's "Use of Scientific Inquiry" the same skill as Illinois's "Experimenting"? Anchorage's "Recording Data" is placed apart from the "Process Skills" category, under a separate and distinct category entitled: "Communication Skills". In Illinois, "recording data" is part of a "knowledge and skill" statement entitled: "Data collection, organization, and interpretation".

Michigan Science Attitude Categories	Anchorage's Attitudes and Values
Longing to Know and Understand	Curiosity/Persistence
Questioning of All Things	Use of Scientific Inquiry
Search for Data and Their Meaning	Developing Self Confidence
Demand for Verification	
Respect for Logic	
Consideration of Premises and Consequences	
Respect for the Order and Beauty of Nature	
Demonstration of Confidence and Satisfaction	
Values the Scientific Heritage	

How do these projects' lists of processes compare with the State of Illinois's? One cannot know with any certainty until the State of Illinois develops, adapts, or adopts operational definitions of the process skills for use within the state. However, Sample Learning Objectives have been given for each process skill for Grades 3, 6, 8, 10, and 12, and comparisons might be made using the examples given (ISBE, 1986).

Schaumburg Elementary School District 54 has classified its science objectives according to the State of Illinois' State Goals for Learning in the Biological and Physical Sciences. Appendix B has the Grade 4 objectives for all four state goals. Each fourth grade unit has multiple objectives calling for students to: observe, classify, infer; predict; measure; communicate; collect, organize and interpret data; develop operational definitions; formulate questions and hypotheses; experiment; formulate models; verify results; and use scientific equipment. The categories are those listed in a draft copy of the State of Illinois' State Goals for Learning in the Biological and Physical Sciences and are in their original "verb format".

Schaumburg has broad curricular models in place that call for regular assessment of its students to be sure that objectives are being met. However, assessment of process skills is a very difficult process. Schaumburg's science testing program, prior to the 1986-87 school year, has been criterion referenced to the content taught in each unit, with the addition of questions to determine student attitudes toward science. In the summer of 1986, a team of teacher-writers from Schaumburg, Fred Tarnow and Marianne Zito, and Mary Kelly, from Community Consolidated School District 181 in Hinsdale, Illinois, worked on a paper and pencil, forced choice, process skills test for Grade 3 in an attempt to begin testing for the process skills themselves. The test is to be read aloud to students by their teachers, with the students circling correct answers on an answer sheet. NAEP released items from prior national assessments and items from M. Padilla's work in Georgia helped to provide templates for designing the Schaumburg items. The test is not content-free , but is criterion referenced to the Schaumburg science objectives, and was piloted in Schaumburg just prior to June of 1987. The test covers seven of the twelve process skills set out in Goal 4 of the Illinois Goals. Since June of 1987, items from the Schaumburg test have been piloted by the Illinois State of Board of Education in other areas throughout the state. (Small, 1988)

If one wanted to see whether all of the science problem-solving skills in Schaumburg's exemplary science curriculum are being evidenced by students in its classrooms, one could set up a model based on Flanders' basic work in interaction process analysis and combine it with the categories in the State of Illinois' State Goals for Learning (Flanders, 1970). However, in order to do so with any great degree of accuracy, one would almost have to videotape hours and hours of classes. When one brings a videocamera into a classroom, one disrupts, immeasureably in any practicable sense, exactly what one hopes to study--a normal, everyday, science classroom lesson.

Attempts have been made to study process science lessons, but most of these studies revolve around either secondary classrooms or issues regarding teacher's abilities and student achievement (Aiello-Nicosia, Sperandeo-Mineo, and Valenza, 1984) , interaction analysis and staff development (Gorham, 1985), classroom climate (Chavez, 1984), and/or wait-time (Rowe, 1974 and Tobin, 1984).

Attempts have also been made to improve the ease of obtaining the needed data, such as Hoover's use of computer technology combined with Flanders' interaction analysis system (Hoover, 1975,1984). However, only one study (Hacker, 1984) seems to actually classify the problem-solving behaviors evidenced by students in elementary science classes in a way that would least disturb the normal progress of the classroom lesson.

Roger Hacker devised the Science Lesson Analysis System (SLAS) in a study that involved the classification of behaviors of 3,751 students in 864 elementary science lessons taught by 144 science teachers. His categories included such abilities as: interpreting observed or recorded data, inferring from observed or recorded data, and designing novel experimental procedures. (See Appendix C.) His study covered children from the age of 6 (beginning their primary years) through children at the upper secondary level (years 11 and 12) in 62 state schools in Western Australia. His observers had very high inter- and intra-observer reliability measures. Hacker suggested in his study that other populations of science classrooms could be tested using his instruments and model. (Hacker, 1984)

The results of this literature search indicate that there is a definite lack of instrumentation that will validly, reliably, and efficiently determine whether or not all of the science problem-solving skills in a given science curriculum are being evidenced by students inside their science classrooms. There is also a very great need to provide a common language from which a given body of teachers and administrators can work. This study will build a set of Operational Definitions for Process Skills in Science: Lake County, Illinois , to cover the thirteen process science skills mandated to be taught in Illinois (Lipowich and Tyler, Eds., 1988). These operational definitions will be jointly developed by a regional body of teachers and administrators and will be field-tested in district in Lake County for clarity and exactness. The operational definitions will provide the framework for categorizing student and teacher verbalizations on a skill by skill basis. Additional categories will be provided to cover the giving of directions for work, discipline, and off-task activity. This study will then provide both a valid, reliable, and efficient methodology for finding the frequency of occurrence of process science skills within a given classroom and/or district and a baseline of comparison, on the fourth grade level, with a federal, exemplary, elementary science program, that of Schaumburg Elementary School District 54, in Schaumburg, Illinois.

CHAPTER III

METHOD

Type of Research

The purpose of this study is to construct a base-line description of the frequency of occurrence of process science skills in an exemplary, elementary science program: Schaumburg Elementary School District 54 in Schaumburg, Illinois. In order to provide a framework and a common language on which to construct the description, Operational Definitions for the thirteen process science skills in Illinois' State Goals for Learning and Sample Learning Objectives: Biological and Physical Sciences are to be developed. In order to provide an efficient method for tallying the data, a computer program is to be designed that will permit immediate entry of categorized verbalizations without the need for costly and time-consuming transcriptionsof the audio tapes to be made. A base-line study such as this comes under the heading of "descriptive research" (Issac and Michael, 1971).

Procedure

Audio tapes are to be made of students' (and teachers') verbal interactions during normal, uninterrupted, fourth grade science classes. The student commentary on these tapes will be analyzed and classified according to the knowledge and skill statements of Goal 4 of the Illinois' State Goals for Learning in the Biological and Physical Sciences (Appendix A). The framework for categorizing the verbalizations will be the Operational Definitions for Process Skills in Science: Lake County, Illinois (Lipowich & Tyler, Eds.) A copy of these operational definitions is in Appendix D. Verbalizations: Categories and Examples (Figure 6) serves as a set of guidelines to the decisions made in discriminating among various possible categories.

Principals are to hear about the project first, at two meetings called by the Assistant Superintendent of Curriculum and Instruction. Suggestions are to be solicited from the principals as to implementing the study with the least possible disruption to their buildings. Aid in setting up a building meeting and in encouraging their teachers to participate is also to be sought. The principals are then to ask their teachers if the teachers are willing to discuss the project with the investigator at a meeting in their own building. Volunteer teachers for the project are to be sought through meetings in those buildings where fourth grade teachers are willing to listen to a description of the project. See Appendix E for the appointment forms that were used.

Two appointments with the volunteer teachers are to be made by the investigator, the second appointment to be during a different week from the first. Two tapes will be made of each volunteer teacher's classroom. The only interruption of the classroom will be for an introduction of the investigator and a very brief explanation of why the investigator is present and what the investigator will be doing. The explanation will be:

"Hi. My name is Mrs. Lipowich. I'm here right now because I'm a real scientist, and I'm doing a real, scientific investigation. The purpose of my investigation is to see what goes on in a real science class in Grade 4 in Schaumburg, Illinois. I'm setting up this tape recorder to run for the whole time your class has science today. I'll be moving it from group to group while you're working. Now, the best way you can help me is to pretend that I'm just not here, that you can't even see me. I'd love to sit down and talk with you about what you're doing...but I can't. I can't even talk to M---, your teacher, because that would spoil the investigation. If I really want to see what's going on in a normal, every-day class, I can't be a part of that class myself...in any way. Now, do YOU have any questions about what I'm going to be doing?" The investigator will answer all questions honestly.

A 4" x 6" portable tape recorder, holding Sony HF 120 cassette tapes (sixty minutes each side) is to be moved from group to group within the classroom. Placement of the recorder is to be on the working space, but "out of the way". Each group is to be taped for a given time to equal the lesson time divided by the number of student work teams. The recorder is to be moved in a set pattern of left to right, and front to back.

Operational definitions for the process skills are to be developed, as well as an accompanying set of examples for each category. The examples and the accompanying explanation are to be used to match student verbalizations to the skill categories. The set of operational definitions is to be content validated by the approximately 60 developers, R. Tyler, and the investigator. This content, or face validation, is to consist of these persons' agreement that the operational definitions for each skill category are appropriate. In addition, the categorization examples of verbalizations for each category are to be content validated by an "expert panel", consisting of Larry Small, Science Coordinator for Schaumburg Elementary School District 54; Fred Tarnow, Science Coordinator for the North-Cook and West-Cook Educational Service Centers; Mary Kelly, Science Coordinator for Hinsdale Elementary School District 181; and the investigator, Science and Mathematics Coordinator for the Lake County Educational Service Center. In addition, the investigator will be using the set of operational definitions in local school districts in Lake County, Illinois, with teachers and administrators in Grades K-12, in the process of developing district Science Objectives, Learning Assessment Plans, and School Improvement Plans to meet state-mandated requirements. Changes in the operational definitions are to be worked out, as needed, to clarify any definitions that are ambiguous. The verbalizations on the tapes are then to be classified according to the State of Illinois' categories, and an analysis is to be made of the results evidenced.

Three categories are to be added to the state's in order to categorize other types of verbalizations noted during a previous pilot study using this plan. The three categories and their operational definitions are given in Figure 3, Additional Categories.

FIGURE 3
ADDITIONAL CATEGORIES

GUIDANCE: DIRECTIONS

Directions given by teacher to students and/or students to students that help to guide the science activity.

REGULATION: DISCIPLINE

Verbalizations from teacher to students and/or from students to students and/or from student to self that are used to focus attention back to the science activity. These verbalizations are prompted by off-task behaviors.

APART: OTHER

Verbalizations from teachers, students, and/or outside sources that interrupt or do not have a bearing upon the science activity. These verbalizations indicate that persons in the classroom are off-task and not focused on the science activity.

Figure 4, Cues and Codes, notes the cues and codes for the skill categories and units that are used in various charts and spreadsheets throughout this study. Where the code letter does not match the first letter of the skill category, i.e. "O" for "Observation", the word that represents the letter chosen is shown in parentheses.

FIGURE 4
CUES AND CODES

CATEGORY/UNIT	CODE	CUE
Observation	O	Obse
Classification	C	Clas
Inference	I	Infer
Prediction	P	Pred
Measurement	M	Meas
Communication	T(alk)	Com
Data collection...	D	Data
Operational definition ...	N(aming)	OpDe
Question and hypothesis ...	Q	Ques
Experimentation	E	Expe
Model formulation	F(ormation of Models)	Mode
Results verification	V(erification)	Res
Scientific equipment use	U(se of ...)	SciEq
Guidance: Direction	G	Guid
Regulation: Discipline	R(egulation)	Regu
Apart: Other	A	Other
Artemia Salina	A.S.	
Buoyant Forces	B.F.	
Forces of Flying	F.F.	
Mystery Powders	M.P.	
Small Things	S.T.	

A computer program is to be designed to permit immediate entry of the categorized verbalizations directly from the audio tapes so that no transcriptions need to be made. This will also permit the person doing the categorization to take into account the tone of voice and the context of each verbalization.

Any generalizations coming from the analysis are to be shared with the volunteer teachers and the district. Strict confidentiality is to be maintained as to the identify of the teachers of each class. It is hoped that the data and the procedures will also form a base-line and a methodology for other districts to use.

The first time a class is taped is called Session 1 for that class; the second time, Session 2. Session 1 lessons are taped on Side A of a given tape; Session 2 lessons are taped on Side B. The tapes of the lessons range from 35 to 60 minutes in length. Since the lessons vary in length and in content,each skill category's results are given as a percentage frequency against the total number of verbalizations in that session. One hundred twenty (120) minute tapes are used, sixty minutes to each side. Thus, even though some lessons extend beyond sixty minutes, any remainder over sixty minutes is not taped.

After obtaining the tapes, the most important step is to develop the operational definitions for each process science skill and to match student verbalizations, in context, to the categories. The definitions are to be developed during a series of seven workshops, "Developing a Local Evaluation Instrument in Science", directed by the investigator at the Lake County Educational Service Center. Approximately 60 teachers and administrators, representing Grades 3, 6, 8, and 11, are to work in groups at grade level to develop the first draft of the document. Input is to be sought from throughout the county and from the Lake County ESC's Science Advisory Committee. The investigator and R. Tyler are to edit the definitions.

The second step is to develop the template of examples and explanation that will be used to match student verbalizations to the process science skills. Figure 6, Verbalizations: Categories and Examples, gives a detailed description of the decisions that were made in categorization.

Thirdly, it is necessary to get the expert panel's practical validation of the categorization decisions made. The expert panel is to go through each skill and write down a sample verbalization that might occur in a fourth grade classroom. The verbalization is to be one the expert considers would be categorized under that skill. After all the experts have written down a sample verbalization for a given skill, discussion is to take place as to whether or not that particular verbalization is correctly categorized. Concensus is to be reached as to the appropriate categorization for each of the experts' samples, and re-writing of the verbalization(s) is to occur as needed. After four verbalizations for every skill have been "validated", trial runs are to be made to see if "concensus" can be reached on a three-minute section of actual classroom tape. If concensus can be reached on three three-minute sections, a trial run is to be held on a twenty-minute section. The following confidentiality agreement, Figure 5, is to be signed by each of the experts on the panel prior to hearing any of the recordings of the science lessons:

FIGURE 5
CONFIDENTIALITY

CONFIDENTIALITY

I, ______________________________, pledge that I will keep confidential the names of any students and teachers that I hear on the audio tapes made by Shelley Lipowich from Schaumburg District 54's Fourth Grade science classes. I further pledge that I will keep confidential the details of any classroom situations that occur on the tapes.

______________________________ ______________

name date

Four Apple IIe computers, with printers, are to be used for the trial runs. A "LIST" of the computer program is to be found in Appendix G. The investigator and the author of the program give full permission herein for its use on the one condition that any person using the program attempts to give the investigator feedback on its use--problems or successes encountered and/or comparisons with the Schaumburg data and/or comparison data within another district.

Once the expert panel has validated the categorization rationale, every tape is to be heard, and every verbalization is to be classified. It is decided by the dissertation committee and the investigator that hearing and categorizing all the tapes in their entirety, rather than sampling them, will give a more accurate base-line frequency of occurence.

The next step is to see whether using the computer actually does facilitate the process enough so that it's efficient for others to use in their classrooms. Once the categorization process is begun, reliability of the categorization is to be checked. A randomly chosen twenty-minute section, chosen from Classes 5-10, is to be categorized twice, with a minimum of one week between trial one (Session 1-1) and trial two (Session 2-2). A standard deviation is to be calculated for each of the categories and for the two trials. Another reliability check (Sessions 2-1 and 2-2), using the same method, is to be done on a randomly chosen twenty-minute section chosen from Classes 25-30. A standard deviation is also to be calculated to compare individual categories from the first tapings with individual categories from the second tapings, as well as all of the categories from the first tapings with all of the categories from the second tapings. The choice of a twenty-minute section is based on Eggleston, Galton, and Jones' work with the Science Teaching Observation Schedule (1975).

A spreadsheet function (Microsoft Works)of Standard Deviation (StDev(values-1, values-2,...) is used to calculate the standard deviations for each category. "The formula used is: Sqrt(Var(values-1, values-2))." (Microsoft Works, 1986, p. 256) The formula used for the variance function is (p. 257):

$$\frac{n*(\sum(x^2))-(\sum x)^2}{n*(n-1)}$$

This formula is the raw score formula, which is appropriate for use here since the number of scores are large, and the means end up as integers. The mean percent frequencies are multiplied by 100 to bring them to integer form. The standard deviations for Session 1 and Session 2 are taken from the mean percentage frequencies, multiplied by 100. A typical formula that is used on the spreadsheet for calculating a comparison of one category in one session against the same category in the second session is:

=StDev(B393, B397)*100

Population

Twenty-seven, fourth grade teachers, teaching approximately 775 students in 31 different classes in 12 schools, volunteered to permit this investigator into their classrooms to make two audio tapes, at least one week apart, of their science lessons. Appendix F details the sample population. One tape, that of a combination health/science class was made, but a decision was made not to use it in the data set because half of one session was the completion of a health unit. The sample population represented 53% of the fourth grade classes and 60% of the buildings in the district. One group of fourth grade students was deliberately excluded from the invitation to participate; that group was part of a gifted, Grade 4-5-6 group being taught in one, multi-grade classroom.

District policy and practice require that all teachers whose classes are taped be volunteers. Since the sample of teachers and classes is not a random sample, the results cannot be generalized to describe every classroom in District 54.

Materials

A Sony ECM-D15 electret condenser microphone with a solar battery and a battery check is to be used on a small, portable tape recorder to make the tapes. This microphone is able to pick up the voices of a small group around it and screen out the background noises. This quality is very important in a process science classroom where many small groups are working independently on exciting projects and, while working, are communicating with each other.

Measurement of Data

Data categories (nominal data) are to be mutually exclusive. A verbalization, defined below, is to belong to only one category. Operational Definitions for Process Skills in Science (Appendix D); State of Illinois, Goal 4, Process Skills in Science (Figure 1) ; and Verbalizations: Categories and Examples (Figure 6) define the mutually exclusive categories. There is no logical order to the categories.

Verbalization Defined

A "verbalization" is defined, for this study, as one, intelligible voice speaking with respect to one of the designated categories. See Figure 6, Verbalizations: Categories and Examples, and Appendix D, Operational Definitions for Process Skills in Science.

A "new verbalization" begins with: a new speaker or a new category by the same speaker. A verbalization may be one word or may be several sentences or several minutes in length. For example, a verbalization under Guidance: Directions, when made by a teacher giving instructions at the beginning of a class, may be several minutes in length and still be tallied as only one verbalization.

As explained in the Introduction, before one can categorize any verbalization, one must first have an understanding of what that category is. In order to develop a common language for what the process skills in science are, operational definitions for the process skills were developed, over a period of seven months, by Lake County, Illinois, science teachers and administrators (from Grades 3, 6, 8, and 11) , Ralph W. Tyler, and Shelley Ann Lipowich. During the period of development, these definitions were used and refined in local districts as districts worked on writing objectives required by state mandate. Lake County Educational Service Center provided the coordination for this activity; Lipowich served as the curriculum consultant to the districts as this work was done; and Tyler brought clarity and focus to the project.

Verbalizations: Categories and Examples

Once the definitions were developed, they were used as the basis for categorizing the verbalizations from theSchaumburg tapes. Figure 6, Verbalizations: Categories and Examples, gives models for each of the thirteen State of Illinois process skills in science and the three categories added for the purpose of this study. Each model, or example, is categorized from context. What comes before and after each verbalization must be considered in making the category decision. The examples are taken from the Schaumburg classroom tapes.

FIGURE 6
VERBALIZATIONS: CATEGORIES AND EXAMPLES* (1/8)

*Each example is categorized from context. What comes before and after each verbalization must be considered in making the category decision.

OBSERVATION

SOURCE	EXAMPLE	
Tape 1A	(S)	"This thing exploded."
Tape 3A	(S)	"It's floating."
Tape 3A	(S)	"Even the big one without paper is floating."
Tape 4A	(S)	"That water's hot!"

CLASSIFICATION

SOURCE	EXAMPLE	
Tape 1A	(T)	" What are the characteristics of the crayons we had the other day? In other words, how are they alike, and how are they different?"
	(S)	"Some had paper, and some didn't."
Tape 7A	(T)	"Can you think of another type of cells that you've heard about?"
	(S_1)	"What about like blood cells."
	(S_2)	"Muscle cells."
	(S_3)	"Cells in your skin?"
	(S_4)	"Like a jail, maybe? Cells?"

FIGURE 6 (Continued)
VERBALIZATIONS: CATEGORIES AND EXAMPLES* (2/8)

*Each example is categorized from context. What comes before and after each verbalization must be considered in making the category decision.

CLASSIFICATION (continued)

SOURCE	EXAMPLE	
Tape 7B	(S)	"Yeah, those are air bubbles." [as opposed to epithelial cells]

INFERENCE

SOURCE	EXAMPLE	
Tape 3A	(S_1)	"It won't float any more because the paper is soggy."
	(S_2)	"..."
	(S_1)	"Yeah, when it gets soggy, it won't work any more."
Tape 3A	(S)	"It's sinking. It had too many holes in it."
Tape 4A	[(S_1)	"How can I get mine to hold more weights?"
	(S_2)	"Maybe if you make the bottom thinner?" [it will hold more weights]
Tape 6B	(T)	"What could have made a difference--what kinds of things could have made a difference in what you saw"? [under the microscope]
	(S_1)	"How thick it [onion skin] was."
	(S_2)	"What kind of stain we used."
Tape 7A	[in response to:	(T) "Do you think an onion's a 'living' thing?"]
	(S1)	"It's a living thing because its, if it's not living it can't come out of the ground."
	(S2)	"and it can't grow roots." [therefore, it <u>is</u> living]

FIGURE 6 (Continued)
VERBALIZATIONS: CATEGORIES AND EXAMPLES* (3/8)

*Each example is categorized from context. What comes before and after each verbalization must be considered in making the category decision.

PREDICTION

SOURCE	EXAMPLE	
Tape 1A	(T)	"Would anyone like to draw a conclusion from what we have so far? It's pretty skimpy right now with all the information we have. Would anyone like to venture a guess as to what [crayon] floats and what doesn't--based on our three characteristics?"
	(S)	"Skinny ones'll float."
Tape 1A	(T)	"Raise your hand if you think this piece of clay will float."
Tape 4A	(S)	"It should hold a lot."
Tape 4B	(T)	"What did you guess it would hold?" [it = the "cargo" of a larger plastic cup after students had measured the "cargo" of a smaller plastic cup]

MEASUREMENT

SOURCE	EXAMPLE	
Tape 1A	(S)	[a crayon floated] "...like for four." [count of four]
Tape 3A	(T)	"We weighed our clay yesterday."
Tape 4A	(S)	"Ours is much bigger, though."
Tape 5B	(S)	"Ours holds six."

FIGURE 6 (Continued)
VERBALIZATIONS: CATEGORIES AND EXAMPLES* (4/8)

*Each example is categorized from context. What comes before and after each verbalization must be considered in making the category decision.

TALKING: COMMUNICATION

SOURCE	EXAMPLE	
Tape 1A	(S_1)	"Remember, I pick it up, and you take it down."
	(S_2)	"O.K."
Tape 4A	(S_1)	"You know you put a little water on the desk, and it helps it stick better."
	(S_2)	"O.K., I'll try that."

DATA COLLECTION, ORGANIZATION, AND INTERPRETATION

SOURCE	EXAMPLE	
Tape 1A	(T)	"How many of you had paper covered crayons that sank?"
	(S)	"Me, yes and no. I have this blue that has paper and its skinny and its long and it floated ..."
Tape 4A	(S)	"...five, six, seven..."
Tape 4B	(T)	"Everyone <u>write</u> their own guess on the plastic one." [how many weights a plastic cup will hold]
Tape 4B	(T)	"So, you're going to figure out how much your boat, number 1, can hold and you can <u>fill in the chart</u> for number 1, and then, number 2, and then, number 3."

OPERATIONAL DEFINITION DEVELOPMENT

SOURCE	EXAMPLE	
Tape 1A	(T)	"What is floating?...Is an object floating if it stays up in the water for a few seconds and then sinks?...We're looking for a definition of 'What is floating'. Is it floating if it sits in the middle of the water? Is it floating if it attaches to the side?"

FIGURE 6 (Continued)
VERBALIZATIONS: CATEGORIES AND EXAMPLES* (5/8)

*Each example is categorized from context. What comes before and after each verbalization must be considered in making the category decision.

OPERATIONAL DEFINITION DEVELOPMENT (continued)

Tape 6A	(T)	"What do we mean by 'focused'?"
	(S_1)	"You can see it better.
	(S_2)	"It's clearer."
Tape 12A	[(T)	"What do we call the force that holds a plane back?"]
	(S)	"Grab." [for "drag"]

QUESTION AND HYPOTHESIS FORMULATION

SOURCE	EXAMPLE	
Tape 1A	(T)	"Does the color make a difference?"
Tape 4A	(S)	"I want to try something. I want to see if it makes a difference in hot or cold water."
Tape 6A	(S)	"What is that?"

EXPERIMENTATION

SOURCE	EXAMPLE	
Tape 1A	(S)	"I tried orange, and it floated."
Tape 1A	(S)	"Well, see, if paper makes it float better, you take a lot of crayons that have paper on 'em and do more of it and put them inone bucket and a lot of them that don't have paper and put 'em in another bucket and see which ones float or not and see how many of the paper ones sink and how many of them float and then you compare them."
Tape 3A	(S)	"Try the paper half on and half off."
Tape 4A	(S)	"O.K., now let's make our own shape and then compare it."

FIGURE 6 (Continued)

VERBALIZATIONS: CATEGORIES AND EXAMPLES* (6/8)

*Each example is categorized from context. What comes before and after each verbalization must be considered in making the category decision.

MODEL FORMULATION

SOURCE	EXAMPLE	
Tape 1A	(T)	"Do we have enough information here to draw a rule or a generalization about this stuff? B---, what do you say? Could you make a rule now about what floats and what doesn't--in crayons?"
	(S)	"Not really, but..."
	(T)	"Haven't figured it out yet? All right. Neither have I."
Tape 4A		[the sequence below is in response to: (S) "How did you get it [clay boat] to hold so much?"]
	(S_1)	"What you have to try and do is get the skinny bottom and the skinny sides..."
	(S_2)	"Real tall, though."
	(S_1)	"Yeah, I know. "
	(S_2)	"And they have to curve in a little."
	(S_1)	"Yeah, they have to curve so the water doesn't come in so much."

RESULTS VERIFICATION

SOURCE	EXAMPLE	
Tape 1A	(T)	"Can we find that all of you had the same results? How many of you had orange-red crayons that floated? Did they also have paper on them?"
Tape 1A	(T)	"Did anyone have an orange-red crayon that sunk?"
Tape 4A	(S)	"I'm going to try that again."
Tape 4B	(T)	"Try to make two boats of the same weight so you can see if you made a better boat."

FIGURE 6 (Continued)
VERBALIZATIONS: CATEGORIES AND EXAMPLES* (7/8)

*Each example is categorized from context. What comes before and after each verbalization must be considered in making the category decision.

SCIENTIFIC EQUIPMENT USE

SOURCE		EXAMPLE
Tape 1A	(T)	"How many of you have used a balance before?"
	(S_1)	"I have."
	(S_2)	"Me, too."
Tape 5A	(S)	"Hey, look through this!"
Tape 5A	(T)	"All right. Is there anyone who hasn't practiced using the cover slip?"
Tape 5A	(S)	"I got it!" [when focusing a microscope]
Tape 6A	(T)	"How can you tell if your mirror is adjusted?"
	(S)	"You can see the light."

GUIDANCE: DIRECTIONS

SOURCE		EXAMPLE
Tape 1A	(T)	"Those of you who didn't get the Buoyant Forces booklet the other day, raise your hand."
Tape 1A	(T)	"I'd like to get everyone together, now, into one conversation."
Tape 1A	(T)	"Thank you, Z--, that's generous."
Tape 2B	(S)	"Don't move that part."
Tape 4B	(S)	"You, guys, put this on the top 'cause you remember yesterday I spilled the water."
Tape 5A	(S)	"Can you help me?"

FIGURE 6 (Continued)
VERBALIZATIONS: CATEGORIES AND EXAMPLES* (8/8)

*Each example is categorized from context. What comes before and after each verbalization must be considered in making the category decision.

REGULATION: DISCIPLINE

SOURCE		EXAMPLE
Tape 1A	(T)	"We have a lot to do today, and when the noise stops, I'll know you're ready to begin."
Tape 2B	(S)	"Go away. I have to focus."
Tape 4A	(S)	"Knock it off."

APART FROM THE REST: OTHER

SOURCE		EXAMPLE
Tape 1A	(S_1)	"She left her recording thing on."
	(S_2)	"Oh, oh."
Tape 4A	(S)	"Man Overboard!"
Tape 6A	(S)	"Me and A--- are friends again."
Tape 8A	(T)	"Island of the Blue Dolphin--anyone check it out from the library?"

Categorizing the Data

Any group analyzing classroom tapes and categorizing the data must make jointly agreed upon decisions so that they are all using a common standard or rubric. While Figure 6, Verbalizations: Categories and Examples, and Appendix D, Operational Definitions for Process

Skills in Science, provide the framework for this study, a more detailed look at the decision making process involved in setting up the system is needed . This section denotes the choices made for this study. Other groups of experts might have made other choices. The critical factor here is that a rubric must be constructed that is jointly agreed upon and followed.

EXAMPLE

Tape 1A	(T)	"How many of you had paper covered crayons that sunk?"
	(S)	"Me, yes and no. I have this blue that has paper, and it's skinny, and it's long, and it floated like for four [count of four]."

CATEGORY		VERBALIZATION
Data...	(T)	"How many of you had paper covered crayons that sunk?"
Data...	(S_1)	"Me, yes and no. I have this blue that has paper, and it's skinny, and it's long, and it floated..."
Measurement	(S_1)	" like for four [count of four]."

DISCUSSION OF EXAMPLE:

"Data..." is tallied twice because the speaker changed. Measurement is also tallied because the verbalization shows that quantification of an event occurred, and thus, the category has changed even though the speaker has not.

EXAMPLE

Tape 1A	(S)	"This thing exploded."

CATEGORY		VERBALIZATION
Observation	(S)	"This thing exploded."

DISCUSSION OF EXAMPLE

Is this verbalization an "Observation" or a "Communication"? For this study, communication is tallied only where there is an "exchange". "Exchange is defined as one speaker's verbalization and another's response. If no apparent direct response is heard, the verbalization is not counted as "Communication".

EXAMPLE

Tape 1A (T) "Did anyone have an orange-red crayon that sunk?"

CATEGORY VERBALIZATION

Results Ver... (T) "Did anyone have an orange-red crayon that sunk?"

DISCUSSION OF EXAMPLE

Is this example "Classification" or "Results Verification"? The example is tallied under "Results Verification" because, in context, the teacher was attempting to lead the students into seeing that there were some orange-reds that had floated and some that had sunk. As a result of the discussion, students decided to go back and try to verify their results.

EXAMPLE

Tape 1A (S) "I tried orange, and it floated."

CATEGORY VERBALIZATION

Experiment... (S) "I tried orange, and it floated."

DISCUSSION OF EXAMPLE

Is this example "Observation"; "Data Collection, Organization, and Interpretation"; or "Experimentation"? Truly all three. The student is making an observation--"using the senses to obtain information". The student is classifying crayons into the categories of "floats" or "doesn't float"--"grouping or sorting into categories using similar or dissimilar characteristics". The student is experimenting by trying out various crayons to see which float and which do not float--"carrying out an activity to test a hypothesis" (Lipowich & Tyler, Eds.)

Because experimentation involves multiple processes, and because multiple processes are involved in this verbalization, this example was tallied under "Experimentation".

One must also note what went "before" a verbalization. In this case, the verbalization was not one of a series of observations or classifications. Rather, it is a "recall" of a process that had been done prior to the current discussion. Since the verbalization is in the nature of a "summary" statement of several steps that were done over time, it is best placed under "Experimentation".

Note: Verbalizations are placed under only one category heading. Placement is done rapidly, keying the categories into the computer. If each verbalization were subjected to the intensive type of discussion needed to determine "how many" categories it would fall under, the whole efficiency of this classification method would be lost.

In an ideal process-science classroom, one hopes that students will begin to take on some of the leadership roles that traditionally a teacher has had. Thus, students may find themselves proposing new directions for work, bringing other students back to the task at hand, and asking questions of themselves and others in their group. Teachers, acting as facilitators, also take on the role of question-asker--not directly questioning the student looking for a one correct answer, but rather modeling the kinds of questions about the work that the teacher hopes the students will then begin to ask.

EXAMPLE

Tape 1A (T) "Do we have enough information here to draw a rule or a generalization about this stuff? B---, what do you say? Could you make a rule now about what floats and what doesn't--in crayons?"

(S) "Not really, but..."

(T) "Haven't figured it out yet? All right. Neither have I."

CATEGORY VERBALIZATION

Model Form... (T) "Do we have enough information here to draw a rule or a generalization about this stuff? Brian, what do you say? Could you make a rule now about what floats and what doesn't--in crayons?"
(S) "Not really, but..."
(T) "Haven't figured it out yet? All right. Neither have I."

DISCUSSION OF EXAMPLE

In this example the teacher and the students are not yet able to form a model for what is going on, but the verbalizations indicate that an attempt is being made to do so. Therefore, three tallies are made under the category "Model Formulation". There is real value for the students in understanding that further experimentation would have to go on before a model could be formed.

Students need to understand that models are not always correct, that models are constantly being tested against new data to see if the model does indeed remain "consistant with" all of the data (Lipowich & Tyer, Eds.)

. Thus, the exercise of attempting to construct that model is of great value and legitimately can be tallied--even though a model was not achieved--at this time.

EXAMPLE

Tape 1A (T) "I'd like to get everyone together, now, into one conversation."

CATEGORY VERBALIZATION

Guidance... (T) "I'd like to get everyone together, now, into one conversation."

Why isn't this example tallied under "Regulation: Discipline"? In a process science classroom, the teacher's role is that of facilitator. Students' interaction is encouraged. Frequently, and ideally, many conversations take place at the same time. In the verbalization above, the teacher is not complaining about the noise level; the teacher simply wants all the students to be able to hear all the shared data so that the students can relate data from others to their own work.

EXAMPLES

Tape 4B (S) "You, guys, put this on the top 'cause you remember yesterday I spilled the water."

Tape 5A (S) "Can you help me?"

CATEGORY		VERBALIZATION
Guidance...	(S)	"You, guys, put this on the top 'cause you remember yesterday I spilled the water."
Guidance...	(S)	"Can you help me?"

In a process science classroom, it is hoped that students will take a leadership role in giving help to each other. Thus, help or instruction, given or received, whether by student or teacher comes under the heading of "Guidance: Directions".

The reading of directions aloud is also tallied under "Guidance: Directions", unless the directions involve instructions for silent (written) work that the students will be doing during the class session. The next example shows this type of situation.

EXAMPLE

Tape 4B (T) "Now, it's not a picture graph because we're not going to draw little pictures. When you fill [it] in, it's going to look like a bar. So, you're going to figure out how much your boat, number 1, can hold and you can fill in the chart for number 1, and then, number 2, and then, number 3."

CATEGORY VERBALIZATION

Guidance:... (T) "Now, it's not a picture graph because we're not going to draw little pictures. When you fill [it] in, it's going to look like a bar."

Data... (T) "So, you're going to figure out how much your boat, number 1, can hold and you can fill in the chart for number 1. and then, number 2, and then, number 3."

DISCUSSION OF EXAMPLE

In this example, the first part of the same speaker comes under "Guidance: Directions", and the second part comes under "Data Collection, Organization, and Interpretation".

EXAMPLES

Tape 1A (S) "I tried orange, and it floated."

Tape 1A (S) "Well, see, if paper makes it float better, you take a lot of crayons that have paper on 'em and do more of it and put them inone bucket and a lot of them that don't have paper and put 'em in another bucket and see which ones float or not and see how many of the paper ones sink and how many of them float and then you compare them."

CATEGORY VERBALIZATION

Experiment... (S) "I tried orange, and it floated."

Experiment... (S) "Well, see, if paper makes it float better, you take a lot of crayons that have paper on 'em and do more of it and put them inone bucket and a lot of them that don't have paper and put 'em in another bucket and see which ones float or not and see how many of the paper ones sink and how many of them float and then you compare them."

DISCUSSION OF EXAMPLES:

The first example is that of a student carrying out someone else's activity to test a hypothesis. The second example is that of a student designing his own activity to test a hypothesis.

EXAMPLE

Tape 4A (S1) "You know you put a little water on the desk, and it helps it stick better."
(S2) "O.K., I'll try that."

CATEGORY VERBALIZATION

Talking: Com... (S1) "You know you put a little water on the desk and it helps it stick better."
Talking: Com... (S2) "O.K., I'll try that."

DISCUSSION OF EXAMPLE

This is a clear example of the "Talking: Communication" category because two people are sharing information gained by (S1)'s prior experimentation.

EXAMPLE

Data... "six, seven, eight..."

Meas. "Ours holds eight."

These distinctions fall into the range of "executive" decisions, but a decision does have to be made. For the purpose of this study, actual counting verbalizations are considered to be "Data Collection..." because the students are in the process of "gathering information". Summary statements of quantification are considered to be "Measurement" since they "quantify the description of an object" (Lipowich & Tyler, Eds.)

EXAMPLES

Tape 1A (T) "Does the color make a difference?"

Tape 4A (S) "I want to try something. I want to see if it makes a difference in hot or cold water."

CATEGORY VERBALIZATION

Quest... (T) "Does the color make a difference?"

Quest... (S) "I want to try something. I want to see if it makes a difference in hot or cold water."

DISCUSSION OF EXAMPLES

The first example comes from a teacher during a discussion session. It meets the criteria of the first part of "Question and Hypothesis Formulation" and is basically and simply a question, an "expression of uncertainty" (Lipowich & Tyler, Eds.).

In the second example a student is "expressing an uncertainty" ("Questioning and Hypothesis Formulation") and is also trying to find out if water temperature is a factor in the experiment. The student is "deciding upon a logical explanation as the basis for further investigation to see whether the results are consistent with the explanation" ("Questioning and Hypothesis Formulation"). In other words, the student's underlying statement is: "The temperature of the water is a factor in whether an object floats or not." Thus, this example meets the criteria of both parts of "Question and Hypothesis Formulation" (Lipowich & Tyler, Eds.)

EXAMPLE

Tape 3A (S) "Even the big one without paper is floating."

CATEGORY VERBALIZATION

Observation (S) "Even the big one without paper is floating."

DISCUSSION OF EXAMPLE

This example is a very difficult one to categorize. For this study, it was categorized under "Observation", since it uses the eyes to "obtain information". It could equally well have been tallied either under "Classification", "since it "group[s] or sort[s] into categories" of size, paper, and floatation, or under "Data Collection...", since observations are a part of "gathering information" (Lipowich & Tyler, Eds.)

Since a basic decision was made not to double-tally any one verbalization in this study, this statement is tallied under "Observation" because, in context, it came in the middle of simpler observations. Context, what came before and what came after, has to be the deciding factor in a situation like this one.

EXAMPLES

Tape 1A	(T)	"How many of you have used a balance before?"
	(S_1)	"I have."
	(S_2)	"Me, too."
Tape 5A	(S)	"Hey, look through this!"
CATEGORY	VERBALIZATION	
Sci. Equip....	(T)	"How many of you have used a balance before?"
	(S_1)	"I have."
	(S_2)	"Me, too."
Sci. Equip....	(S)	"Hey, look through this!"

DISCUSSION OF EXAMPLES

The first example is similar to the written version that is used by Larry Small in Schaumburg in evaluating whether or not students have used a given piece of scientific equipment during a given year. The question, "Have you used a microscope this year?", appears on fourth grade students' annual district evaluation.

The second example, heard in context, indicates that a student has focused a microscope, seen something, and wants to share what has been seen. If the statement had been "Look at this!", the tally would have gone under the "Observation" category. The word, "through", and the context surrounding the verbalization indicates that the student's excitement is about his focusing and his ability to obtain a clear picture, rather than about what he is viewing.

EXAMPLE

Tape 8A (T) "Island of the Blue Dolphin--anyone check it out from the library?"

CATEGORY		VERBALIZATION
Apart...: Other	(T)	"Island of the Blue Dolphin--anyone check it out from the library?"

DISCUSSION OF THE EXAMPLE

It's important to realize that "off-task" verbalizations can originate with the teacher or from outside the classroom, as well as from students.

CHAPTER IV

RESULTS

Summary Data

Narrative results are to be augmented with figures that describe patterns, differences, uniqueness, and possible explanations for the data. Spreadsheets of the data may be found in Appendix H, Verbalizations: Percent Frequency of Process Science Skills--Raw Scores and Percents by Unit, Class, and Session (Spreadsheet) and Appendix I, Frequency Distribution of "Observation" by Unit and Class (Spreadsheet). The template for the basic spreadsheet used to analyze the data may be seen from the layout of Figure 7, Summary Sheet of Verbalizations: Percent Frequency of Process Science Skills--Raw Scores and Percents by Unit, Class, and Session (Spreadsheet).

FIGURE 7
SUMMARY SHEET OF VERBALIZATIONS:
PERCENT FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES AND PERCENTS BY UNIT, CLASS, AND SESSION

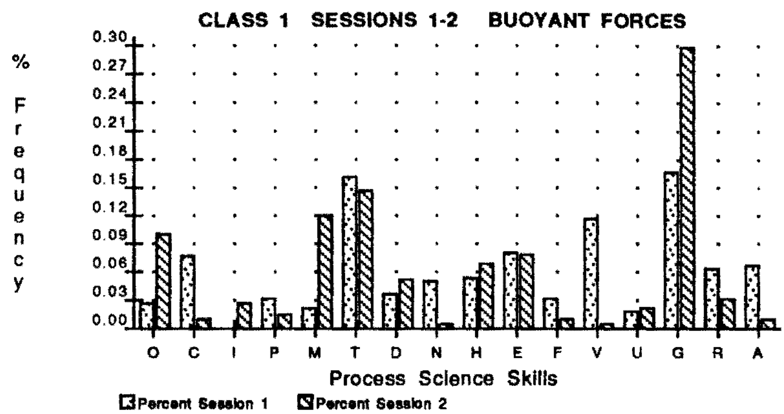
X %				VERBALIZATION CATEGORIES													
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Teac	Discip	Other
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A
X % Sessions 1	12%	3%	2%	2%	4%	17%	5%	0%	5%	8%	1%	3%	4%	24%	3%	6%
X % Sessions 2	13%	4%	2%	2%	5%	18%	5%	0%	4%	6%	1%	2%	4%	26%	4%	5%
Grand X Percent	13%	3%	2%	2%	5%	17%	5%	0%	5%	7%	1%	2%	4%	25%	3%	5%

Data by Classes

Audio tapes from sixty classrooms were analyzed, and a total of 12,680 verbalizations were categorized. The data from each classroom, Sessions 1 and 2 together, was then graphed for study. Seventy-seven percent (23/30) of the classes analyzed for Sesssions 1 and

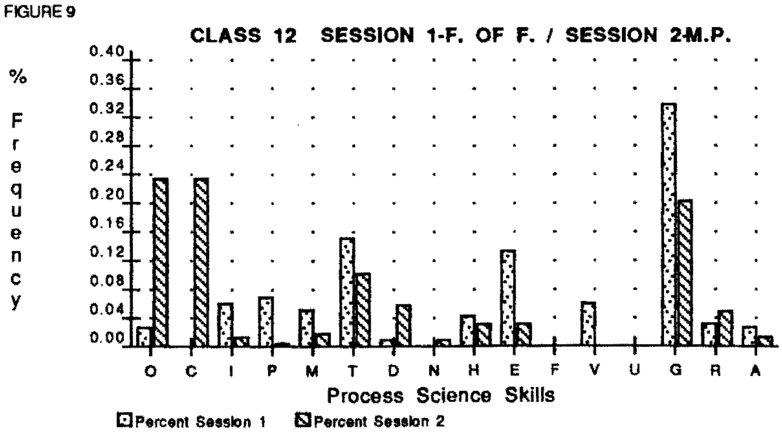
2 were working in <u>one unit</u> for both sessions. Figure 8, Class 1 Sessions 1-2 <u>Buoyant Forces</u>: Graph of Comparative Data, is an example of this type of class.

FIGURE 8



Twenty-three percent (7/30) of the classes analyzed were working in one unit during Session 1 and a different one during Session 2. Figure 9, Class 12 Session 1 <u>Forces of Flying</u> / Session 2 <u>Mystery Powders</u>: Graph of Comparative Data, is an example of a two-unit class.

FIGURE 9



No particular patterns or trends emerged from the study of individual classes, looked at class by class.

Data by Units

When the sessions were grouped by the units each class studied, however, trends did begin to emerge. Figures 10-14 show these trends.

FIGURE 10

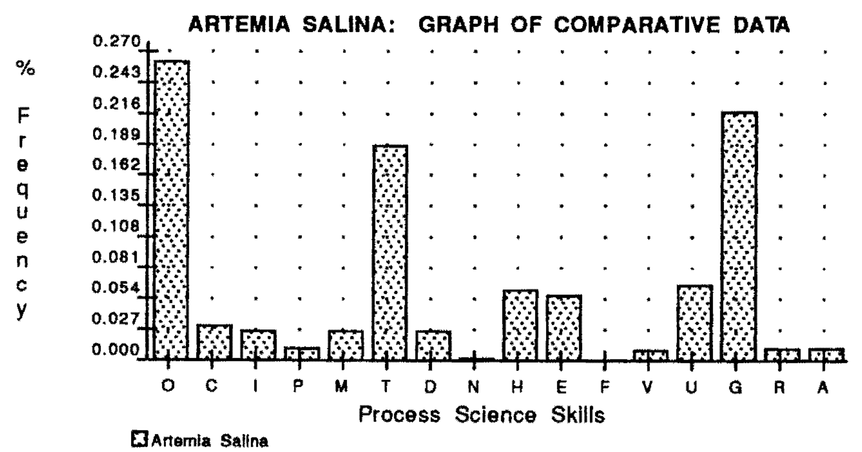


FIGURE 11

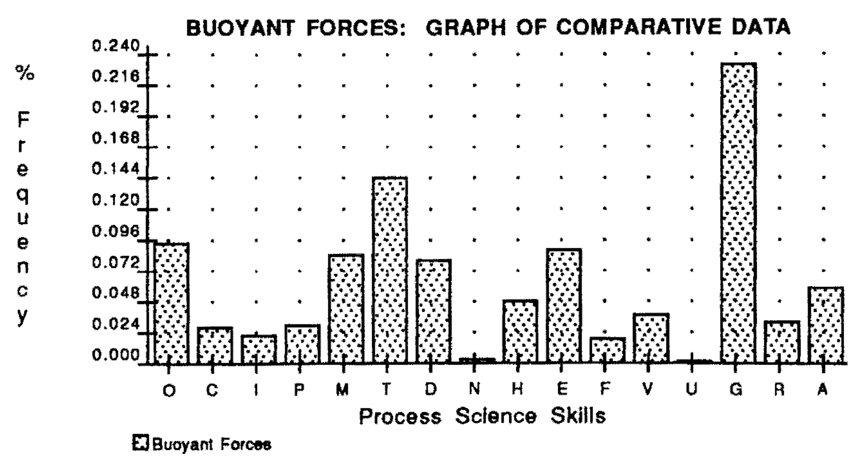


FIGURE 12

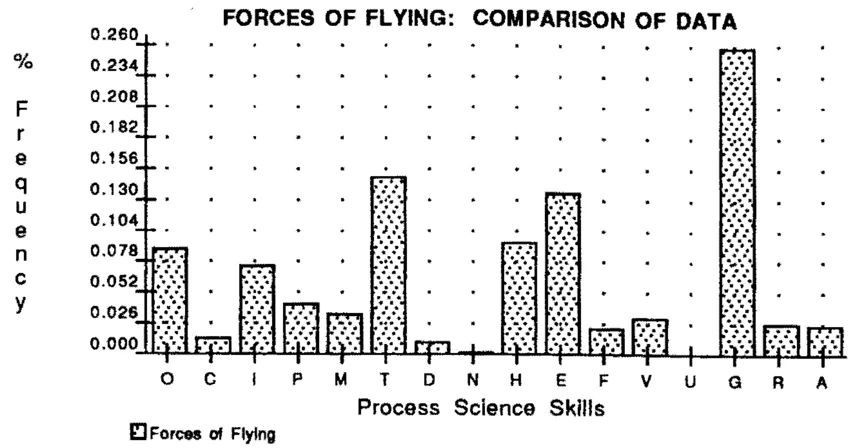


FIGURE 13

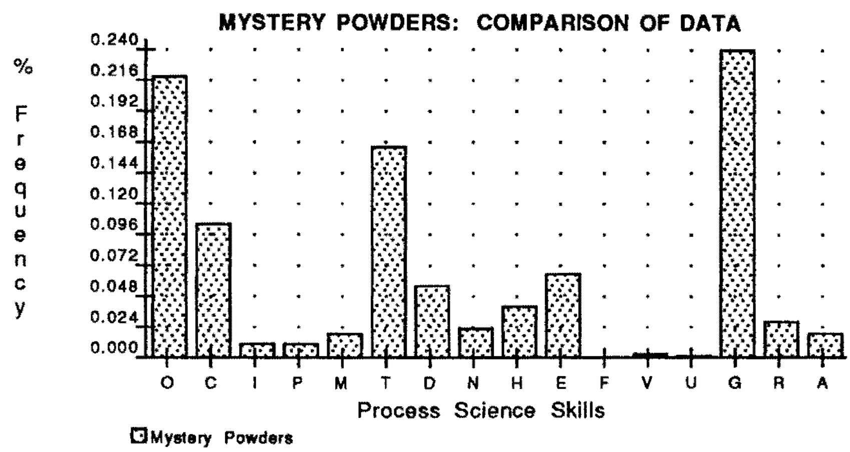
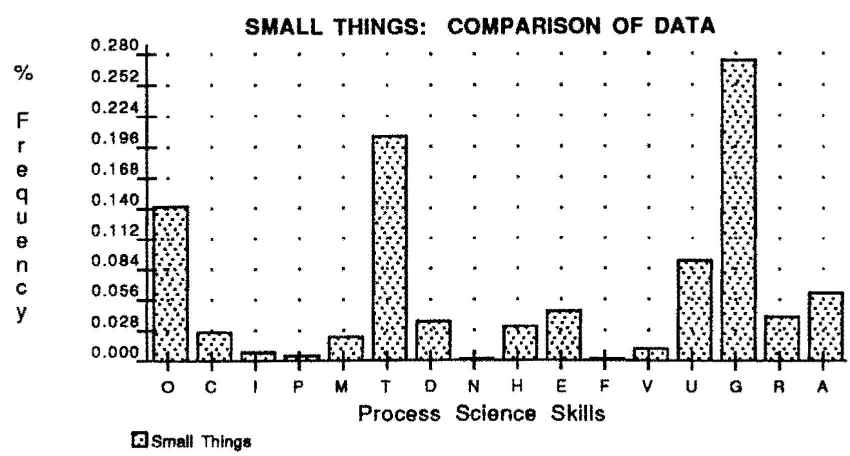


FIGURE 14



Each of the units show strengths in skill areas that are built into the units. For example,Artemia Salina, in Figure 10, is a unit that introduces both the use of the microscope and the study of brine shrimp. Thus, it is logical to see the unit ranking high in both "Observation" and "Communication".

Data by Sessions

Students in Schaumburg are frequently observed by adults from their own district and from outside the district. Visitors are generally noted, introduced, and then classes go on as usual. Visitors may be individuals or teams, but their presence does not seem to interfere with normal, classroom activity. Nevertheless, taping was done in two Sessions to see if there would be a major difference between the tapes obtained from Sessions 1 and 2. Figure 15 compares the mean percentage frequencies, in each category, from all thirty classes in Session 1 with all thirty classes in Session 2.

FIGURE 15

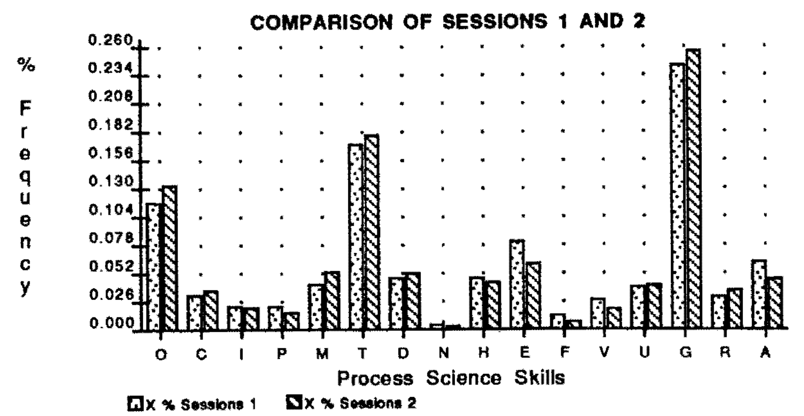


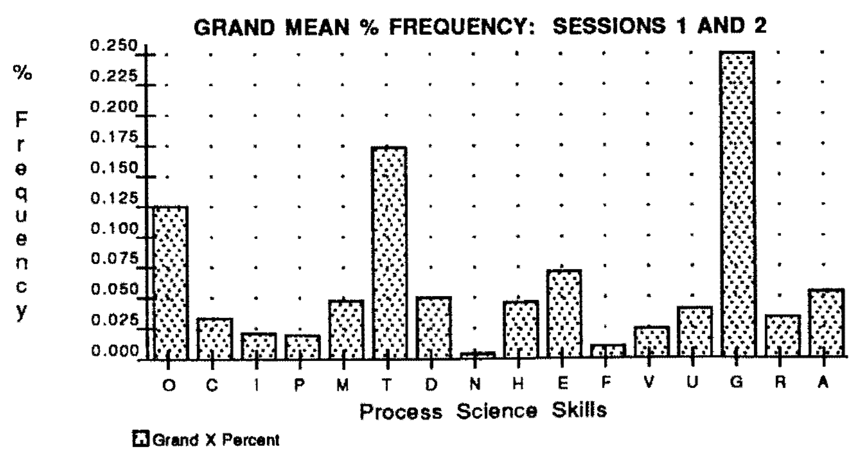
Figure 16 shows the standard deviations between Session 1 and Session 2 for each category. The S.D.'s range from .03 to 1.17 showing that both sessions were remarkably similar in percent frequency of occurrence of the process skills.

FIGURE 16
STANDARD DEVIATION: SESSIONS 1 AND 2

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNI																
SUMMARY SHEET: STANDARD DEVIATIONS																
				VERBALIZATION CATEGORIES												
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A
STANDARD DEVIATION: SESSIONS 1 AND 2																
X % Sessions 1	12%	3%	2%	2%	4%	17%	5%	0%	5%	8%	1%	3%	4%	24%	3%	6%
X % Sessions 2	13%	4%	2%	2%	5%	18%	5%	0%	4%	6%	1%	2%	4%	26%	4%	5%
StDev: Skills	1.17	0.29	0.10	0.42	0.76	0.60	0.28	0.03	0.31	1.49	0.33	0.55	0.08	0.87	0.36	1.16

Figure 17 shows the grand mean percentage frequency of occurrence for Sessions 1 and combined. Each and every skill category required by the state is present in fourth grade classrooms in Schaumburg District 54.

FIGURE 17



While the "Apart: Other" category has a higher percent frequency of occurrence in Session 1, so do the categories of: "Prediction", "Operational Definition Formulation", Questioning and Hypothesis Formulation", "Experimentation", "Model Formulation", and "Results Verification".

It seems reasonable to assume that the data from Session 1 is representative of a "normal classroom" with a slight rise in off-focus activity because of the presence of the tape recorder.

Clusters of Skills

Figure 18, Classes Observed Per Unit, shows that classrooms working in the units Buoyant Forces and Small Things were observed for 24 and 22 classes respectively, while the other three units were observed three to six classrooms. Buoyant Forces is based on the ESS unit Clay Boats, while Small Things is also based on the ESS unit of the same name. These referents should be helpful to other districts, both because of the availability of the ESS units and the large number of classes in Schaumburg that were analyzed. The Schaumburg objectives for their versions of the ESS units are in Appendix B.

FIGURE 18
Classes Observed Per Unit

SCIENCE UNITS	CLASSES OBSERVED PER UNIT
Artemia Salina	5
Buoyant Forces	24
Forces of Flying	6
Mystery Powders	3
Small Things	22

The percent frequency distribution of one skill, "Observation", by all classes does not show any resemblance to a pattern. Figure 19 shows this lack of pattern. However, when one groups the skill "Observation" by unit, rather than by class, one can see clustering in the two units, Buoyant Forces and Small Things, that have broad coverage of all the lessons within the unit. See Figures 20-24, grouped on the next two pages.

FIGURE 19
PERCENT FREQUENCY DISTRIBUTION OF "OBSERVATION" BY ALL CLASSES

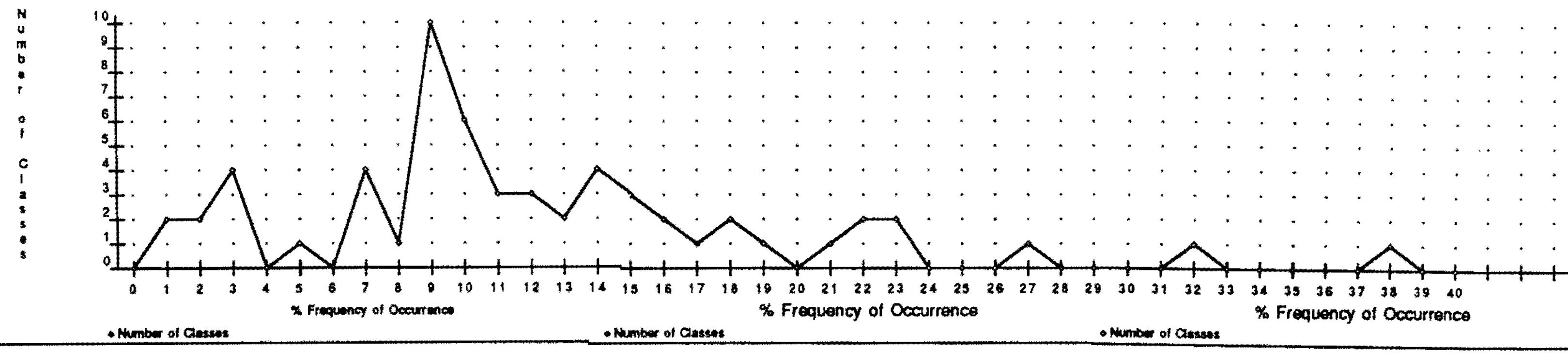


FIGURE 20
FREQUENCY DISTRIBUTION OF "OBSERVATION" BY UNIT: ARTEMIA SALINA

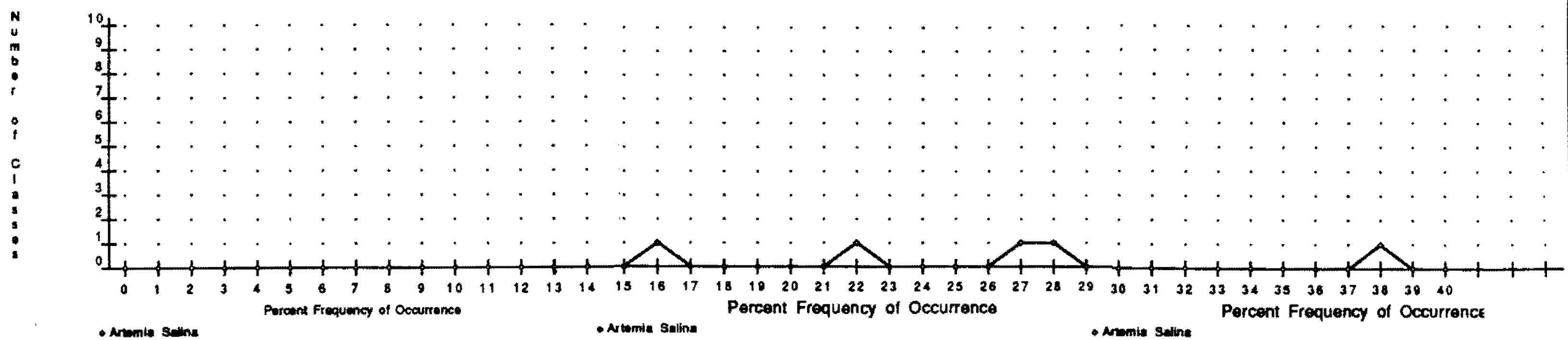


FIGURE 21
FREQUENCY DISTRIBUTION OF "OBSERVATION" BY UNIT: BUOYANT FORCES

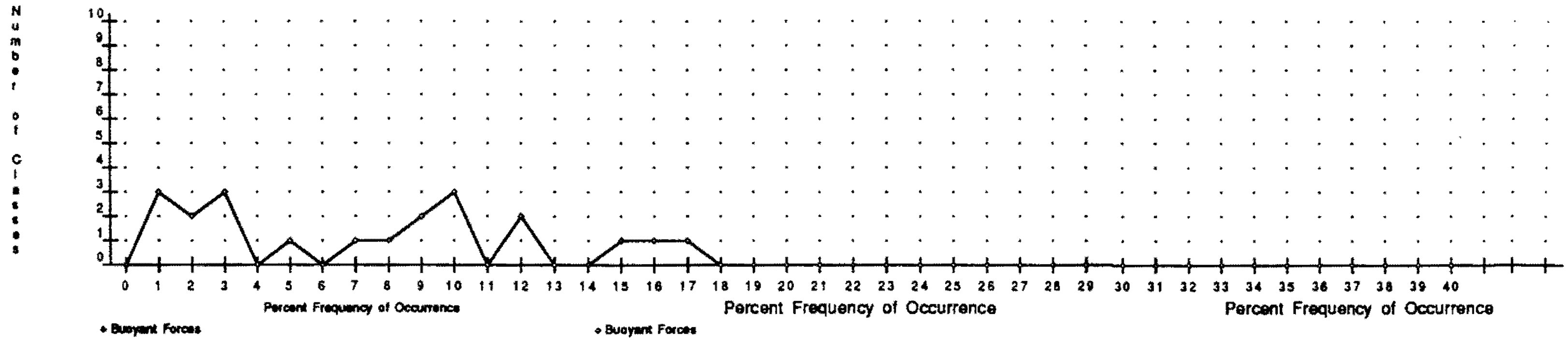


FIGURE 22
FREQUENCY DISTRIBUTION OF "OBSERVATION" BY UNIT: FORCES OF FLYING

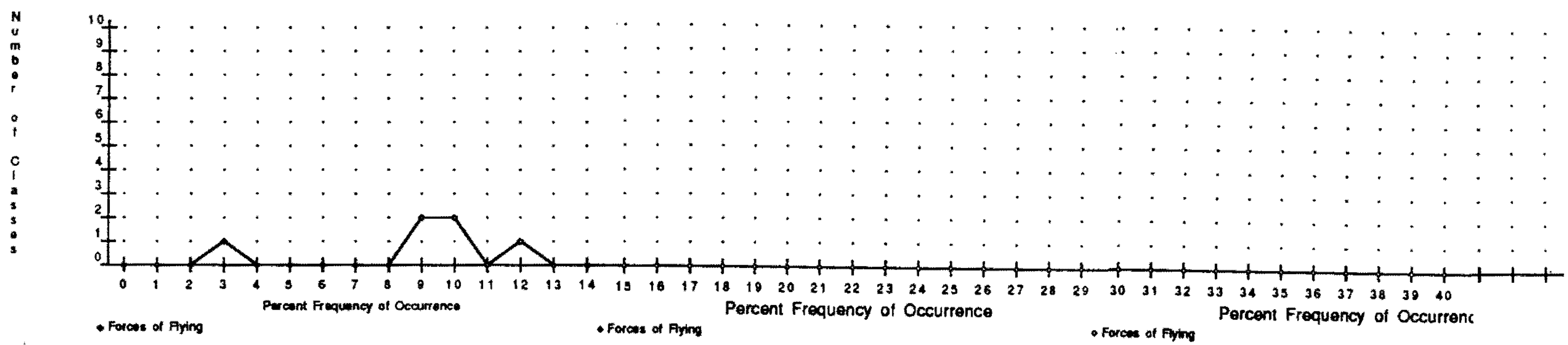


FIGURE 23
FREQUENCY DISTRIBUTION OF "OBSERVATION" BY UNIT: MYSTERY POWDERS

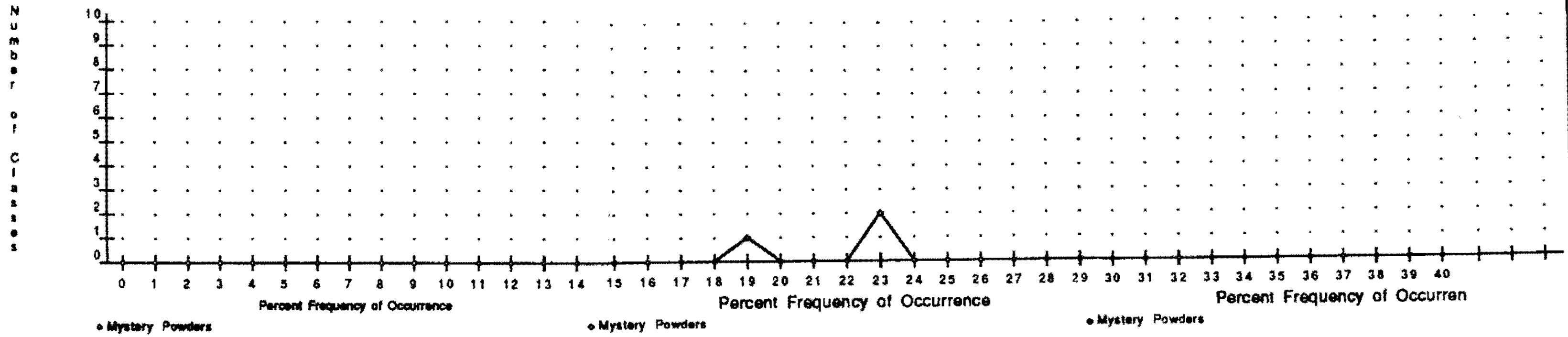
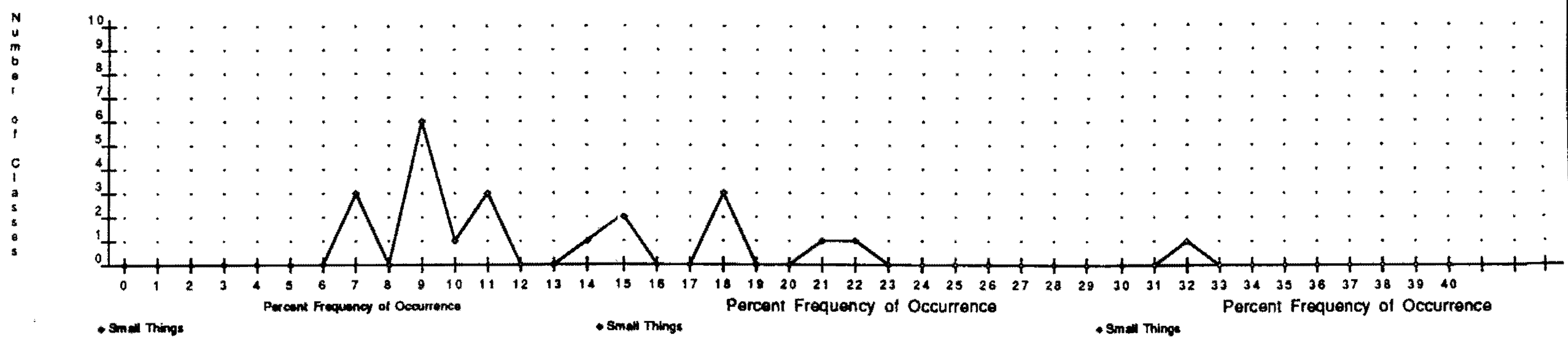


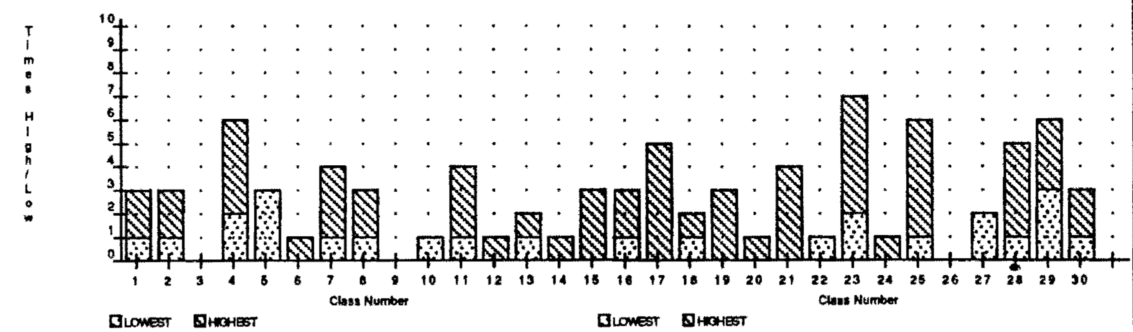
FIGURE 24
FREQUENCY DISTRIBUTION OF "OBSERVATION" BY UNIT: SMALL THINGS



Highs and Lows

In an effort to see whether "one class" had a higher percentage frequency of occurrence of the skills than "other classes", the total sample was grouped for highest, second highest, lowest, second lowest percent frequency of occurrence, by category. Figure 25, Process Science Skill Categories: Number of Times Each Class Tallied High(est) and Low(est) in a Given Category, shows that, while Classes 17 and 21 appear to be ranking high, 23/30, or 77% of all the classes ranked at least once in the High(est) percent frequency of occurrence. Moreover, 14/30, or 47%, scored in both highest and lowest ranks of percent frequency of occurrence, by category.

FIGURE 25
PROCESS SCIENCE SKILL CATEGORIES:
NUMBER OF TIMES EACH CLASS TALLIED HIGH(EST) AND LOW(EST)



Figures 10-14, Graphs of Comparative Data, by units, reinforces the above observation that it is the unit, rather than the class, that seems to be the stronger indicator of whether or not a particular class will score high(est) or low(est) in a given category.

Process Skills vs "Other"

A comparison was made between the percent frequency of occurrence of the process science skills and the "Other" categories of Guidance: Directions; Regulation: Discipline; and Apart: Other (Figure 26 and Appendix I).

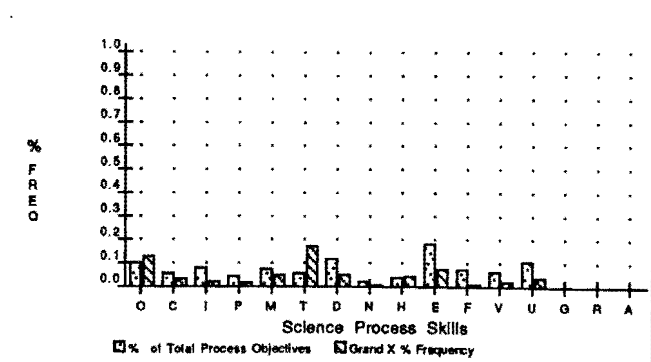
FIGURE 26
PROCESS SKILLS VS "OTHER"

Guidance: Direction	25%
Regulation: Discipline	3%
Apart: Other	5%
Process Science Skills	66%

What's Happening in the Classroom vs What's on Paper

Finally, a category-by-category comparison between (each category's percent of the total number of process science objectives in Schaumburg) and (the mean percent frequency of occurrence of that category in fourth grade classrooms) is made in Figure 27. Appendix B lists the Schaumburg objectives, by skill categories, so that a comparison can be made to similar units of study outside Schaumburg.

FIGURE 27
COMPARISON OF % FREQUENCY OF OCCURRENCE WITH PROCESS SCIENCE OBJECTIVES



CHAPTER V

DISCUSSION

Limitations of the Study

This study is a quantatative description of the frequency of occurrence of process science skills. It seeks to establish a base-line of data for one middle grade, the fourth, in a federal, exemplary, elementary science program, Schaumburg Elementary School District 54. Its intent is "to collect detailed factual information that describes existing phenomena" (Isaac & Michael, 1984), and not to make judgments as to the quality of the count. The data is presented, along with the methodology of obtaining it, in order to establish a base-line for future, controlled-variable studies.

No parametric assumptions can be made about the data because:

1. The sample population was not randomly selected. District policy and practice require that all teachers whose classes are taped be volunteers. The investigator was not "invited" by each building to give the basic presentation within the building, so not every teacher was invited to participate in the study in the same way. Every building that did hear the presentation did not participate in the study. Sixty percent of the K-6 buildings, twelve out of twenty, that were open and in service in 1986-87 had teachers who volunteered to have their classrooms taped. In each of the twelve buildings that did participate, all of the teachers who taught science to heterogeneously grouped fourth graders in that building did volunteer. Twenty-seven out of fifty-nine teachers (53 %) teaching at that grade level in that year did volunteer. It was felt that asking teachers to fill out a questionaire about why they had volunteered would reduce the number of classes available for the sample. The intent was to obtain as many teachers and lessons as possible to get closest to what might be a base-line. The year 1986-87, for many reasons connected with the new mandates for reform, appeared to

be a stressful year in terms of additional requirements put upon teachers and administrators in general. Therefore, it was decided that the teachers not be given an additional task, that of filling out a questionaire about their motivations for participation, or nonparticipation, in the study. Moreover, there was no way to ascertain what happened within every building after the administrators had attended the two meetings held to outline the proposed study. The sample is definitely skewed, but it is the sample that was available at the time of the study.

The number of classes taped, for each unit, is not equal. Again, the sample of units represents those taught at the times that could be arranged for tapings; the times for the tapings were dependent upon: teachers' schedules, building schedules, and the investigator's schedule. Choice of the appointment times were originally to be at the discretion of the teacher and the teacher's administrator ; however, many of the appointments were revised, some more than once. In addition, the schedule for rotation of the units between teachers and buildings had been set up prior to the study, and the units being taught by the teachers at the times of the tapings could not be controlled by this study. This is one area wherein this study is flawed, but another might be controlled. Groupings appear by units, rather than by classes, leading one to want to try to group for the lessons within the units.

2. The distribution of scores in the population, within a class, would be very difficult to determine. Students move from place to place within a room, usually freely, to share observations and techniques for working. From the "high/low" groupings that were made, individual classes appear to rank high in a particular skill according to the unit they're studying. If the skill is not built into the unit, it generally does not appear on the tally sheet.

3. It is also possible that the samples are not independent. Students transfer from school to school in Schaumburg, and it is possible that a fourth grade student might have been taped in more than one class. To the investigator's knowledge, this did not happen, but with

the number of students involved in the study, approximately 775, it was not possible to "take attendence" in each class without causing additional disruption to the process of obtaining an "as normal as possible" lesson sample.

Reliability

The investigator tallied two full classes twice, one week apart, to determine whether the investigator was categorizing in a reliable manner. Standard deviations were calculated between the first time and the second time for each category. The range of the standard deviation for the first reliability session was from .03 to 1.44. The range for the second session was from .18 to .71. See Figure 28, Reliability: Standard Deviation, by Skill Categories, from Identical Sessions Tallied One Week Apart. This range, however, is for one investigator, an investigator who has been working on differentiating between these skills on a daily basis for over two years. The one attempt that was made to obtain an inter-rater reliability rating was not a success in that it did not achieve its purpose--an inter-reliability rating for all of the designated categories. It did demonstrate to all four of the "experts" that a great deal of discussion was needed to obtain any kind of concensus--even with prior agreement to accept the Operational Definitions attached to this study. Since three of the "experts" had not been involved in working out the operational definitions, the "acceptance level" was harder to achieve. The major concensus reached during the work session was that Directions should, at this time, be a separate category.

FIGURE 28
RELIABILITY: STANDARD DEVIATION, BY SKILL CATEGORIES, FROM IDENTICAL SESSIONS TALLIED ONE WEEK APART

RELIABILITY: Standard Deviation, by Skill Categories, from Identical Sessions Tallied One Week Apart (Tallied by Investigator)																	
					PROCESS SCIENCE OBJECTIVES												
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
Rating Session 1-1																	
Raw Score	12	0	6	3	3	34	0	0	8	14	5	4	0	40	1	0	130
% Session 1-1	9%	0%	5%	2%	2%	26%	0%	0%	6%	11%	4%	3%	0%	31%	1%	0%	100%
Rating Session 1-2																	
Raw Score	11	0	5	2	2	36	0	0	7	12	5	4	0	42	2	0	128
% Session 1-2	9%	0%	4%	2%	2%	28%	0%	0%	5%	9%	4%	3%	0%	33%	2%	0%	100%
St.Dev./Skill	0.45	0	0.50	0.52	0.52	1.39	0	0	0.48	0.98	0.04	0.03	0	1.44	0.56	0	
Rating Session 2-1																	
Raw Score	51	29	0	0	3	78	17	1	8	13	0	0	65	88	10	12	375
% Session 2-1	14%	8%	0%	0%	1%	21%	5%	0%	2%	3%	0%	0%	17%	23%	3%	3%	1
Rating Session 2-2																	
Raw Score	54	28	0	0	2	74	16	2	7	12	0	0	66	90	9	14	374
% Session 2-2	14%	7%	0%	0%	1%	20%	4%	1%	2%	3%	0%	0%	18%	24%	2%	4%	1
St.Dev./Skill	0.59	0.17	0	0	0.18	0.71	0.18	0.18	0.18	0.18	0	0	0.22	0.42	0.18	0.38	

Formulating Operational Definitions for the Process Skills

While the end data is quantitative, the process necessary to achieve the data is a very qualitative one. The methodology is simple to use, but cannot be used without having inter-rater concensus established within a given group prior to any attempt to categorize new data. One of the most difficult aspects of this study is in trying to reach concensus on a definition for each process skill. How does "Inference" really differ from "Prediction"? How does "Observation" really differ from "Data collection"? When "x" number of science teachers each write a definition for a given skill, one has "x" different definitions. The first task is to achieve concensus at a given grade level. Then, one has to mesh the various grade level "concensus-definitions" within a district. In this study, Grades 3, 6, 8, and 11 are the grades under consideration since these are the grades that "must test" in Illinois. Is "Inference" the same skill in Grade 3 as it is in Grade 11? Must an inference be "correct" to be tallied? Again, it is the questions raised, considered, and answered, for the time being, according to one's local conditions and needs, that are significant and are of benefit.

A teacher cannot facilitate a child's "inferring" until that teacher first understands what inference is--concretely, in everyday terms, at grade level, and couched in both behavior and content. Once a teacher has this knowledge, that teacher can facilitate the child's acquisition of the skill. One cannot teach, much less evaluate, an unknown quality.

The weakest link in any attempt to replicate this study lies in the lack of that "common language" between teacher and teacher, expert and expert. The greatest strength in any attempt to replicate this study lies in the necessity of having to establish that "common language". The "common language" established does not have to be that which was established within this study; in fact, since the intent is to criterion-reference any process skills to a local science curriculum, and since the skills are different in name from district to district, only districts in Illinois will have all of these skills named in this manner. Nonetheless, the great strength of replication remains that a similarly constructed framework of common reference must first be established. It is from the discussion and common understandings gained during this process that any benefits will accrue. The process becomes far more important than the product.

Frequency of Occurrence of Process Science Skills in Schaumburg

What, then, can one say about the frequency of occurrence of process science skills in the fourth grade of this one federal, exemplary elementary science district? This study shows that all of the skills are being practiced by some of the students in some of the classrooms. Figure 29 shows the grand mean percent frequency from both sessions of taping combined.

FIGURE 29
GRAND MEAN % FREQUENCY

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT																
SUMMARY SHEETS 1/2																
			VERBALIZATION CATEGORIES													
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Datat	OpDe	Quest	Expe	Mode	Resu	SciEq	Guida	Regu	Other
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A
GRAND X % FRE	13%	3%	2%	2%	5%	17%	5%	0%	5%	7%	1%	2%	4%	25%	3%	5%

Does a sheet like this mean that no "Operational Definition Development" is going on? Not at all. Figure 30, Operational Definition Formulation: Highs and Lows, shows that Class 1 had a 5% frequency of occurrence when it was studying Buoyant Forces. Is this because the teacher was skillful in Class 1? On this skill, the second highest groups were also the second lowest.

FIGURE 30
OPERATIONAL DEFINITION FORMULATION: HIGHS AND LOWS

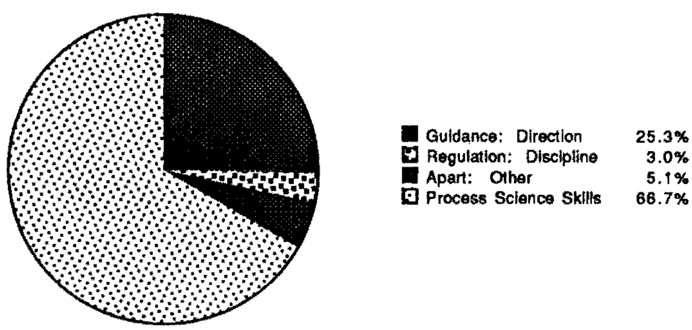
SESSION 1		SESSION 2	
HIGHEST % Freq	5%	HIGHEST % Freq	3%
Class:	1	Classes:	17/30
Unit:	B.F.	Units:	M.P./M.P.
2nd HIGHEST % Freq	3%	* 2nd HIGHEST % Freq	1%
Class:	7	Classes:	4 Classes
Unit:	S.T.	Units:	2-B.F. 1-F.F. 1-M.P.
LOWEST % Freq.	0%	LOWEST % Freq.	0%
Classes:	25 Classes	Classes:	23 Classes
Units:	1-A.S. 12-B.F. 4-F.F. 8-S.T.	Units:	3-A.S. 7-B.F. 1-F.F. 12-S.T.
2nd LOWEST % Freq.	1%	* 2nd LOWEST % Freq.	1%
Classes:	Classes 23/27	Class:	4 Classes
Units:	A.S./B.F.	Unit:	2-B.F. 1-F.F. 1-M.P.

* 2nd Highest=2nd Lowest (same classes)

One recommendation might be to look at some of the units from S-APA that were built upon Operational Definition Development and incorporate similar activities into Schaumburg units. Another possibility might be to compare the lessons Schaumburg already has in its curriculum, on a lesson by lesson comparison. Using this kind of lesson-by-lesson comparison, it might be possible to see what roles various other factors play.

Figure 31 shows the percent frequency of occurrence of the science process skills, across the fourth grade classes studied. Compared with "other" aspects of a fourth grade classroom, almost sixty-seven percent of the verbalizations involve the process skills of science. Figure 31 also shows that approximately one-fourth of the verbalizations involve guidance or direction.

FIGURE 31
PERCENT FREQUENCY OF OCCURRENCE:
PROCESS SCIENCE SKILLS VS (DIRECTION, DISCIPLINE, OTHER)



Directions for Future Study

Ideally, future directions for this kind of study would involve two aspects:

1. a lesson-by-lesson, rather than a unit-by-unit approach;

2. a re-working of the operational definitions on a national basis, similar to the National Council of Teachers of Mathematics "Standards" committees; and

3. cooperation with other disciplines to see what "over-lap" exists from discipline to discipline in the "process skills".

"Experimentation" is going on constantly in the classrooms that were observed, but it does not rank as high as "Observation". It is very possible that, in practice, the process skills in Goal 4 in Illinois are not discrete, mutually exclusive skill categories. There is a very real need to decide what these process skills are so that educators do have a "common language" in which to communicate--from teacher to teacher, from district to district, and from region to region.

Implications for Science Reform in Illinois

This study strongly indicates that science reform in Illinois exists in both the real world and the ideal world. Pages 5-8 of the State Goals are definitely in accord with the highest recommendations coming from such national groups as NAEP, NSF, and NSTA. Districts providing such a program to all of their students would indeed be exemplary. Approximately eight to twelve percent of the districts in this nation have process science curricula. There is no question that the such districts are rare, nationally, and in Illinois. Implementing a process science curriculum requires measures that Illinois has yet to fully support. In exemplary districts, such as Schaumburg, these programs have evolved through time--many years' time. These programs have also involved heavy staff development and training in both process science skills and cooperative learning techniques. The exemplary programs have also been shown to have a very high degree of committment, from both the administration and the community. Where exemplary programs have evolved, there have also been dollar and personnel committment: these districts have set aside dollars for equipment and have had a science "ombudsperson" to facilitate the process.

The "real world" aspect of reform is "assessment". We cannot reliably, validly, and efficiently measure achievement in most of the process skills in science at this point. We can, however, begin to look at whether students are demonstrating the process science skills within their class sessions. This study shows clearly that the process skills are tied closely to the curriculum that is used. Observation of students' work within the class setting, while they are doing process science activities, is still the best method available for looking at student performance at the local district level. Thus, the first steps for a textbook-only district are: process science within the science curriculum, staff development, and materials. At the same time, it is crucial that educators and psychometricians work toward developing, first, a common language for what the process skills are, and then, valid, reliable, and efficient methods for their assessment.

SUMMARY

This study establishes a quantitative base-line of the frequency of occurrence of process science skills in Illinois's Schaumburg Elementary District 54, a district declared "Exemplary" by both the NSF and the NSTA under the Search for Excellence in Science Education.

In this time of state-legislated reform and accountability, many states have mandated that process science skills be taught, achievement measured, results publicly reported, and programs revised, based upon the assessment results. Yet, educators do not have nationally standardized, valid, reliable, and efficient instruments to assess all of the process science skills.

This study matches 12,680 student and teacher verbalizations from sixty class periods, thirty different classes from twelve schools, to sixteen categories (Observation; Classification; Inference; Prediction; Measurement; Communication; Data collection, organization and interpretation; Operational definition development; Question and hypothesis formulation; Experimentation; Model formulation; Results verification; and Scientific equipment use) in order to determine the extent to which students are demonstrating the use of these skills in their classroom activities.

This study includes: Operational Definitions for Process Skills in Science: Lake County, Illinois, developed by a group of 60 educators, representing Grades 3, 6, 8, and 11 and edited by Lipowich and Tyler, R. W.; a computer-assisted method of counting the frequency of occurrence of process science skills; and the Schaumburg objectives, listed by skill categories, so that comparisons can be made.

The Schaumburg units are based on public domain units such as Clay Boats and Small

Things. Each unit shows strengths in the skill areas that are built into the unit. The results indicate that it is the unit, rather than the class, that is the stronger indicator of whether or not a particular class will score high(est) or low(est) in a given category.

All skill categories required by Illinois are present in fourth grade classrooms in Schaumburg. Frequencies of occurrence are given by category, by class, by unit, and by session. Using the grand mean results from all sixty class periods, Process Science Skills occurred 66.7% of the time.

This methodology can be used to compare another fourth grade classroom or another grade level to Schaumburg's fourth grade.

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APPENDIX A

STATE GOALS FOR LEARNING
AND SAMPLE LEARNING OBJECTIVES

BIOLOGICAL AND PHYSICAL SCIENCES
GRADES 3, 6, 8, 10, 12

Illinois State Board of Education
Department of School Improvement Services

BIOLOGICAL AND PHYSICAL SCIENCES

STATE GOAL FOR LEARNING 1

As a result of their schooling, students will have a working knowledge of the concepts and basic vocabulary of biological, physical, and environmental sciences and their application to life and work in contemporary technological society.

GENERAL KNOWLEDGE/SKILLS RELATED TO GOAL 1

The following knowledge and skills are related to this State Goal for Learning:

A Symmetries or patterns in the natural and physical world.

B Orderliness in nature and the schemes we use to express this order.

C Fundamental units used to express the structure of nature.

D How two or more things interact and the effect each has on the other.

E Common characteristics of plant and animal communities.

F Characteristics of energy and matter.

G Equilibrium applied to simple systems.

H Influence of a field on objects within its domain.

I Cause and effect relationships which allow predictions to be made.

J Cycles in which conditions or events are repeated at regular intervals.

K Systems as defined by boundaries.

L Stages, mechanisms, and rates of change.

M Organism as a system which can be characterized by the processes of life.

N Relationship of structure to function.

O The nature of force.

P Perception as our way of interpreting the world.

Q Time and space as dimensions which separate things and events.

BIOLOGICAL AND PHYSICAL SCIENCES

STATE GOAL FOR LEARNING 2

As a result of their schooling, students will have a working knowledge of the social and environmental implications and limitations of technological development.

GENERAL KNOWLEDGE/SKILLS RELATED TO GOAL 2

The following knowledge and skills are related to this State Goal for Learning:

A Relationships between science and technology.

B Selected nonrenewable and renewable natural resources.

C Relationships between the natural and technological world.

D Influence of scientific and technological research on the needs, interest, and financial support of society.

E Application of scientific research to consumer decision making.

F Application of selected ecological concepts to human and environmental situations.

G Society's responsibility for improving the environment and protecting natural resources.

H Environmental issues in light of scientific and technological knowledge and ethical principles.

BIOLOGICAL AND PHYSICAL SCIENCES

STATE GOAL FOR LEARNING 3

As a result of their schooling, students will have a working knowledge of the principles of scientific research and their application in simple research projects.

GENERAL KNOWLEDGE/SKILLS RELATED TO GOAL 3

The following knowledge and skills are related to this State Goal for Learning:

A Ethical practices which include:

1. honesty and integrity in the recording and reporting of the results of scientific inquiry;
2. disclosure, including open discussion of ideas, techniques and results;
3. rights of subjects, humanness and respect for life.

B Basic scientific standards and research abilities which include:

1. Accuracy, skill and safe practices in laboratory activities:
2. Application of an operational definition using terms to physically describe the activity or result of a procedure;
3. Good experimental techniques which will be evident by the precision practiced during the investigation;
4. Systematization of data to maintain an orderly manner of review;
5. Effectiveness in communicating laboratory procedures and results:
6. Ability to analyze, ev luate or replicate the experimental work of others.

BIOLOGICAL AND PHYSICAL SCIENCES

STATE GOAL FOR LEARNING 4

As a result of their schooling, students will have a working knowledge of the processes, techniques, methods, equipment and available technology of science.

GENERAL KNOWLEDGE/SKILLS RELATED TO GOAL 4

The following knowledge and skills are related to this State Goal for Learning:

A Observation.

B Classification.

C Inference.

D Prediction.

E Measurement.

F Communication.

G Data collection, organization and interpretation.

H Operational definition development.

I Question and hypothesis formulation.

J Experimentation.

K Model formulation.

L Results verification.

M Scientific equipment use.

APPENDIX B

SCHAUMBURG DISTRICT 54: GRADE 4 SCIENCE OBJECTIVES CLASSIFIED ACCORDING TO THE STATE OF ILLINOIS' STATE GOALS FOR LEARNING IN THE BIOLOGICAL AND PHYSICAL SCIENCES

OUTCOME STATEMENT 1: As a result of their schooling, students will have a working knowledge of the concepts, principles, theories, and laws of physical, biological and environmental sciences and their application to life and work in contemporary technological society. Because science demands student participation and involvement in both laboratory and field situations at all grade levels, students should demonstrate the ability to:

OUTCOME A: Identify symmetries or patterns in the natural and physical world.

GRADE:	UNIT:	L.OBJ.:
4	Artemia Salina	Understand that brine shrimp belong to a family similar to spiders, lobsters, and insects.
4	Mystery Powders	Identify similarities in a set of common household powders.
4	Small Things	Recognize similarities in animal and plant cells.

OUTCOME B: Identify orderliness in nature and the schemes we use to express this order.

GRADE:	UNIT:	L. OBJ.:
4	Mystery Powders	Understand that matter has qualities, called properties, that help identify a material.
4	Mystery Powders	Understand that properties help determine for what purposes a material can be used.

OUTCOME C: Identify fundamental entities which are useful in expressing the structure of nature.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand that acids have a sour taste and turn litmus paper red.
4	Artemia Salina	Understand that bases have a bitter taste, feel slippery, and turn litmus paper blue.
4	Buoyant Forces	Understand the importance of standardized units in comparing cargo carrying ability.
4	Forces of Flying	Identify gravity as a force that affects flight.
4	Forces of Flying	Identify lift as a force that affects flight.
4	Forces of Flying	Identify thrust as a force that affects flight.
4	Forces of Flying	Identify drag as a force that affects flight.
4	Small Things	Recognize that living organisms have a common unit called a cell.

OUTCOME D: Describe interactions of two or more things and the effect each has on the other.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand the effect water has on dried brine shrimp eggs.
4	Artemia Salina	Understand how natural bodies of water become salty.
4	Forces of Flying	Describe the interaction of gravity & air pressure: upside-down water-filled cup & paper.
4	Forces of Flying	Describe the interaction of air pressure (air bag) and a table.
4	Forces of Flying	Describe the interaction of air pressure and gravity.
4	Forces of Flying	Describe the effect of lift on an airplane.
4	Forces of Flying	Describe the effect of drag on an airplane.
4	Forces of Flying	Describe the effect of gravity on an airplane.
4	Forces of Flying	Describe the effect of thrust on an airplane.
4	Mystery Powders	Describe the interaction of heat with the common household powders.
4	Mystery Powders	Describe the interaction of warm water with the common household powders.
4	Mystery Powders	Describe the interaction of peroxide with the common household powders.
4	Mystery Powders	Describe the interaction of alcohol with the common household powders.
4	Mystery Powders	Describe the interaction of food coloring with the common household powders.
4	Mystery Powders	Describe the interaction of iodine with the common household powders.
4	Small Things	Recognize that a microscope changes the appearance of the units seen, not the size.
4	Small Things	Describe what effect stains may have on clothing, fingers, and cells.

OUTCOME E: Describe populations that have similarities or common characteristics.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Recognize that all the members of a brine shrimp population will have common characteristic

OUTCOME F: Describe energy/matter and their various forms and relationships.

GRADE:	UNIT:	L. OBJ.:
4	Forces of Flying	Observe that air pushes down equally on water in a glass & water in a straw in that glass.
4	Mystery Powders	Understand that energy may occur as heat, light, or electricity.
4	Mystery Powders	Understand that energy is needed or given off for a chemical change to occur.
4	Mystery Powders	Differentiate among elements, compounds, and mixtures.
4	Mystery Powders	Observe the circumstantial evidence that atoms and molecules do exist.
4	Mystery Powders	Observe the heat energy given off when plaster of Paris hardens.

4	Mystery Powders	Understand that heat energy is applied until no more changes occur.

OUTCOME G: Describe equilibrium and its affecting factors.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand that litmus paper that turns red indicates the presence of an acid.
4	Artemia Salina	Understand that litmus paper that turns blue indicates the presence of a base.
4	Artemia Salina	Understand that litmus paper that does not change color is neutral.

OUTCOME H: Describe how a field influences objects within its domain.

GRADE:	UNIT:	L.OBJ.:
4	Artemia Salina	Understand that brine shrimp live in salt water and die in fresh water.
4	Buoyant Forces	Understand the different effects on an object in an ocean and in a fresh body of water.

OUTCOME I: Understand cause and effect relationships which allow predictions to be made.

GRADE:	UNIT:	L.OBJ.:
4	Forces of Flying	Understand the effect of a propeller or jet engine on an airplane.
4	Forces of Flying	Understand the effects of gravity and drag on an airplane.
4	Forces of Flying	Understand what the source of thrust is for a glider.
4	Mystery Powders	Understand that an indicator can show the presence of a given substance.
4	Mystery Powders	Understand that an indicator can show the absence of a given substance.

OUTCOME J: Understand cycles in which conditions or events are repeated at regular intervals.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand the food chain beginning with brine shrimp.
4	Artemia Salina	Understand the life cycle of brine shrimp.

OUTCOME K: Understand systems as defined by boundaries.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Observe the circulation in a living brine shrimp.

4	Artemia Salina	Observe food in the gut of a living brine shrimp.
4	Artemia Salina	Observe eggs in the egg sac of a living brine shrimp.
4	Artemia Salina	Understand that brine shrimp belong to a family that has tough armor and joined feet.
4	Artemia Salina	Describe the properties of brine shrimp eggs.
4	Forces of Flying	Understand that paper gliders do not belong to the engine-powered airplane system.
4	Mystery Powders	Distinguish between physical and chemical properties.
4	Small Things	Distinguish between living and non-living.

OUTCOME L: Understand change including its rate, stages and mechanisms.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand change as it relates to the life cycle of brine shrimp.
4	Artemia Salina	Understand that the first batch of eggs of a brine shrimp hatch inside the female body.
4	Artemia Salina	Understand that the second batch of eggs of a brine shrimp hatch outside the female body.
4	Artemia Salina	Understand that the second batch of eggs of a brine shrimp must dry out before hatching.
4	Buoyant Forces	Understand that changing the shape of a lump of clay does not change its weight.
4	Forces of Flying	Change the rotational direction of a whirligig by changing its top panels' direction.
4	Mystery Powders	Understand that when materials change size, a physical change takes place.
4	Mystery Powders	Understand that when materials change form or state, a physical change takes place.
4	Mystery Powders	Understand that when a material is heated and expands, a physical change takes place.
4	Mystery Powders	Understand that in most physical changes, a material can be changed back to the original.
4	Mystery Powders	Understand that a material that has undergone chemical change is a new material.
4	Mystery Powders	Understand that a chemically changed material cannot be changed back to the original.
4	Mystery Powders	Understand that energy is either needed or given off for a chemical change to occur.
4	Mystery Powders	Understand why sugar dissolves faster in hot water than in cold water.
4	Small Things	Recognize that the units seen in cork are empty cell walls--no longer alive.
4	Small Things	Investigate the effect of using different dilutions of stain on the rate of change.
4	Small Things	Understand that different stains darken different parts of the cell structure.
4	Small Things	Understand that a cell without a nucleus may have broken open during preparation of slide.
4	Small Things	Understand that a cell wall breaks down with cooking of the material.

OUTCOME M: Understand organism as a system which can be characterized by the processes of life.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand the organism, brine shrimp, as a system characterized by the life processes.
4	Artemia Salina	Compare the results of brine shrimp activities with students' own environment.

OUTCOME N: Understand structure and function.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand that brine shrimp have feet that are adapted for breathing.
4	Artemia Salina	Understand that brine shrimp eggs may remain viable for years if they're kept dry.
4	Artemia Salina	Understand that fewer legs on a brine shrimp cause jerky movement.
4	Artemia Salina	Understand that more legs on a brine shrimp allow for gliding movement.
4	Buoyant Forces	Understand that the shape of the clay relates directly to whether it floats or sinks.
4	Buoyant Forces	Understand that the shape of the clay relates directly to the cargo carrying ability.
4	Buoyant Forces	Understand that the lightness and flexibility of aluminum is an advantage for boats.
4	Buoyant Forces	Understand that clay would need to be rolled very thin in order to approximate aluminum.
4	Buoyant Forces	Understand that aluminum and clay would not "hold up" in the same ways.
4	Buoyant Forces	Understand the function of the keel to keep the sailboat upright.
4	Buoyant Forces	Understand the function of the rudder to steer the sailboat.
4	Buoyant Forces	Understand the function of the sail to catch wind to power the sailboat.
4	Forces of Flying	Recognize that the shape of a piece of paper (crumpled-flat) affects its resistance to air.
4	Forces of Flying	Understand that enlarging the wings of a whirligig will help it stay up longer.
4	Forces of Flying	Understand that changing the whirligig's top panels changes its rotational pattern.
4	Forces of Flying	Understand the functions of the right and left ailerons on an airplane
4	Forces of Flying	Understand the function of the rudder on an airplane.
4	Forces of Flying	Understand the function of the elevators on an airplane.
4	Small Things	Recognize the nucleus as the control center of a cell.
4	Small Things	Recognize the cell wall as the outside, supporting boundary of a plant cell.
4	Small Things	Recognize that cells performing the same function are often similar in shape.
4	Small Things	Recognize that cells performing different functions are often different in size and shape.

OUTCOME O: Understand force as push or pull.

GRADE:	UNIT:	L. OBJ.:
4	Buoyant Forces	Understand buoyancy as an upward push (force) of a fluid on an object immersed in it.
4	Buoyant Forces	Understand that the fluid pushing upward may be a liquid (water) or a gas (air).
4	Buoyant Forces	Understand that when an object is placed in a fluid, the object displaces fluid.
4	Buoyant Forces	Understand that the weight of the displaced fluid is equal to the buoyant force.
4	Buoyant Forces	Understand that an object floats if its weight = the weight of the displaced fluid.
4	Buoyant Forces	Understand that an object sinks if its weight > the weight of the displaced fluid.
4	Buoyant Forces	Understand that the amount of cargo held by boats of the same size & shape is identical.
4	Buoyant Forces	Understand wind as a source of energy for a sailboat.
4	Buoyant Forces	Understand the relationship between floating in water and lighter-than-air craft.
4	Forces of Flying	Understand that a piece of paper must push air aside as the paper falls to the ground.
4	Forces of Flying	Understand drag as a force that slows an object's forward movement.
4	Forces of Flying	Understand thrust as a force that pushes an object forward.
4	Forces of Flying	Understand lift as a force that moves an object up.
4	Forces of Flying	Understand gravity as a force that pulls an object downward.
4	Forces of Flying	Understand which force of flight works against lift.
4	Forces of Flying	Understand which force of flight works against drag.

OUTCOME P: Understand perception as our way of interpreting the world.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand that what appears to be green water is really algae, food for brine shrimp.
4	Artemia Salina	Understand that what appears to be just brown stuff may be dried brine shrimp eggs.
4	Artemia Salina	Understand what a small amount is in terms of using yeast as fo
4	Mystery Powders	Use sight to identify common household powders by color and texture.
4	Mystery Powders	Use smell to identify common household powders by odor.
4	Mystery Powders	Use touch to identify common household powders by hardness.

OUTCOME Q: Understand time and space as dimensions which separate things and events.

GRADE:	UNIT:	L. OBJ.:

OUTCOME STATEMENT 2: As a result of their schooling, students will have a working knowledge of the social and environmental implications and limitations of technological development. Because technological development has a direct effect on society, students should demonstrate the ability to:

OUTCOME A: Distinguish between science and technology.

GRADE:	UNIT:	L. OBJ.:
4	Mystery Powders	Identify Claud Louis Berthollet as an innovator in physical and applied chemistry.
4	Mystery Powders	Investigate the relationship between chemistry and the career of a pharmacist.
4	Mystery Powders	Investigate the relationship between "mystery powders" and the career of a chemist.
4	Small Things	Identify Van Leeuwenhoek as the first to study, measure, and draw specimens under a scope.
4	Small Things	Identify technology (making of great lenses) attributable to Anton Van Leeuwenhoek.

OUTCOME B: Identify selected nonrenewable and renewable natural resources

GRADE: UNIT: L. OBJ.:

OUTCOME C: Understand the relationship between the natural and technological world.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Identify environmental factors that affect brine shrimp.
4	Artemia Salina	Understand that chlorine is put into tap water to improve its quality for humans.
4	Artemia Salina	Understand that chlorine can be removed from tap water by letting the water stand.
4	Artemia Salina	Understand that chlorine in water is harmful to brine shrimp.
4	Artemia Salina	Investigate to find out what marine life has been seriously affected by water pollution.
4	Artemia Salina	Understand the relationship between disease organisms and vaccines.
4	Artemia Salina	Understand that technological improvements have waste products that can pollute.
4	Artemia Salina	Investigate the operation of a water treatment plan.
4	Artemia Salina	Investigate the operation of a water reclamation plan.
4	Buoyant Forces	Understand how a hydrometer is used to check anti-freeze in a car's radiator.
4	Buoyant Forces	Understand that a sailboat uses wind energy for power.
4	Buoyant Forces	Understand the relationship between floating in water and lighter-than-air craft.
4	Forces of Flying	Understand the relationship between man-made objects and the forces that help them to fly.

4	Forces of Flying	Understand how lift affects an airplane.
4	Forces of Flying	Understand how drag affects an airplane.
4	Forces of Flying	Understand how gravity affects an airplane.
4	Forces of Flying	Understand how thrust affects an airplane.

OUTCOME D: Understand how scientific and technological research is influenced by the needs, interest, and financial support of society.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand the role of the Department of Agriculture in the protection of our food supply.
4	Artemia Salina	Understand the roles of the state and local Departments of Health.

OUTCOME E: Apply the results of scientific research in consumer decision making.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Draw posters urging the prevention of pollution.
4	Artemia Salina	Understand the role of the Food & Drug Administration in protecting our medicines.

OUTCOME F: Apply selected ecological principles to human and environmental situations.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Understand that pollution alters the environment.
4	Artemia Salina	Understand that pollution limits the usefulness of the environment.
4	Artemia Salina	Understand that people produce pollution.
4	Artemia Salina	Understand the term pollution to mean any material that dirties air, water, or soil.

OUTCOME G: Evaluate society's responsibility for improving the environment and protecting natural resources.

GRADE:	UNIT:	L. OBJ.:
4	Artemia Salina	Determine what laws have been enforced to protect our water and marine life.
4	Small Things	Recognize how life in pond water changes with age and quality of water.

OUTCOME H: Evaluate environmental issues using scientific and technological knowledge and ethical principles.

GRADE:	UNIT:	L. OBJ.:

OUTCOME STATEMENT 3: As a result of their schooling, students will have a working knowledge of the principles of scientific research and of their application. Because scientific investigation requires accountability, students should:

OUTCOME A: Demonstrate ethical practices which include: A. honesty and integrity in the recording and reporting of the results of scientific inquiry; B. disclosure, including open discussion of ideas, techniques and results; C. rights of subjects, humaneness and respect for life.

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Discuss experimental results with others.
4	Small Things	Handle specimens humanely.
4	Mystery Powders	Discuss experimental results with others.
4	Mystery Powders	Compare students' direct observations.
4	Mystery Powders	Understand that no one answer is "right".
4	Mystery Powders	Understand that differences of opinion are good when they lead to real discussion.
4	Buoyant Forces	Discuss experimental results with others.
4	Buoyant Forces	Compare students' direct observations.
4	Buoyant Forces	Understand that no one answer is "right".
4	Buoyant Forces	Understand that wet weights could cause inconsistent results.
4	Artemia Salina	Develop a respect for life through studying brine shrimp.
4	Artemia Salina	Recognize that a swimming brine shrimp has graceful movements.
4	Artemia Salina	Understand that we experiment with brine shrimp because they do not have a well-developed n

OUTCOME B: Demonstrate basic scientific standards and research abilities which include: A. accuracy, skill, and safe practices in laboratory activities; B. application of an operational definition using terms to physically describe the activity or result of a procedure; C. good experimental techniques which will be evident by the precision practiced during the investigation; D. systematization of data to maintain an orderly manner of review; E. effectiveness in communicating laboratory procedures and results; F. ability to analyze, evaluate or replicate the experimental work of others.

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Recognize the importance of order to help ensure proper care of equipment--assigned scope.
4	Small Things	Recognize the need for proper care of equipment--check scopes BEFORE use--use plastic bag.
4	Small Things	Observe and compare other students' slides.
4	Small Things	Recognize that stains are poisonous and should be handled with care.

4	Small Things	Focus "up" rather than "down".
4	Small Things	Understand the need not to draw conclusions on the basis of little evidence.
4	Mystery Powders	Use small samples to minimize waste.
4	Mystery Powders	Understand that iodine is a poisonous substance.
4	Mystery Powders	Understand that science can be somewhat messy, but still needs to be under control.
4	Mystery Powders	Construct tables categorizing unknown substances by characteristic differences.
4	Mystery Powders	Understand the importance of labeling by number each of the mystery powders.
4	Mystery Powders	Understand the need for protecting desk tops when working with certain substances.
4	Mystery Powders	Understand that contamination of powder sample may lead to different observations.
4	Mystery Powders	Use "bubbling" or "fizzing" to describe the giving off of carbon dioxide or another gas.
4	Mystery Powders	Use "goes into the water and disappears" to describe the process of dissolving.
4	Mystery Powders	Use "goes into the water and does not disappear" to describe insoluble.
4	Buoyant Forces	Use "paper clip" or other item of uniform weight as a standardized unit of weight.
4	Buoyant Forces	Use a shoebox to store certain objects for use in further experimentation.
4	Buoyant Forces	Establish strategic spots in the classroom for garbage bags or boxes to help clean-up.
4	Buoyant Forces	Understand the system of management for storing and passing out materials.
4	Buoyant Forces	Recognize the need to wait after each weight addition to make sure the shape still floats.
4	Buoyant Forces	Understand that scientists use graphs (pictographs) to give results in a clear form.
4	Buoyant Forces	Follow the directions to dry the weights after each test for consistent results.
4	Forces of Flying	Measure the rigging lines to be sure all are equal in length.
4	Forces of Flying	Use a safe outdoor drop site for the parachute experiments.
4	Artemia Salina	Find new and better ways to help brine shrimp eggs hatch.
4	Artemia Salina	Evaluate your work on the activities for brine shrimp by using the Self-Evaluation Chart.

OUTCOME STATEMENT 4: As a result of their schooling, students will have a working knowledge of the processes, techniques, methods, equipment and available technology of science . Because science at all grade levels requires certain skills to answer questions and solve problems, students should in both laboratory and field settings:

OUTCOME A: Observe

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Distinguish between various size water-drop lenses.
4	Small Things	Explore the cellular structure of a plant.

4	Small Things	Explore the life in pond water.
4	Mystery Powders	Observe the smell of common household powders.
4	Mystery Powders	Observe the feel of common household powders.
4	Mystery Powders	Do NOT observe the taste of common household powders--NEVER taste an unknown.
4	Mystery Powders	Observe the color of common household powders.
4	Mystery Powders	Observe the heaviness of common household powders.
4	Mystery Powders	Observe the hardness of common household powders. OPTIONAL
4	Mystery Powders	Observe the elasticity of common household powders. OPTIONAL
4	Mystery Powders	Observe the melting and boiling temperatures of common household powders. OPTIONAL
4	Mystery Powders	Observe the ability of common household powders to dissolve in various solvents.
4	Mystery Powders	Observe the ability of common household powders to conduct heat and electricity. OPTIONAL
4	Buoyant Forces	Observe which crayons float and which crayons sink.
4	Buoyant Forces	Observe the differences between clay and aluminum foil boats.
4	Buoyant Forces	Observe the different factors that determine how much cargo a given ship holds.
4	Buoyant Forces	Observe the relative positions of a vial in water as more sand is added.
4	Buoyant Forces	Observe how density affects buoyancy.
4	Forces of Flying	Observe how air pressure can lift a book, a table, and a student.
4	Forces of Flying	Observe repeated flights of a whirligig.
4	Forces of Flying	Observe gliders' flights to determine what qualities make a glider go a long distance.
4	Forces of Flying	Observe the effect of a moving stream of air above a column of water.
4	Forces of Flying	Observe thrust as air is released from an inflated balloon.
4	Forces of Flying	Observe the effects of drag on a racer holding a large piece of cardboard.
4	Forces of Flying	Observe the effects of drag created by running with an open versus a closed umbrella.
4	Artemia Salina	Observe the life cycle of brine shrimp on a daily basis.
4	Artemia Salina	Observe the effects of differing amounts of salinity on the hatching of brine shrimp.
4	Artemia Salina	Observe the short-term effects of overcrowding on a brine shrimp population.
4	Artemia Salina	Observe the lont-term effects of overcrowding on a brine shrimp population.
4	Artemia Salina	Observe the results of overfeeding a brine shrimp population.

OUTCOME B: Classify

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Differentiate between plant and animal cells.
4	Small Things	Compare the variety of cells in an onion bulb.
4	Small Things	Compare living and non-living substances to find out which are composed of cells.

4	Small Things	Compare the similarities and differences between simple and compound microscopes.
4	Small Things	Differentiate between thin as opposed to small.
4	Small Things	Differentiate between air bubbles and cells.
4	Mystery Powders	Identify similarities and differences in a set of common household powders.
4	Mystery Powders	Differentiate between shades of white: i.e., grayish-white and yellowish-white.
4	Buoyant Forces	Compare the volume of containers of various sizes and shapes.
4	Buoyant Forces	Compare the weights of containers of various sizes and shapes.
4	Buoyant Forces	Compare weight limits between floating objects of various sizes, shapes, and materials.
4	Artemia Salina	Differentiate the male brine shrimp from the female.
4	Artemia Salina	Classify different varieties of shrimp.
4	Artemia Salina	Classify California, Washington, and Utah as states having brine shrimp.
4	Artemia Salina	Classify ammonia as a base.
4	Artemia Salina	Classify vinegar as an acid.
4	Artemia Salina	Classify lemon juice as an acid.

OUTCOME C: Infer

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Formulate what might be done to make the inside of a cell easier to see.
4	Small Things	Formulate the amount of stain needed to stain their specimen.
4	Small Things	Formulate the effect of stain on clothes and fingers.
4	Small Things	Formulate what the origin of the microorganisms in the hay infusion might be.
4	Mystery Powders	Predict the identity of a "mystery powder" by matching it with a "known" powder.
4	Buoyant Forces	Analyze the factors that might be involved in the crayons' floating or sinking.
4	Buoyant Forces	Suggest the various factors that might determine how much cargo a given ship holds.
4	Buoyant Forces	Suggest relationships between weight, size, and shape in floating and sinking.
4	Buoyant Forces	Suggest whether water, salt water, or alcohol is the most dense.
4	Buoyant Forces	Suggest whether it would be easier for a person to float in fresh or salt water.
4	Forces of Flying	Understand the relationship between a parachute's canopy area and its drop time.
4	Forces of Flying	Determine if there is a relationship between a parachute's payload's weight & drop time.
4	Forces of Flying	Explain why an uncrumpled paper takes longer to fall than that same sheet crumpled up.
4	Forces of Flying	Discuss the question of whether a person could be lifted using the air bag procedure.
4	Forces of Flying	Determine the factors that make a glider go a long distance.
4	Forces of Flying	Account for what happens when a stream of air is blown between two hanging balloons.
4	Forces of Flying	Discuss how Bernoulli's principle might apply to flying.

4	Forces of Flying	Discuss how an atomizer sprays perfume.
4	Forces of Flying	Discuss whether a moving stream of air has more or less pressure than still air.
4	Forces of Flying	Discuss the relationship of angle of inclination to an airplane's take-off.
4	Artemia Salina	Infer what will happen next as the brine shrimp begin to hatch and grow.
4	Artemia Salina	Infer what the size of the organism will be based on the size of the brine shrimp egg.
4	Artemia Salina	Infer what will happen to increasing populations in a limited space.

OUTCOME D: Predict

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Predict whether dry grass infusion will produce an environment to support microorganisms.
4	Small Things	Predict whether adding sugar to pond water would encourage growth of microorganisms.
4	Small Things	Predict what are the best light and temperature conditions for growth.
4	Buoyant Forces	Predict how many weights a plastic medicine cup will hold as cargo.
4	Buoyant Forces	Predict how many weights an aluminum foil boat will hold.
4	Buoyant Forces	Predict how many weights an aluminum foil boat of twice the size will hold.
4	Buoyant Forces	Predict whether a tightly crumpled, solid ball of aluminum foil will float.
4	Buoyant Forces	Predict whether other metals than aluminum will float.
4	Buoyant Forces	Predict whether ten items will float or sink.
4	Forces of Flying	Predict what kinds of shapes would fall through the air more quickly.
4	Forces of Flying	Predict what kinds of shapes would stay in the air longer.
4	Forces of Flying	Predict what a stream of air blown between two hanging balloons will do.
4	Artemia Salina	Predict the origin and nature of the "brown stuff".

OUTCOME E: Measure

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Use a hair width (hw) as a standard unit of measurement to measure a specimen.
4	Small Things	Identify the size of the microscope field.
4	Small Things	Compare the size of specimens.
4	Mystery Powders	Measure "powderiness" by rubbing in and blowing away powder from black construction paper.
4	Buoyant Forces	Investigate the amount of weight a floating plastic cup will hold.
4	Buoyant Forces	Identify the amount of weight a floating clay boat will hold.
4	Buoyant Forces	Compare weight limits between floating objects of various sizes, shapes, and materials.
4	Buoyant Forces	Use a "standardized unit" of uniform weight such as washers or paper clips.

4	Buoyant Forces	Use metric linear units to measure the size of crayons.
4	Buoyant Forces	Measure the volume of plastic medicine cups to make sure they all hold identical volumes.
4	Buoyant Forces	Measure the volume of two different sized containers.
4	Buoyant Forces	Compare the clay boat PLUS WEIGHTS to the same-shaped aluminum foil boat PLUS WEIGHTS.
4	Buoyant Forces	Use metric units of weight to measure vials of air and sand.
4	Buoyant Forces	Measure the densities of water, salt water, and alcohol with an hydrometer.
4	Forces of Flying	Measure the time it takes for a parachute to drop.
4	Forces of Flying	Measure the distance from the drop of a parachute to the ground.
4	Forces of Flying	Measure the length of a parachute.
4	Forces of Flying	Measure the width of a parachute.
4	Forces of Flying	Find the surface area of the canopy of a parachute.
4	Artemia Salina	Measure the water level on the side of the brine shrimp habitat using a crayon or tape.
4	Artemia Salina	Measure five drops of liquid with a medicine dropper.

OUTCOME F: Communicate

GRADE:	UNIT:	L.OBJ.:
4	Small Things	Report results of experiment and compare data with data collected by others.
4	Mystery Powders	Discuss the reaction of a given test between powder and test reagent.
4	Buoyant Forces	Discuss personal experiences with floating and sinking.
4	Buoyant Forces	Discuss results of experiments and compare data with date collected by others.
4	Buoyant Forces	Express generalizations about floating and sinking.
4	Buoyant Forces	Compare the graphs of the cargos of the aluminum foil boats.
4	Buoyant Forces	Discuss personal experiences with lighter-than-air craft.
4	Buoyant Forces	Relate through discussion floating in water with floating in air.
4	Forces of Flying	Follow directions cooperatively to use air pressure to lift heavy objects.
4	Forces of Flying	Compare experiences with parachutes.
4	Forces of Flying	Compare parachute data.
4	Forces of Flying	Report experiences with paper gliders.
4	Forces of Flying	Report the results of lowering the air pressure above a column of water.
4	Forces of Flying	Discuss what would happen to objects without gravity.
4	Artemia Salina	Describe the hatching of brine shrimp.
4	Artemia Salina	Describe the diet of brine shrimp.
4	Artemia Salina	Describe the growth of brine shrimp.

OUTCOME G: Collect, organize and interpret data.

GRADE:	UNIT:	L.OBJ.:
4	Small Things	Draw pictures of what is observed.
4	Small Things	Record finding on activity sheets.
4	Small Things	Compile a notebook of activity sheets and observations.
4	Small Things	Compare cells from different parts of different plants.
4	Mystery Powders	Collect, organize, & interpret data from the interactions of the powders & test reagents.
4	Mystery Powders	Construct a table categorizing unknown substances by characteristic differences.
4	Buoyant Forces	Identify and record the amount of weight a floating clay boat will hold.
4	Buoyant Forces	Record the linear sizes of the crayons that float and that sink.
4	Buoyant Forces	Draw shapes of clay that will float.
4	Buoyant Forces	Record the cargo (variety of objects) held in the floating clay shape.
4	Buoyant Forces	Record the number of ceramic weights held in the floating clay shape.
4	Buoyant Forces	Compare the number of ceramic weights held in different floating clay shapes.
4	Buoyant Forces	Review the making of a pictograph.
4	Buoyant Forces	Create a pictograph to show various shapes & the number of ceramic weights held by each.
4	Buoyant Forces	Draw the position of the plastic cup in the water after each weight is added.
4	Buoyant Forces	Create a pictograph to show the amount of cargo held by boats of the same size & shape.
4	Buoyant Forces	Use graph paper for more detailed drawings.
4	Buoyant Forces	Review the making of a vertical bar graph.
4	Buoyant Forces	Construct a graph of weights per volume of cargo in two different containers.
4	Buoyant Forces	Review the making of a horizontal bar graph.
4	Buoyant Forces	Construct a graph of weights per boat for three differently shaped aluminum foil boats.
4	Buoyant Forces	Understand that the clay boat PLUS WEIGHTS should EQUAL the aluminum boat PLUS WEIGHTS.
4	Buoyant Forces	Construct a graph of floating hydrometers in various liquids.
4	Buoyant Forces	Use the hydrometer graph to interpret densities of the liquids.
4	Forces of Flying	Draw a graph relating drop time to canopy area.
4	Forces of Flying	Record the time it took for a parachute to drop.
4	Forces of Flying	Record the site of a parachute drop.
4	Forces of Flying	Record the distance from the drop of a parachute to the ground.
4	Forces of Flying	Record the surfact of a parachute's canopy.
4	Artemia Salina	Identify and illustrate the development of brine shrimp from egg to adult.
4	Artemia Salina	Record and interpret the activities and developments of brine shrimp.

4	Artemia Salina	Record observations on the chart: "How Much Is Enough?"
4	Artemia Salina	Record observations on the chart: "The More the Merrier".
4	Artemia Salina	Record observations on the chart: "Food, Glorious Food".
4	Artemia Salina	Record observations on the chart: "Pollution, Pollution".

OUTCOME H: Develop operational definitions.

GRADE:	UNIT:	L. OBJ.:
4	Mystery Powders	Describe the giving off of carbon dioxide or another gas as "bubbling" or "fizzing".
4	Mystery Powders	Describe the process of dissolving as "goes into the water and disappears".
4	Mystery Powders	Describe insoluble as "goes into the water and does not disappear".
4	Buoyant Forces	Establish a "standardized unit" using uniform weights such as washers or paper clips.
4	Forces of Flying	Describe "air pressure" as the force that glides objects through the air.
4	Artemia Salina	Understand that brine shrimp is the common name for Artemia salina.

OUTCOME I: Formulate questions and hypotheses.

GRADE:	UNIT:	L. OBJ.:
4	Mystery Powders	Formulate methods to identify "mystery powders".
4	Buoyant Forces	Design and construct tests for floating objects.
4	Buoyant Forces	Question the difference size, material, amount of added air, and dye make in the crayons.
4	Buoyant Forces	Question what it is that causes a crayon to float or to sink.
4	Buoyant Forces	Express and record hypotheses as to cargo carried by containers of different volumes.
4	Forces of Flying	Determine how the design could be altered to make a whirligig stay up longer.
4	Forces of Flying	Formulate a hypothesis as to whether a whirligig will always fly in the same pattern.
4	Artemia Salina	Formulate a hypothesis regarding how much salt is best for a brine shrimp environment.
4	Artemia Salina	Formulate a hypothesis regarding how much food is best for a brine shrimp environment.
4	Artemia Salina	Formulate a hypothesis as to what kind of food is best for a brine shrimp environment.
4	Artemia Salina	Develop hypotheses & work out experiments to answer more questions on brine shrimp.

OUTCOME J: Experiment

GRADE:	UNIT:	L. OBJ.:
4	Mystery Powders	Discover ways of detecting the presence of a specific powder in a mixture of powders.
4	Small Things	Discover the function of the knobs, the mirror, and the lens of a simple microscope.
4	Small Things	Use a microscope to discover the appearance and structure of minute objects.
4	Small Things	Use a microscope to differentiate between living and non-living minute objects.
4	Small Things	Use different dilutions of stain on specimens.
4	Small Things	Investigate root, leaf, flesh, and outer skin of an onion.
4	Small Things	Investigate the root system of annual rye grass for relationship of structure & function.
4	Small Things	Investigate the living organisms in a hay infusion.
4	Small Things	Investigate the behavior of the paramecium, euglena, and amoeba.
4	Buoyant Forces	Construct and investigate floating shapes of clay.
4	Buoyant Forces	Construct and investigate floating shapes of aluminum foil.
4	Buoyant Forces	Investigate the amount of weight a floating plastic cup will hold.
4	Buoyant Forces	Investigate the buoyant force of air pressure.
4	Buoyant Forces	Demonstrate curiosity and persistence in the study of buoyancy.
4	Buoyant Forces	Replicate investigations with liquids having a higher or lower density than water.
4	Buoyant Forces	Replicate investigations adding other substances to the water, such as salt.
4	Buoyant Forces	Detect what happens when salt is added gradually to water in which a hard egg is placed.
4	Buoyant Forces	Complete an experiment in a pre-determined time.
4	Buoyant Forces	Test and compare other metals to aluminum foil for floating properties.
4	Buoyant Forces	Test a tightly crumpled, solid ball of aluminum foil for floating properties.
4	Buoyant Forces	Test a hydrometer in water, salt water, and alcohol.
4	Buoyant Forces	Investigate the functions of the moveable parts on a model sailboat.
4	Buoyant Forces	Analyze that if the wind is at your back, you turn the rudder to the left to turn right.
4	Buoyant Forces	Investigate the working of a lighter-than-air craft--a helium balloon.
4	Forces of Flying	Construct a glider that will fly long distances.
4	Forces of Flying	Construct a glider that will stay in the air for long periods of time.
4	Forces of Flying	Construct a glider that will fly accurately.
4	Forces of Flying	Demonstrate that air pressure can lift a book, a table, and a student.
4	Forces of Flying	Apply the air bag procedure to lift a table, chair, & student--all at one time.
4	Forces of Flying	Formulate additional whirligig experiments based on students' questions.
4	Forces of Flying	Create optical illusions by coloring stripes on the flaps of a whirligig.
4	Forces of Flying	Find a way to change the rotational pattern of a whirligig.
4	Forces of Flying	Make a working parachute.

4	Forces of Flying	Test a parachute several times to make sure it opens smoothly.
4	Forces of Flying	Test a parachute several times to make sure it descends without rocking.
4	Forces of Flying	Test a parachute several times to make sure it lands without damage to canopy or cargo.
4	Forces of Flying	Modify a parachute so that it operates well.
4	Forces of Flying	Modify a parachute's canopy with a hole at the center point to stabilize its flight.
4	Forces of Flying	Create a paper glider that will land accurately.
4	Forces of Flying	Create a paper glider that will stay in the air for a long time.
4	Forces of Flying	Create a paper glider that will travel long distances.
4	Forces of Flying	Create a paper glider that will travel along a straight line.
4	Forces of Flying	Establish what happens to a column of water when the air pressure above it is lowered.
4	Forces of Flying	Utilize lowered air pressure to lift a strip of paper.
4	Forces of Flying	Utilize lowered air pressure to lift a curved wing-like index card.
4	Forces of Flying	Test the control surfaces (ailerons, rudder, and elevators) of an airplane.
4	Artemia Salina	Follow directions to prepare a solution to hatch brine shrimp eggs.
4	Artemia Salina	Conduct experiments to determine the presence of pollutants in brine shrimp environments.
4	Artemia Salina	Experiment to find the best environment for brine shrimp to live and grow.
4	Artemia Salina	Use soil-conditioned water for a brine shrimp habitat.
4	Artemia Salina	Use rainwater or melted snow for a brine shrimp habitat.
4	Artemia Salina	Use real seawater for a brine shrimp habitat.
4	Artemia Salina	Use dyed yeast to observe the brine shrimp's gut more clearly.
4	Artemia Salina	Find out what evaporated salt water looks like.
4	Artemia Salina	Observe what happens when brine shrimp are fed at different times of the day.

OUTCOME K: Formulate models.

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Recognize that paramecium's behavior may be caused by lack of sight.
4	Mystery Powders	Construct tests to identify an unknown powder's physical properties.
4	Mystery Powders	Construct tests to identify an unknown powder's chemical properties.
4	Mystery Powders	Formulate ways of detecting the presence of a specific powder in a mixture.
4	Mystery Powders	Understand identification by the process of elimination: using negative test results.
4	Mystery Powders	Recognize that if a powder does NOT "fizz" with vinegar, it does NOT contain baking soda.
4	Buoyant Forces	Determine a possible shape for the clay that will float.
4	Buoyant Forces	Take a position on whether changing the shape of the clay changes its weight.
4	Buoyant Forces	Formulate a model of a plastic cup that would float with a larger amount of cargo.

4	Buoyant Forces	Generate factors determining how much cargo a given ship holds.
4	Buoyant Forces	Understand that given equal size and shape, a lighter vessel will float higher in fluid.
4	Buoyant Forces	Understand that given equal size and shape, a heavier vessel will float lower in fluid.
4	Buoyant Forces	Formulate a model of the relationship between density and floating.
4	Forces of Flying	Establish that it is air pressure that keeps an object up in the air.
4	Forces of Flying	Formulate a model relating the shapes of flying objects to air resistance.
4	Forces of Flying	Use a large washer as a model for a payload.
4	Forces of Flying	Observe the rotational pattern of a whirligig once the top panels have been changed.
4	Forces of Flying	Test to see whether a moving stream of air has more less pressure than still air.
4	Forces of Flying	Test the functions of the control surfaces (ailerons, rudder, & elevators) of an airplane.
4	Artemia Salina	Formulate a model of a good environment for brine shrimp to live and grow.
4	Artemia Salina	Formulate a model of how much an organism will eat based on that organism's size.
4	Artemia Salina	Draw conclusions from the experiments with pollutants.

OUTCOME L: Verify results.

GRADE:	UNIT:	L. OBJ.:
4	Small Things	Draw pictures of cells.
4	Small Things	Describe the length and width of a cell in terms of hair widths.
4	Mystery Powders	Use test reagents, or indicators, to identify common household powders.
4	Mystery Powders	Use heat to make sugar melt, bubble, and turn black.
4	Mystery Powders	Use iodine to turn starch black.
4	Mystery Powders	Use vinegar to make baking soda "bubble" or "fizz".
4	Mystery Powders	Use iodine to turn baking soda orange.
4	Mystery Powders	Use iodine to turn plaster of Paris yellow.
4	Mystery Powders	Use starch to indicate the presence of iodine.
4	Mystery Powders	Use vinegar to curdle a solution of powdered milk.
4	Buoyant Forces	Test a possible shape of clay to see if it will float.
4	Buoyant Forces	Test the changed shape of clay to see if its weight has changed.
4	Buoyant Forces	Replicate twice more the test on cargos carried by boats of the same size & shape.
4	Buoyant Forces	Construct tests to show which factors determine how much cargo a given ship can hold.
4	Buoyant Forces	Test the predictions as to how much cargo an aluminum boat twice the size would hold.
4	Buoyant Forces	Test the ten predictions of objects that would sink or float.
4	Forces of Flying	Confirm the rotational pattern of a whirligig once the top panels have been changed.
4	Artemia Salina	Use controls and variables to observe the effects of pollution on brine shrimp.

OUTCOME M: Use scientific equipment.

GRADE:	UNIT	L. OBJ.:
4	Small Things	Construct and use a water drop magnifier.
4	Small Things	Become familiar with the simple microscope.
4	Small Things	Properly prepare a specimen for a slide.
4	Small Things	Properly prepare a slide.
4	Small Things	Become familiar with the compound microscope.
4	Small Things	Become familiar with the properties of lenses.
4	Small Things	Become familiar with the properties of different stains on the parts of a cell.
4	Small Things	Use methyl cellulose or gelatin solution to slow down very active microorganisms.
4	Small Things	Use a medicine dropper to transfer protozoa to a slide.
4	Small Things	Use a microprojector.
4	Small Things	Observe function of a microprojector.
4	Mystery Powders	Construct an individual "chemistry kit" of powders and testing agents.
4	Mystery Powders	Use a microscope to identify "mystery powders".
4	Buoyant Forces	Use a balance to measure the weight of lumps of clay in varying shapes.
4	Buoyant Forces	Use uniform weights such as paper clips as standardized units for weighing.
4	Buoyant Forces	Use graph paper for recording more detailed observations.
4	Buoyant Forces	Use a hydrometer in water, salt water, and alcohol to determine relative densities.
4	Buoyant Forces	Construct and investigate a wind-energy machine--a sailboat.
4	Buoyant Forces	Construct and investigate a lighter-than-air craft--a helium balloon gondola.
4	Forces of Flying	Use multiple air bags to lift a table, chair, and student.
4	Forces of Flying	Use a whirligig to learn about structure and function.
4	Forces of Flying	Use a parachute as a device to learn about air pressure.
4	Forces of Flying	Use a time piece to measure the time a parachute takes to fall to the ground.
4	Artemia Salina	Understand the use of a micro-projector to enable a whole class to observe together.
4	Artemia Salina	Use a microscope to observe brine shrimp.
4	Artemia Salina	Use an observation chart to record the activities of brine shrimp and their habitat.
4	Artemia Salina	Use red and blue litmus paper as indicators to test water samples.
4	Artemia Salina	Use slides with a well to study living brine shrimp.
4	Artemia Salina	Use a hand lens to observe brine shrimp.
4	Artemia Salina	Use a dye to color the yeast eaten by a living brine shrimp to see the gut more clearly.
4	Artemia Salina	Use a medicine dropper to measure drops.

APPENDIX C

THE SCIENCE LESSON ANALYSIS SYSTEM

THE INTELLECTUAL ABILITY BEING PRACTISED:	VERBAL INTERACTIONS					NON-VERBAL INTERACTIONS With Resource Materials			
	TEACHER – INITIATED			STUDENT – INITIATED		SCIENCE MATERIALS		MULTI-MEDIA MATERIALS	
	A	B	C	D	E	F	G	H	I
	QUESTIONS answered by:	STATEMENT concerned with:	DIRECTIVE for the purpose of:	REFERRAL to teacher for the purpose of:	CONSULTATION with student for the purpose of:	TEACHER interacts for the purpose of:	STUDENT interacts for the purpose of:	TEACHER interacts for the purpose of:	STUDENT interacts for the purpose of:
1. Acquiring, recalling or confirming facts									
2. Delineating scientific concepts, principles or theoretical models									
3. Identifying problems									
4. Solving concrete problems									
5. Solving problems by applying scientific concepts, principles or models									
6. Making or testing hypothesis or speculation									
7. Identifying or describing apparatus, equipment or materials									
8. Describing or practising conventional experimental procedures									
9. Designing novel experimental procedures									
10. Making, describing or recording observations									
11. Interpreting observed or recorded data									
12. Inferring from observed or recorded data									

FIGURE 1

THE SCIENCE LESSON ANALYSIS SYSTEM

APPENDIX D

LAKE COUNTY EDUCATIONAL SERVICE CENTER

OPERATIONAL DEFINITIONS FOR PROCESS SKILLS IN SCIENCE[1]
Developed by Science Teachers in Lake County, Illinois

OBSERVATION:

Using the Senses to Obtain Information

CLASSIFICATION:

Grouping or Sorting into Categories Using Similar or Dissimilar Characteristics

INFERENCE:

Explaining HOW or WHY Something IS HAPPENING or DID HAPPEN, Using Some Kind of Logic, and Remaining Consistent with Known Facts or Observations

PREDICTION:

Determining a Possible Future Result , Telling WHAT MAY HAPPEN, Based on Concurrent and/or Prior Observations, Measurements, and/or Conclusions

MEASUREMENT:

Quantifying the Description of an Object or an Event, Using an Instrument or an Estimation, and Standard or Non-Standard Units

COMMUNICATION:

Sharing Ideas and Information, Verbally and/or Non-Verbally

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[1] Operationally Defined by Lake County, Illinois, Science Teachers, Tyler, Ralph W., and Lipowich, Shelley Ann according to the General Knowledge and Skill Areas listed under Goal 4 of the Illinois' *State Goals for Learning in Biological and Physical Sciences.*

OPERATIONAL DEFINITIONS FOR PROCESS SKILLS IN SCIENCE[1]
Developed by Science Teachers in Lake County, Illinois

DATA COLLECTION, ORGANIZATION AND INTERPRETATION:

a. Gathering Information
b. Organizing Information into Words, Tables, Charts, and Graphs
c. Examining the Information Looking for Patterns and Relationships
d. Explaining What the Information Means

OPERATIONAL DEFINITION DEVELOPMENT:

Using Words to Describe What Is Happening During a Process

For Example:

a. A student sees "effervescence"and calls it "fizzing".[2]
b. A student sees water boiling and says, "It's bubbling." [3]
c. A student sees rapid oxidation and says, "It makes a glowing stick burn more brightly."[4]

QUESTION AND HYPOTHESIS FORMULATION:

QUESTIONING: Expressing Uncertainties

HYPOTHESIZING: Deciding Upon a Logical Explanation as the Basis for Further Investigation to See Whether the Results are Consistent with the Explanation.

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[1]Operationally Defined by Lake County, Illinois, Science Teachers, Tyler, Ralph W., and Lipowich, Shelley Ann according to the General Knowledge and Skill Areas listed under Goal 4 of the Illinois' *State Goals for Learning in Biological and Physical Sciences.*
[2]Lipowich, 1988.
[3]Tyler, 1988.
[4]*Science - A Process Approach, DESIGNING A PROGRAM,* p. 29.

OPERATIONAL DEFINITIONS FOR PROCESS SKILLS IN SCIENCE[1]
Developed by Science Teachers in Lake County, Illinois

EXPERIMENTATION:

a. Designing an Activity to Test a Hypothesis
b. Carrying out an Activity to Test a Hypothesis
c. Designing a Different Activity to Test the Same Hypothesis[2]

MODEL [SYSTEM][3] FORMULATION:

Creating an Explanation that Is Consistent with a Series of Observations

For Example:

"Magnets separate objects into those that are attracted to magnets and those that are not attracted to magnets. The category that is attracted to magnets must have some common characteristic."[4]

RESULTS VERIFICATION:

a. Repeating an Experimental Procedure in the Same Way
b. Checking the New Results against the Results from a Previous Trial to See If the New Results Are the Same or Different
c. Comparing Results among Groups Doing the Same Activity

SCIENTIFIC EQUIPMENT USE:

a. Using a Given Piece of Scientific Equipment
b. Reading Measurements to an Appropriate Precision
c. Carrying, Handling, and Caring for the Equipment Appropriately
d. Choosing the Appropriate Equipment for the Intended Use[5]

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[1] Operationally Defined by Lake County, Illinois, Science Teachers, Tyler, Ralph W., and Lipowich, Shelley Ann according to the General Knowledge and Skill Areas listed under Goal 4 of the Illinois' *State Goals for Learning in Biological and Physical Sciences.*
[2] Tyler, 1988.
[3] Tyler and Lipowich, 1988.
[4] Lipowich, 1988.
[5] Tyler, 1988.

APPENDIX E

To: K-6 PRINCIPALS

From: Larry Small / Shelley Lipowich

Below is a copy of a letter to all Fourth Grade Teachers in our district. We would very much appreciate your distributing the letter in your building. We also ask that you please set up a meeting with those teachers and Shelley so that she can describe the study and answer any and all questions.

Thank you for your understanding and cooperation!

To: Grade 4 Teachers
From: Larry Small / Shelley Lipowich

Please Help!

Would you let us study some of your "really good" Science classes?

"Study" means:

- having an observer (Shelley) in your class;
- having a tape recorder running;
- complete anonymity as to individual class results (classes would be A., B., C....);
- and being able to share the results of the study.

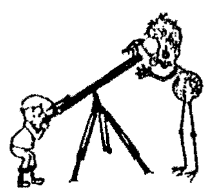
Shelley will meet with you--at a convenient time--to further describe the study and answer any and all questions. If you'd like to talk with her before your meeting, please call the Science/Health Office at 885-6678.

Thank you for your help with this project!

Please return the bottom of the form AFTER your meeting with Shelley.
Send to: Small / Lipowich, Program Service Center

Larry / Shelley,

I'd be glad to help with the study. Please come visit my class on:



First Date Date:____________________

Time:__________ Room ________

Second Date Date:____________________

Time:__________ Room ________

____
Teacher's Name

School:____________________

Please return to: Small / Lipowich, Program Service Center. Thank You!

Please return to: Small / Lipowich, Program Service Center. Thank You!

To: Larry / Shelley

From: ______________________________
Principal

____
School

I've met with our fourth grade teachers:

____

____

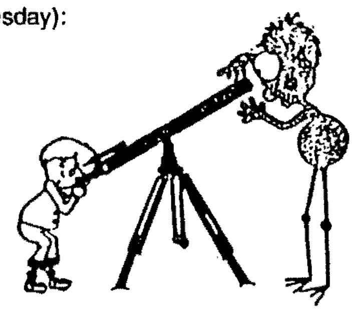
____

____

They will be able to meet with you on (any day except Wednesday):

First Choice: Date ____________
Time ____________
Room ____________

Second Choice: Date ____________
Time ____________
Room ____________



We understand that Shelley will call us and confirm one of the above dates.
She also will send written confirmation to each teacher and principal involved.

Please return to: Small / Lipowich, Program Service Center. Thank You!

APPENDIX F

SAMPLE POPULATION

Schaumburg Elementary School District 54, Schaumburg, Illinois

William Kritzmire, Superintendent of Schools

Eleanor Thorson, Assistant Superintendent

Larry Small, Science Coordinator

1986-87 Classes and Teachers	Schools	Principals	Classes	Sessions/ Teacher	Classes Taped
Keith Anderson	Blackwell School	Bernard Lucier	1	2	2
Louis Axelrod	Churchill School	Daniel Farinosi	3	2	6
Elaine Beaghan	Blackwell School	Bernard Lucier	1	2	2
Judith Binder	Hoover School	John Jones	1	2	2
Marie Burger	Hoover School	John Jones	1	2	2
Mary Carlson	Dooley School	Bill Shatkus	3	2	6
Felicia Cichy	Fairview School	Marilyn Halliday	1	2	2
Pat Cleek	Einstein School	Marv Husby	1	2	2
Particia Dewitt	Macarthur School	Roy Johnson	1	2	2
Anne Donnell	Link School	Judith Shipka	1	2	2

Margaret Dover	Armstrong School	Bernard Osterberger	1	2	2
Sara Engelson	Blackwell School	Bernard Lucier	1	2	2
Nancy Gaughan	Link School	Judith Shipka	1	2	2
Sanford Greenberg	Macarthur School	Roy Johnson	1	2	2
Irene Hurban	Aldrin School	Leland Cook	1	2	2
Lisa Juna	Armstrong School	Bernard Osterberger	1	2	2
Debra Kimball	Muir School	Milton Derr	1	2	2
Mary Lynch	Fox School	James Binder	1	2	2
Karen Martin	Armstrong School	Bernard Osterberger	1	2	2
Sandra Mestek	Link School	Judith Shipka	1	2	2
Darlene Muser	Muir School	Milton Derr	1	2	2
Edna Ortez	Aldrin School	Leland Cook	1	2	2
Donna Osmanski	Hoover School	John Jones	1	2	2
Sandra Prescott	Fox School	James Binder	1	2	2
Patricia Russell	Einstein School	Marv Husby	1	2	2
Barbara Skiff	Armstrong School	Bernard Osterberger	1	2	2
Gary Whiting	Fairview School	Marilyn Halliday	1	2	2
			31		62

APPENDIX G

```
100  REM    ****    VARIABLES AND THEIR MEANINGS   ****
101  REM
108  REM ****                   INTEGER VARIABLES                  ****
109  REM
110  REM VTX  this keeps track of vertical position on a page of text
111  REM HTX  this keeps track of horizontal position on a page of text
112  REM X this is used for simple loops like timing delays...
115  REM TPNO number of topics that have been defined
117  REM SESNO input at first run, # of taping sessions
119  REM CLSNO input at first run, # of classes per session
120  REM ANS  a numerical value of what ANS$ may have been
125  REM A2ANS this hold the last round's value of what ans was
127  REM CODE  takes on a value in onerror goto in 3800 for dos errors
130  REM PROG array of progress values 40 long.-1=undone,1=done
135  REM SN   array of 16x40 holds 40 classrooms, 16 topics/class
150  REM CSESS   current session loaded up
155  REM CCLS    current classroom being examined
160  REM DTIN this = -1 if CSESS isn't read in to SN()
170  REM BASE  this is the total of items in a class. calced at 4500
175  REM AVG an array used to calc % of items/topic at 4500
180  REM YES/NO  yes is 1, and no is -1.  used as logic devises in 4400
185  REM PF printer flag, 1 = on, -1 means off set in 4800,4850
199  REM
200  REM ****                   STRING VARIABLES                   ****
201  REM
205  REM ANS$  this is a multi-use variable for input responses
210  REM MANS$ menu answer stored here incase errors cause loss of point
249  REM
250  REM ****        ASSOC. TEXT FILE NAMES                 ****
251  REM
260  REM START.DATA  if exist, holds SESNO and CLSNO values
270  REM SESSION.X     X is 1-SESNO, file holds classes 1-CLSNO
```

```
299  REM
399  REM
400  REM ****                      INITIAL PARAMETERS                    ****
405  CLEAR
410  LET TPNO = 16: REM              this is the number of topics
415  LET D$ =  CHR$ (4): REM              this is ctrl-d for dos access
420  DIM PROG(40): REM                  0=undone 1=done  for each class
425  DIM SN(40,16): REM      40 classrooms/16 topics
427  DIM AVG(16): REM     16 topics- holds the % for each in a class
430  LET DTIN =  - 1: REM          ie data not read in yet
440  LET YES = 1: LET NO =  - 1
450  LET PF =  - 1: REM           This starts the printer as "off"
499  REM
500  REM                 ****  TITLE PAGE ****
501  REM
505  PR# 3: REM         turn on 80 columns
510  HOME : PRINT
520  VTAB 5: HTAB 25
540  PRINT "FREQUENCY OF PROCESS SCIENCE SKILLS"
550  PRINT : HTAB 27: PRINT "PROGRAMMED BY ALEX BEN LIPOWICH"
560  VTAB 20: HTAB 30
570  INPUT "HIT RETURN TO CONTINUE ";ANS$
580  GOSUB 3000
590  REM     this holds a line for the return from 3000 routine.
599  REM
600  REM                        ****  OPENING MENU ****
601  REM
605  LET VTX = 8:HTX = 30
607  HOME
610  VTAB 6: HTAB 35: PRINT "MAIN MENU"
612  VTAB 6: HTAB 10: PRINT "SESSION   : ";CSESS
614  VTAB 7: HTAB 10: PRINT "CLASSROOM: ";CCLS
620  VTAB VTX
630  HTAB HTX: PRINT "1.  COLLECT DATA"
640  HTAB HTX: PRINT "2.  SHOW/PRINT/DELETE A CLASS"
```

```
650  HTAB HTX: PRINT "3.  SHOW PROGRESS"
660  HTAB HTX: PRINT "4.  SAVE PROGRAM"
670  HTAB HTX: PRINT "5.  DELETE ASSOC. FILES"
680  HTAB HTX: PRINT "6.  LEAVE PROGRAM"
690  HTAB HTX: PRINT "7.  CHANGE SESSION/CLASS"
699  REM
700  VTAB VTX + 8: HTAB HTX: PRINT "ENTER YOUR CHOICE ";: GET ANS$
701  REM
705  LET MANS$ = ANS$
710  IF  VAL (ANS$) <  > 0 THEN  GOTO 730: REM       screen bad input
720  PRINT  CHR$ (7)
722  VTAB VTX + 8: HTAB HTX
724  PRINT "TYPE IN A NUMBER PLEASE"
725  FOR X = 1 TO 650: NEXT
726  GOTO 600: REM                            replot this menu at start
728  REM
730  IF ANS$ = "4" THEN  GOTO 20000: REM         save program on D1/2
731  IF ANS$ = "5" THEN  GOTO 30000: REM         delete those files
734  IF ANS$ = "6" THEN  GOTO 10000: REM         ie bounce out of pg
736  LET ANS$ = MANS$
737  IF ANS$ = "7" THEN  GOSUB 3800: REM         change session/class
739  ON  VAL (ANS$) GOSUB 2000,4000,6000: REM        ordered as above
740  REM
750  GOTO 600
900  REM ****              END OF MAIN MENU                ****
980  INPUT "HIT RETURN TO CONTINUE ";ANS$
1998  REM
1999  REM
2000  REM ****              COLLECTING DATA                ****
2001  REM  \
2005  GOSUB 5000: REM      READ IN CURRENT SESSION
2006  LET PROG(CCLS) = 1: REM       now 1 shows completion
2010  HOME : VTAB 1: HTAB 25
2020  PRINT "DATA COLLECTING FOR SESSION ";CSESS;" CLASS ";CCLS
2030  LET VTX = 2: REM      will use this for the "--->" positioning
```

```
2040  LET HTX = 25
2045  VTAB VTX: PRINT : REM      the print will offset VTX by 1
2050  HTAB HTX: PRINT "(O)  Observation        "
2052  HTAB HTX: PRINT "(C)  Classification     "
2054  HTAB HTX: PRINT "(I)  Inference          "
2056  HTAB HTX: PRINT "(P)  Prediction         "
2058  HTAB HTX: PRINT "(M)  Measurement"
2060  HTAB HTX: PRINT "(T)  Talking: Communication"
2062  HTAB HTX: PRINT "(D)  Data collect'n/organizat'n/interpretat'n"
2064  HTAB HTX: PRINT "(N)  Naming: Operational definition development"
2066  HTAB HTX: PRINT "(H)  Hypothesis: Question-hypothesis formulation"
2068  HTAB HTX: PRINT "(E)  Experimentation"
2070  HTAB HTX: PRINT "(F)  Formulation: Model formulation"
2072  HTAB HTX: PRINT "(V)  Verification: Results verification"
2074  HTAB HTX: PRINT "(U)  Use: Scientific equipment use"
2076  HTAB HTX: PRINT "(G)  Guidance:  Directions"
2078  HTAB HTX: PRINT "(R)  Regulation:  Discipline"
2080  HTAB HTX: PRINT "(A)  Apart from the rest: Other"
2094  PRINT
2095  HTAB HTX: PRINT "(1)  ERASE mistake"
2096  HTAB HTX: PRINT "(2)  END collecting data"
2099  REM                                   entry to get topic #
2100  VTAB VTX + TPNO + 5: HTAB HTX
2110  PRINT "TYPE LETTER TO ADD TO:  >";
2120  GET ANS$
2130  VTAB VTX + TPNO + 5: HTAB HTX
2140  PRINT "                              ";
2150  REM                        assign a # to choice
2160  LET ANS =  - 1
2170  IF ANS$ = "O" THEN  LET ANS = 1
2172  IF ANS$ = "C" THEN  LET ANS = 2
2174  IF ANS$ = "I" THEN  LET ANS = 3
2176  IF ANS$ = "P" THEN  LET ANS = 4
2178  IF ANS$ = "M" THEN  LET ANS = 5
2180  IF ANS$ = "T" THEN  LET ANS = 6
```

```
2182  IF ANS$ = "D" THEN  LET ANS = 7
2184  IF ANS$ = "N" THEN  LET ANS = 8
2186  IF ANS$ = "H" THEN  LET ANS = 9
2188  IF ANS$ = "E" THEN  LET ANS = 10
2190  IF ANS$ = "F" THEN  LET ANS = 11
2192  IF ANS$ = "V" THEN  LET ANS = 12
2193  IF ANS$ = "U" THEN  LET ANS = 13
2194  IF ANS$ = "G" THEN  LET ANS = 14
2196  IF ANS$ = "R" THEN  LET ANS = 15
2197  IF ANS$ = "A" THEN  LET ANS = 16
2198  IF ANS$ = "1" THEN  LET ANS = 18: REM  note sequence out of order
2199  IF ANS$ = "2" THEN  LET ANS = 19: REM  done to space display
2200  REM                                     screen out invalid entry
2210  IF ANS < > - 1 THEN  GOTO 2230
2212  PRINT  CHR$ (7)
2214  VTAB VTX + TPNO + 6: HTAB HTX
2216  PRINT "INVALID KEY TYPED";
2217  FOR X = 1 TO 650: NEXT
2218  VTAB VTX + TPNO + 6: HTAB HTX
2219  PRINT "                 ";
2220  GOTO 2100
2225  REM                                              end of screen
2226  REM
2228  REM                                            point to choice
2229  REM
2230  VTAB VTX + A2ANS: HTAB HTX - 5: PRINT "    ": REM  erase old
2231  VTAB VTX + ANS: HTAB HTX - 5: PRINT "--->": REM     draw new
2238  REM
2239  REM                                          decrement last one
2240  IF ANS$ < > "1" THEN  GOTO 2260
2243  FOR X = 1 TO 300: NEXT
2245  VTAB VTX + ANS: HTAB HTX - 5: PRINT "    "
2250  VTAB VTX + A2ANS: HTAB HTX - 5: PRINT "XXX>"
2254  LET ANS = A2ANS: REM        tricky but ensures erase of XXX>
2255  GOTO 2480
```

```
2259  REM
2260  IF ANS$ = "2" THEN  GOSUB 2800: RETURN
2270  REM
2300  REM                         ***  TIME TO INCREMENT AN ARRAY  ***
2305  LET SN(CCLS,ANS) = SN(CCLS,ANS) + 1
2310  REM
2399  REM                        ***  END OF  INCREMENT AN ARRAY  ***
2400  REM
2480  LET A2ANS = ANS: REM          store in case need to erase later
2500  GOTO 2100: REM       go back, cont collection
2799  REM
2800  REM                                            Save the data here
2805  HOME
2820  VTAB 10: PRINT "NOW SAVING DATA TO DISK"
2825  REM ALL 1002: PRINT D$;"MON,I,C,O"
2830  CALL 1002: PRINT D$;"OPEN SESSION."; STR$ (CSESS);",L200"
2840  CALL 1002: PRINT D$;"WRITE SESSION."; STR$ (CSESS);",R"; STR$ (CCLS)
2850  CALL 1002: PRINT PRG(CCLS): REM       write a 0/1 ie empty/full
2852  FOR X = 1 TO TPNO
2854  PRINT SN(CCLS,X)
2856  NEXT X
2860  CALL 1002: PRINT D$;"CLOSE SESSION."; STR$ (CSESS)
2865  CALL 1002: PRINT D$;"NOMON ,I,C,O"
2900  RETURN
2999  REM
3000  REM ****                      LOAD DATA FROM DISK           ****
3005  REM
3007  REM ALL 1002: PRINT D$;"MON,I,C,O"
3008  VTAB 20: HTAB 30
3009  PRINT "  LOOKING FOR FILES   "
3010  ONERR  GOTO 3300: REM            so that if error, no interuption
3015  LET CODE = 0: REM   code is set in onerr goto if an error occures
3017  PRINT
3020  CALL 1002: PRINT D$;"VERIFY START.DATA,D1"
3030  POKE 216,0
```

```
3040  VTAB 2: HTAB 20
3050  IF CODE <  > 6 THEN  GOTO 3200
3055  HOME : PRINT : PRINT
3057  PRINT "THIS IS THE FIRST RUNNING OF THE PROGRAM.": PRINT
3058  PRINT "PLEASE ENTER THE FOLLOWING PARAMETERS:": PRINT : PRINT : PRINT
3060  INPUT "HOW MANY TIMES WILL YOU TAPE EACH CLASSROOM THIS YEAR? ";SESNO
3065  INPUT "HOW MANY CLASSROOMS WILL YOU BE TAPING ";CLSNO
3080  CALL 1002: PRINT D$;"OPEN START.DATA"
3082  CALL 1002: PRINT D$;"WRITE START.DATA"
3084  PRINT SESNO
3086  PRINT CLSNO
3088  CALL 1002: PRINT D$;"CLOSE START.DATA"
3089  REM
3090  FOR X = 1 TO SESNO
3100  CALL 1002: PRINT D$;"OPEN SESSION."; STR$ (X);",L200"
3105  REM
3110  FOR Y = 1 TO CLSNO
3120  CALL 1002: PRINT D$;"WRITE SESSION."; STR$ (X);",R"; STR$ (Y)
3130  CALL 1002: PRINT  - 1: REM       -1 means unused, ie empty now
3140  NEXT Y
3150  CALL 1002: PRINT D$;"CLOSE SESSION."; STR$ (X)
3155  REM
3160  NEXT X
3165  REM
3200  REM              if here, then files have been established
3210  CALL 1002: PRINT D$;"OPEN START.DATA"
3212  CALL 1002: PRINT D$;"READ START.DATA"
3214  INPUT SESNO
3216  INPUT CLSNO
3218  CALL 1002: PRINT D$;"CLOSE START.DATA"
3265  VTAB 20: HTAB 30
3270  PRINT "    FILES IN PLACE    ": FOR X = 1 TO 1000: NEXT X
3280  IF CODE = 6 THEN  GOTO 590: REM    onerr loses return ptrs
3285  CALL 1002: PRINT D$;"NOMON,I,C,O"
3290  RETURN
```

```
3299  REM
3300  REM  ****                    START OF ON ERROR CODING        ****
3305  REM
3310  LET CODE =  PEEK (222): REM              gets error code
3315  HOME
3320  VTAB 20: HTAB 30
3330  IF CODE = 6 THEN  PRINT "  NO PREVIOUS DATA   "
3340  IF CODE <  > 6 THEN  PRINT "    OTHER ERROR    ";CODE
3345  FOR X = 1 TO 1000: NEXT X
3350  POKE 216,0: REM                        resets from onerr to regular
3370  REM     this routine loses return pointers on the stack.
3400  GOTO 3040: REM                          end of onerr code
3799  REM
3800  REM ****                  CHANGE SESSION/CLASS              *****
3810  REM
3820  LET MANS$ = "0": REM  HOPEFULLY FOOL INTO SKIPPING ON-GOTO
3825  LET VTX = 15:HTX = 7
3830  VTAB VTX: HTAB HTX
3840  PRINT "ENTER SESSION 1-";SESNO;
3842  LET LO = 1:HI = SESNO:CV = VTX:CH = 25: GOSUB 4300
3845  LET CSESS = ANS
3850  VTAB VTX + 1: HTAB HTX
3860  PRINT "ENTER CLASSROOM 1-";CLSNO;
3863  LET LO = 1:HI = CLSNO:CV = VTX + 1:CH = 27: GOSUB 4300
3865  LET CCLS = ANS
3867  LET DTIN =  - 1: REM      important, new CSESS may not be loaded
3880  REM ET MANS$ = "0"
3885  LET ANS$ = "0"
3890  RETURN
3999  REM
4000  REM   ****                DISPLAY A CLASSROOM                ****
4001  REM
4005  GOSUB 5000: REM        READ IN CURRENT SESSION
4007  GOSUB 4500: REM      go and average the class
4010  HOME : VTAB 1: HTAB 25
```

```
4020  PRINT "DATA DISPLAY FOR SESSION ";CSESS;" CLASS ";CCLS
4030  LET VTX = 2
4040  LET HTX = 8
4045  VTAB VTX: HTAB HTX: PRINT "PERCENT","RAW"
4050  HTAB HTX: PRINT AVG(1),SN(CCLS,1),"Observation"
4052  HTAB HTX: PRINT AVG(2),SN(CCLS,2),"Classification"
4054  HTAB HTX: PRINT AVG(3),SN(CCLS,3),"Inference"
4056  HTAB HTX: PRINT AVG(4),SN(CCLS,4),"Prediction"
4058  HTAB HTX: PRINT AVG(5),SN(CCLS,5),"Measurement"
4060  HTAB HTX: PRINT AVG(6),SN(CCLS,6),"Communication"
"4062  HTAB HTX: PRINT AVG(7),SN(CCLS,7),"Data collect'n/organizat'n/interpret'n
4064  HTAB HTX: PRINT AVG(8),SN(CCLS,8),"Operational definition development"
4066  HTAB HTX: PRINT AVG(9),SN(CCLS,9),"Question and hypothesis formulation"
4068  HTAB HTX: PRINT AVG(10),SN(CCLS,10),"Experimentation"
4070  HTAB HTX: PRINT AVG(11),SN(CCLS,11),"Model formulation"
4072  HTAB HTX: PRINT AVG(12),SN(CCLS,12),"Results verification"
4074  HTAB HTX: PRINT AVG(13),SN(CCLS,13),"Scientific equipment use"
4076  HTAB HTX: PRINT AVG(14),SN(CCLS,14),"Guidance:  Directions"
4078  HTAB HTX: PRINT AVG(15),SN(CCLS,15),"Discipline"
4080  HTAB HTX: PRINT AVG(16),SN(CCLS,16),"Other"
4085  IF PF = 1 THEN  GOSUB 4850: REM   will turn off printer, and reset flag.
4094  PRINT
4095  HTAB HTX: PRINT "(1)  RETURN to main menu           (3) PRINT this page"
4096  HTAB HTX: PRINT "(2)  DELETE this class data"
4099  REM
4100  VTAB VTX + TPNO + 5: HTAB HTX
4110  PRINT "TYPE DIRECTIONS PLEASE  >";
4115  LET CV = VTX + TPNO + 5:CH = HTX + 26
4120  LET LO = 1:HI = 3: GOSUB 4300: REM     get a number input
4230  IF ANS = 1 THEN  RETURN
4234  IF ANS = 3 THEN  GOSUB 4800
4235  IF ANS = 3 THEN  GOTO 4010
4240  IF ANS = 1 THEN  RETURN
T020ELETET;CV = VTX + TPNO + 5: VTAB CV: HTAB HTX: PRINT "ARE YOU SURE YOU WANT
4242  LET CH = HTX + 32: GOSUB 4400: REM           get a y/n
```

```
4243  IF ANS = NO GOTO 4010
4245  FOR X = 1 TO TPNO
4246  LET SN(CCLS,X) = 0
4247  NEXT X
4249  LET PROG(CCLS) = 0: REM                         set class to empty
4250  GOSUB 2800: RETURN : REM                      2800 saves the class
4255  REM    end of delete class
4260  RETURN
4270  REM
4280  REM *****                 END OF DISPLAY CLASSROOM           ****
4290  REM
4300  REM ****                NUMBER INPUT ROUTINE                 ****
4305  REM
4310  REM LO = lowest number allowed
4315  REM HI = higest number allowed
4320  REM ANS = returned value of input into ANS$
4330  VTAB CV: HTAB CH
4340  INPUT ANS$
4350  IF ( VAL (ANS$) >  = LO) AND ( VAL (ANS$) <  = HI) THEN 4390
4360  VTAB 24: HTAB 5
4363  PRINT  CHR$ (7);
*4365 PRINT "****** PLEASE ENTER A NUMBER (";LO;"-";HI;") THEN HIT RETURN *****
4366  FOR X = 1 TO 600: NEXT X
4367  HTAB"5: PRINT "
4370  VTAB CV: HTAB CH: PRINT "   ";: HTAB CH
4380  GOTO 4340
4390  LET ANS =  VAL (ANS$): RETURN
4395  REM
4400  REM ****                Y OR N INPUT ROUTINE                 ****
4410  REM
4430  VTAB CV: HTAB CH
4440  INPUT ANS$
4450  IF ( LEFT$ (ANS$,1) = "Y") OR ( LEFT$ (ANS$,1) = "N") THEN 4490
4460  VTAB 24: HTAB 5
4463  PRINT  CHR$ (7);
```

```
4465  PRINT "****** PLEASE TYPE   Y/N  FOLLOWED BY RETURN  *****";
4466  FOR X = 1 TO 600: NEXT X
4467  HTAB 5: PRINT "
4470  VTAB CV: HTAB CH: PRINT "   ";: HTAB CH
4480  GOTO 4440
4490  IF  LEFT$ (ANS$,1) = "Y" THEN ANS = YES
4495  IF  LEFT$ (ANS$,1) = "N" THEN ANS = NO
4497  RETURN
4499  REM
4500  REM ****        GET AVERAGES FOR A CLASSROOM        ****
4510  REM
4520  LET BASE = 0: REM                        set total to 0 initially
4530  FOR X = 1 TO TPNO
4540  LET BASE = BASE + SN(CCLS,X)
4550  NEXT X
4555  IF BASE = 0 THEN BASE = 1: REM     protect against /0
4560  FOR X = 1 TO TPNO
4570  LET I = (SN(CCLS,X) * 100) / BASE
4573  GOSUB 4600: REM                            go round I
4575  LET AVG(X) = I
4580  NEXT X
4590  RETURN
4599  REM
4600  REM ****                  ROUNDING A NUMBER                  ****
4605  REM   let I be the number to be rounded. set when called.
4610  LET FRAC = I -  INT (I)
4620  IF FRAC =  > 0.5 THEN I =  INT (I) + 1
4630  IF FRAC < .5 THEN I =  INT (I)
4640  RETURN
4699  REM
4800  REM ********* TURN ON PRINTER  *******
4810  REM
4820  CALL 1002: PRINT D$;"PR#1"
4825  LET PF = 1: REM    sets the printer pointer to on
4830  RETURN
```

```
4840  REM ***** END OF TURN ON PRINTER   ******
4845  REM
4850  REM *****  TURN OFF PRINTER  *****
4860  REM
4870  CALL 1002: PRINT D$"PR#3"
4875  LET PF =  - 1: REM    sets the printer pointer to off
4880  RETURN
4890  REM ***** END OF OFF PRINTER ******
4999  REM
5000  REM ****                    READ IN A SESSION          ****
5010  REM
5012  IF DTIN = 1 THEN  GOTO 5210: REM       ie data loaded already
5015  REM  : CALL 1002: PRINT D$;"MON,I,C,O"
5020  HOME
5050  IF CSESS = 0 THEN  GOSUB 3800
5054  LET VTX = 18:HTX = 7
5055  VTAB VTX: HTAB HTX
5060  PRINT "OK TO LOAD UP SESSION.";CSESS;
5065  LET CV = 18:CH = 31: GOSUB 4400: REM             goes and gets a Y/N
5070  IF ANS = YES THEN  GOTO 5090: PRINT
5075  PRINT : HTAB HTX
5080  PRINT "ENTER SESSION TO LOAD 1-";SESNO;"  ";
5085  LET CV = VTX + 2:CH = 34:LO = 1:HI = CSESS: GOSUB 4300: REM   get CSESS
5086  LET CSESS = ANS
5090  PRINT
5100  CALL 1002: PRINT D$;"OPEN SESSION."; STR$ (CSESS);",L200"
5110  FOR X = 1 TO CLSNO
5120  CALL 1002: PRINT D$;"READ SESSION."; STR$ (CSESS);",R"; STR$ (X)
5130  INPUT PROG(X): REM                 should be 0/1 0empty/1filled
5140  IF PROG(X) =  - 1 THEN  GOTO 5190
5150  FOR Y = 1 TO TPNO: REM             tpno = # topics
5160  INPUT SN(X,Y): REM    X=classroom, y=topic
5170  NEXT Y
5190  NEXT X
5200  CALL 1002: PRINT D$;"CLOSE SESSION."; STR$ (CSESS)
```

```
5205  PRINT : CALL 1002: PRINT D$;"NOMON,I,C,O"
5208  LET DTIN = 1: REM                    ie now data loaded for Csess
5210  RETURN
5900  REM ****                END OF SHOW DATA                  ****
5999  REM
6000  REM ****               SHOWING PROGRESS                   ****
6001  REM
6004  GOSUB 5000
6005  HOME
6010  VTAB 2: HTAB 30: PRINT "PROGRESS"
6020  VTAB 5: PRINT "TAPE NUMBER";
6025  HTAB 15: PRINT "         1         2         3         4"
6030  HTAB 15: PRINT "1234567890123456789012345678901234567890"
6040  PRINT "SESSION.";CSESS
6050  VTAB 7: HTAB 15
6060  FOR X = 1 TO CLSNO
6070  IF PROG(X) =  - 1 THEN  PRINT "O";
6080  IF PROG(X) = 1 THEN  PRINT "X";
6090  NEXT X
6100  LET VTX = 17:HTX = 30: VTAB VTX:CV = VTX + 3:CH = HTX + 20
6110  HTAB HTX: PRINT "(1)  RETURN to main menu"
6120  HTAB HTX: PRINT "(2)  EXAMINE session totals"
6130  PRINT
6140  HTAB HTX: PRINT "TYPE IN SELECTION >";
6150  LET LO = 1:HI = 2: GOSUB 4300
6160  IF ANS = 1 THEN  RETURN
6170  IF ANS = 2 THEN  GOSUB 7000: RETURN
6990  REM
6999  REM  ****                END OF PROGRESS                  ****
7000  REM   ****       DISPLAY A SESSION/SESSIONS TOTALS         ****
7001  REM
7005  GOSUB 7500: REM          DECIDE WHAT TO SHOW
7006  HOME
7030  LET VTX = 2
7040  LET HTX = 25
```

```
7045  VTAB VTX: HTAB HTX: PRINT "PERCENT"
7050  HTAB HTX: PRINT AVG(1),"Observation"
7052  HTAB HTX: PRINT AVG(2),"Classification"
7054  HTAB HTX: PRINT AVG(3),"Inference"
7056  HTAB HTX: PRINT AVG(4),"Prediction"
7060  HTAB HTX: PRINT AVG(6),"Communication"
7062  HTAB HTX: PRINT AVG(7),"Data collect'n/organizat'n/interpretat'n"
7064  HTAB HTX: PRINT AVG(8),"Operational definition development"
7066  HTAB HTX: PRINT AVG(9),"Question and hypothesis formulation"
7068  HTAB HTX: PRINT AVG(10),"Experimentation"
7070  HTAB HTX: PRINT AVG(11),"Model formulation"
7072  HTAB HTX: PRINT AVG(12),"Results verification"
7074  HTAB HTX: PRINT AVG(13),"Scientific equipment use"
7076  HTAB HTX: PRINT AVG(14),"Guidance:  Directions"
7078  HTAB HTX: PRINT AVG(15),"Discipline"
7080  HTAB HTX: PRINT AVG(16),"Other"
7094  PRINT
7095  HTAB HTX: PRINT "(1)  RETURN to main menu"
7096  HTAB HTX: PRINT "(2)  CHOOSE different display"
7099  REM
7100  VTAB VTX + TPNO + 5: HTAB HTX
7110  PRINT "TYPE DIRECTIONS PLEASE  >";
7115  LET CV = VTX + TPNO + 5:CH = HTX + 26
7120  LET LO = 1:HI = 2: GOSUB 4300: REM        get a number input
7130  IF ANS = 1 THEN  RETURN
7140  IF ANS = 2 THEN  GOTO 7000
7190  RETURN
7500  REM               MENU FOR CHOOSING ONE/ALL SESSIONS
7501  REM
7505  HOME
7510  VTAB VTX
7530  HTAB HTX: PRINT "1.  SHOW FOR JUST ONE SESSION"
7540  HTAB HTX: PRINT "2.  SHOW FOR ALL SESSIONS"
7570  VTAB VTX + 3: HTAB HTX: PRINT "ENTER YOUR CHOICE";
7580  LET CV = VTX + 3:CH = 19 + HTX:LO = 1:HI = 2: GOSUB 4300
```

```
7590  IF ANS = 1 THEN  GOSUB 7600: RETURN
7595  IF ANS = 2 THEN  GOSUB 7700: RETURN
7599  REM
7600  REM             SET UP DISPLAY ARRAY WITH ONE SESSIONS DATA
7610  REM
7612  FOR X = 1 TO TPNO:AVG(X) = 0: NEXT X
7615  HOME
7620  GOSUB 5000: REM            load up with session data
7625  LET CV = 10:HTX = 10: VTAB CV: HTAB HTX:CH = HTX + 21
7626  PRINT "SUM UP CLASS 1 TO >";
7627  LET LO = 1:HI = CLSNO: GOSUB 4300
7628  LET CND = ANS: REM    cnd is for class end of summation
7630  FOR X = 1 TO TPNO: REM              go though the topics
7640  FOR Y = 1 TO CND: REM              go up to class end chosen
7650  LET AVG(X) = AVG(X) + SN(Y,X)
7660  NEXT Y
7665  LET I = (AVG(X) / CND) * 100
7670  GOSUB 4600:AVG(X) = I: REM         4600 rounds I for us
7680  NEXT X: REM              now do the next topic
7699  RETURN
7700  REM            SET UP DISPLAY ARRAY WITH ALL SESSIONS DATA
7799  RETURN
9999  REM
10000  HOME : REM                           end of the program
10010  VTAB 12: HTAB 25
10020  PRINT "THANK YOU, COME AGAIN"
10030  END
20000  LET D$ =  CHR$ (4)
20009  PRINT : CALL 1002
20010  PRINT D$;"SAVE THESIS,D2"
20020  PRINT D$;"SAVE THESIS,D1"
20030  GOTO 100
30000  REM  *****   DELETE ASSOCIATED FILES  *****
30001  PRINT : PRINT : HTAB HTX
```

```
30003  PRINT "YOU ARE ABOUT DESTROY ALL DATA"
30004  HTAB HTX: PRINT "ARE YOU SURE YOU WANT TO DO THIS"
30005  LET CV = 19:CH = HTX + 33: GOSUB 4400
30008  IF ANS = NO GOTO 600
30009  REM  ALL 1002: PRINT D$;"MON,I,C,O"
30010  CALL 1002: PRINT D$;"OPEN START.DATA"
30020  CALL 1002: PRINT D$;"READ START.DATA"
30030  INPUT SESNO
30040  INPUT CLSNO
30050  CALL 1002: PRINT D$;"CLOSE START.DATA"
30060  CALL 1002: PRINT D$;"DELETE START.DATA"
30100  FOR X = 1 TO SESNO
30110  CALL 1002: PRINT D$;"DELETE SESSION."; STR$ (X)
30120  NEXT X
30125  CALL 1002: PRINT D$;"NOMON ,I,C,O"
30130  GOTO 100
```

APPENDIX H

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSION

				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Clas	Infere	Predi	Meas	Comr	Data	OpDe	Ques	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 1: SESSION 1			UNIT:			Buoyant Forces											
Raw Score	6	17	0	7	5	36	8	11	12	18	7	26	4	37	14	15	223
% Freq: Sessi	3%	8%	0%	3%	2%	16%	4%	5%	5%	8%	3%	12%	2%	17%	6%	7%	100%
CLASS 1: SESSION 2			UNIT:			Buoyant Forces											
Raw Score	19	2	5	3	23	28	10	1	13	15	2	1	4	57	6	2	191
% Freq: Sessi	10%	1%	3%	2%	12%	15%	5%	1%	7%	8%	1%	1%	2%	30%	3%	1%	100%
CLASS 2: SESSION 1			UNIT:			Small Things											
Raw Score	51	29	0	0	3	78	17	1	8	13	0	0	65	88	10	12	375
% Freq: Sessi	14%	8%	0%	0%	1%	21%	5%	0%	2%	3%	0%	0%	17%	23%	3%	3%	100%
CLASS 2: SESSION 2			UNIT:			Small Things											
Raw Score	26	6	0	0	1	72	0	0	1	19	0	1	0	89	24	15	254
% Freq: Sessi	10%	2%	0%	0%	0%	28%	0%	0%	0%	7%	0%	0%	0%	35%	9%	6%	100%
CLASS 3: SESSION 1			UNIT:			Buoyant Forces											
Raw Score	36	12	5	0	3	62	34	0	14	35	9	13	0	52	12	13	300
% Freq: Sessi	12%	4%	2%	0%	1%	21%	11%	0%	5%	12%	3%	4%	0%	17%	4%	4%	100%
CLASS 3: SESSION 2			UNIT:			Buoyant Forces											
Raw Score	24	3	2	3	24	74	19	0	1	11	5	6	0	73	12	14	271
% Freq: Sessi	9%	1%	1%	1%	9%	27%	7%	0%	0%	4%	2%	2%	0%	27%	4%	5%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIO																	
				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Ques	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 4: SESSION 1			UNIT:			Buoyant Forces											
Raw Score	11	8	3	5	40	66	44	0	9	19	3	31	0	63	14	19	335
% Freq: Sessi	3%	2%	1%	1%	12%	20%	13%	0%	3%	6%	1%	9%	0%	19%	4%	6%	100%
CLASS 4: SESSION 2			UNIT:			Buoyant Forces											
Raw Score	2	0	0	14	17	77	31	0	1	1	0	11	0	64	9	3	230
% Freq: Sessi	1%	0%	0%	6%	7%	33%	13%	0%	0%	0%	0%	5%	0%	28%	4%	1%	100%
CLASS 5: SESSION 1			UNIT:			Small Things											
Raw Score	15	2	1	0	2	29	0	0	0	0	0	2	16	65	12	31	175
% Freq: Sessi	9%	1%	1%	0%	1%	17%	0%	0%	0%	0%	0%	1%	9%	37%	7%	18%	100%
CLASS 5: SESSION 2			UNIT:			Small Things											
Raw Score	28	7	0	0	0	60	0	0	1	8	0	0	14	66	26	47	257
% Freq: Sessi	11%	3%	0%	0%	0%	23%	0%	0%	0%	3%	0%	0%	5%	26%	10%	18%	100%
CLASS 6: SESSION 1			UNIT:			Small Things											
Raw Score	52	23	0	0	8	85	7	6	7	5	0	0	23	54	0	15	285
% Freq: Sessi	18%	8%	0%	0%	3%	30%	2%	2%	2%	2%	0%	0%	8%	19%	0%	5%	100%
CLASS 6: SESSION 2			UNIT:			Small Things											
Raw Score	21	11	6	0	4	36	10	0	5	4	0	4	9	21	3	3	137
% Freq: Sessi	15%	8%	4%	0%	3%	26%	7%	0%	4%	3%	0%	3%	7%	15%	2%	2%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIO																	
				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Teac	Discij	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 7: SESSION 1				UNIT:		Small Things											
Raw Score	10	6	5	12	4	10	3	4	12	5	0	6	5	48	2	4	136
% Freq: Sessi	7%	4%	4%	9%	3%	7%	2%	3%	9%	4%	0%	4%	4%	35%	1%	3%	100%
CLASS 7: SESSION 2				UNIT:		Small Things											
Raw Score	27	12	2	0	10	54	10	0	2	12	0	2	24	64	9	10	238
% Freq: Sessi	11%	5%	1%	0%	4%	23%	4%	0%	1%	5%	0%	1%	10%	27%	4%	4%	100%
CLASS 8: SESSION 1				UNIT:		Small Things											
Raw Score	68	33	5	0	12	77	4	0	8	2	0	2	39	49	5	10	314
% Freq: Sessi	22%	11%	2%	0%	4%	25%	1%	0%	3%	1%	0%	1%	12%	16%	2%	3%	100%
CLASS 8: SESSION 2				UNIT:		Small Things											
Raw Score	22	18	4	1	7	52	3	0	4	7	0	11	19	62	4	19	233
% Freq: Sessi	9%	8%	2%	0%	3%	22%	1%	0%	2%	3%	0%	5%	8%	27%	2%	8%	100%
CLASS 9: SESSION 1				UNIT:		Small Things											
Raw Score	12	8	3	0	3	27	4	0	9	9	0	0	20	56	8	23	182
% Freq: Sessi	7%	4%	2%	0%	2%	15%	2%	0%	5%	5%	0%	0%	11%	31%	4%	13%	100%
CLASS 9: SESSION 2				UNIT:		Small Things											
Raw Score	15	6	1	0	5	33	2	0	3	3	0	0	24	67	6	10	175
% Freq: Sessi	9%	3%	1%	0%	3%	19%	1%	0%	2%	2%	0%	0%	14%	38%	3%	6%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIO																	
				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 10: SESSION 1			UNIT:			Small Things											
Raw Score	28	6	4	0	10	66	7	1	4	22	8	2	16	58	13	55	300
% Freq: Sessi(	9%	2%	1%	0%	3%	22%	2%	0%	1%	7%	3%	1%	5%	19%	4%	18%	100%
CLASS 10: SESSION 2			UNIT:			Small Things											
Raw Score	18	2	0	1	1	48	4	0	5	9	0	0	19	48	17	37	209
% Freq: Sessi(	9%	1%	0%	0%	0%	23%	2%	0%	2%	4%	0%	0%	9%	23%	8%	18%	100%
CLASS 11: SESSION 1			UNIT:			Buoyant Forces											
Raw Score	7	0	6	1	46	45	28	0	13	24	1	21	0	79	7	15	293
% Freq: Sessi(	2%	0%	2%	0%	16%	15%	10%	0%	4%	8%	0%	7%	0%	27%	2%	5%	100%
CLASS 11: SESSION 2			UNIT:			Forces of Flying											
Raw Score	34	6	19	22	7	51	2	0	34	51	6	12	0	72	12	3	331
% Freq: Sessi(	10%	2%	6%	7%	2%	15%	1%	0%	10%	15%	2%	4%	0%	22%	4%	1%	100%
CLASS 12: SESSION 1			UNIT:			Forces of Flying											
Raw Score	6	0	14	16	12	35	2	0	10	31	0	14	0	78	7	6	231
% Freq: Sessi(	3%	0%	6%	7%	5%	15%	1%	0%	4%	13%	0%	6%	0%	34%	3%	3%	100%
CLASS 12: SESSION 2			UNIT:			Mystery Powders											
Raw Score	52	52	3	1	4	23	13	2	7	7	0	0	0	45	11	3	223
% Freq: Sessi(	23%	23%	1%	0%	2%	10%	6%	1%	3%	3%	0%	0%	0%	20%	5%	1%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIO

				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	DataC	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 13: SESSION 1			UNIT:		Buoyant Forces												
Raw Score	22	9	2	5	7	29	20	0	10	25	3	3	4	54	13	10	216
% Freq: Sessi	10%	4%	1%	2%	3%	13%	9%	0%	5%	12%	1%	1%	2%	25%	6%	5%	100%
CLASS 13: SESSION 2			UNIT:		Buoyant Forces												
Raw Score	24	11	5	4	37	26	42	1	13	31	6	6	0	48	10	35	299
% Freq: Sessi	8%	4%	2%	1%	12%	9%	14%	0%	4%	10%	2%	2%	0%	16%	3%	12%	100%
CLASS 14: SESSION 1			UNIT:		Small Things												
Raw Score	18	11	2	0	1	30	6	0	4	4	0	1	28	50	8	4	167
% Freq: Sessi	11%	7%	1%	0%	1%	18%	4%	0%	2%	2%	0%	1%	17%	30%	5%	2%	100%
CLASS 14: SESSION 2			UNIT:		Small Things												
Raw Score	10	1	0	0	7	20	3	0	3	5	0	0	11	41	4	1	106
% Freq: Sessi	9%	1%	0%	0%	7%	19%	3%	0%	3%	5%	0%	0%	10%	39%	4%	1%	100%
CLASS 15: SESSION 1			UNIT:		Artemia Salina												
Raw Score	29	21	1	0	5	35	2	0	3	6	0	5	16	48	5	6	182
% Freq: Sessi	16%	12%	1%	0%	3%	19%	1%	0%	2%	3%	0%	3%	9%	26%	3%	3%	100%
CLASS 15: SESSION 2			UNIT:		Buoyant Forces												
Raw Score	2	3	1	11	19	13	18	0	8	11	1	4	0	35	5	4	135
% Freq: Sessi	1%	2%	1%	8%	14%	10%	13%	0%	6%	8%	1%	3%	0%	26%	4%	3%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIOI

				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesi	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 16: SESSION 1			UNIT:			Buoyant Forces											
Raw Score	7	18	1	7	7	7	16	0	8	5	1	5	0	34	3	10	129
% Freq: Sessi(	5%	14%	1%	5%	5%	5%	12%	0%	6%	4%	1%	4%	0%	26%	2%	8%	100%
CLASS 16: SESSION 2			UNIT:			Buoyant Forces											
Raw Score	10	8	10	2	29	40	33	2	13	26	16	13	0	76	8	12	298
% Freq: Sessi(	3%	3%	3%	1%	10%	13%	11%	1%	4%	9%	5%	4%	0%	26%	3%	4%	100%
CLASS 17: SESSION 1			UNIT:			Forces of Flying											
Raw Score	19	1	18	9	7	17	1	0	23	39	5	2	0	47	3	1	192
% Freq: Sessi(	10%	1%	9%	5%	4%	9%	1%	0%	12%	20%	3%	1%	0%	24%	2%	1%	100%
CLASS 17: SESSION 2			UNIT:			Mystery Powders											
Raw Score	78	21	3	2	9	37	15	9	26	34	0	3	1	84	8	6	336
% Freq: Sessi(	23%	6%	1%	1%	3%	11%	4%	3%	8%	10%	0%	1%	0%	25%	2%	2%	100%
CLASS 18: SESSION 1			UNIT:			Buoyant Forces											
Raw Score	30	2	3	2	6	16	1	0	5	20	9	2	0	47	7	34	184
% Freq: Sessi(	16%	1%	2%	1%	3%	9%	1%	0%	3%	11%	5%	1%	0%	26%	4%	18%	100%
CLASS 18: SESSION 2			UNIT:			Buoyant Forces											
Raw Score	28	13	4	1	13	38	3	1	16	12	3	3	0	85	5	16	241
% Freq: Sessi(	12%	5%	2%	0%	5%	16%	1%	0%	7%	5%	1%	1%	0%	35%	2%	7%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIOI

				VERBALIZATION CATEGORIES												VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 19: SESSION 1			UNIT:		Buoyant Forces											
Raw Score	24	0	4	5	22	32	8	0	16	17	0	2	0	44	4	14	192
% Freq: Sessic	13%	0%	2%	3%	11%	17%	4%	0%	8%	9%	0%	1%	0%	23%	2%	7%	100%
CLASS 19: SESSION 2			UNIT:		Forces of Flying											
Raw Score	17	4	12	4	6	23	1	0	23	26	9	4	0	40	5	12	186
%Freq	9%	2%	6%	2%	3%	12%	1%	0%	12%	14%	5%	2%	0%	22%	3%	6%	100%
CLASS 20: SESSION 1			UNIT:		Buoyant Forces											
Raw Score	24	0	0	10	3	32	7	0	5	27	6	0	0	32	6	16	168
% Freq: Sessic	14%	0%	0%	6%	2%	19%	4%	0%	3%	16%	4%	0%	0%	19%	4%	10%	100%
CLASS 20: SESSION 2			UNIT:		Buoyant Forces											
Raw Score	27	18	5	7	11	20	8	0	6	14	2	3	0	34	3	1	159
% Freq: Sessic	17%	11%	3%	4%	7%	13%	5%	0%	4%	9%	1%	2%	0%	21%	2%	1%	100%
CLASS 21: SESSION 1			UNIT:		Buoyant Forces											
Raw Score	16	3	5	8	39	27	38	0	18	10	1	19	0	50	4	5	243
% Freq: Sessic	7%	1%	2%	3%	16%	11%	16%	0%	7%	4%	0%	8%	0%	21%	2%	2%	100%
CLASS 21: SESSION 2			UNIT:		Buoyant Forces											
Raw Score	25	0	3	6	34	29	45	0	16	14	2	8	0	82	7	5	276
% Freq: Sessic	9%	0%	1%	2%	12%	11%	16%	0%	6%	5%	1%	3%	0%	30%	3%	2%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIO																	
				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	DataC	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 22: SESSION 1			UNIT:		Buoyant Forces												
Raw Score	26	0	4	5	4	24	1	0	2	24	7	0	0	38	10	32	177
% Freq: Sessio	15%	0%	2%	3%	2%	14%	1%	0%	1%	14%	4%	0%	0%	21%	6%	18%	100%
CLASS 22: SESSION 2			UNIT:		Buoyant Forces												
Raw Score	14	9	4	2	12	13	5	0	8	11	0	0	0	42	4	11	135
% Freq: Sessio	10%	7%	3%	1%	9%	10%	4%	0%	6%	8%	0%	0%	0%	31%	3%	8%	100%
CLASS 23: SESSION 1			UNIT:		Buoyant Forces												
Raw Score	38	4	18	11	5	20	4	2	16	47	15	4	0	51	12	21	268
% Freq: Sessio	14%	1%	7%	4%	2%	7%	1%	1%	6%	18%	6%	1%	0%	19%	4%	8%	100%
CLASS 23: SESSION 2			UNIT:		Forces of Flying												
Raw Score	20	6	20	5	5	18	6	2	18	13	0	3	0	37	6	7	166
% Freq: Sessio	12%	4%	12%	3%	3%	11%	4%	1%	11%	8%	0%	2%	0%	22%	4%	4%	100%
CLASS 24: SESSION 1			UNIT:		Small Things												
Raw Score	6	0	0	0	2	12	7	0	7	6	0	1	4	31	4	6	86
Percent % Freq	7%	0%	0%	0%	2%	14%	8%	0%	8%	7%	0%	1%	5%	36%	5%	7%	100%
CLASS 24: SESSION 2			UNIT:		Small Things												
Raw Score	34	0	1	1	1	26	6	0	1	4	0	0	29	50	10	0	163
% Freq: Sessio	21%	0%	1%	1%	1%	16%	4%	0%	1%	2%	0%	0%	18%	31%	6%	0%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIO																	
				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 25: SESSION 1			UNIT:		Artemia Salina												
Raw Score	46	0	2	0	5	23	4	0	10	15	0	0	27	37	2	0	171
% Freq: Sessi	27%	0%	1%	0%	3%	13%	2%	0%	6%	9%	0%	0%	16%	22%	1%	0%	100%
CLASS 25: SESSION 2			UNIT:		Artemia Salina												
Raw Score	78	0	14	5	6	34	0	0	23	0	0	3	14	28	1	2	208
% Freq: Sessi	38%	0%	7%	2%	3%	16%	0%	0%	11%	0%	0%	1%	7%	13%	0%	1%	100%
CLASS 26: SESSION 1			UNIT:		Small Things												
Raw Score	30	4	1	0	11	46	19	0	12	24	0	8	0	41	3	4	203
% Freq: Sessi	15%	2%	0%	0%	5%	23%	9%	0%	6%	12%	0%	4%	0%	20%	1%	2%	100%
CLASS 26: SESSION 2			UNIT:		Small Things												
Raw Score	52	0	0	3	4	44	8	0	11	18	0	2	26	63	21	32	284
% Freq: Sessi	18%	0%	0%	1%	1%	15%	3%	0%	4%	6%	0%	1%	9%	22%	7%	11%	100%
CLASS 27: SESSION 1			UNIT:		Artemia Salina												
Raw Score	44	0	9	6	8	42	12	2	15	9	0	1	0	46	1	2	197
% Freq: Sessi	22%	0%	5%	3%	4%	21%	6%	1%	8%	5%	0%	1%	0%	23%	1%	1%	100%
CLASS 27: SESSION 2			UNIT:		Artemia Salina												
Raw Score	41	5	0	0	0	35	5	0	7	18	0	0	2	35	0	0	148
% Freq: Sessi	28%	3%	0%	0%	0%	24%	3%	0%	5%	12%	0%	0%	1%	24%	0%	0%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY CLASS, UNIT, & SESSIO																	
			VERBALIZATION CATEGORIES														VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
CLASS 28: SESSION 1			UNIT:			Buoyant Forces											
Raw Score	26	0	14	15	9	35	12	0	18	25	0	8	0	27	0	1	190
% Freq: Sessi	14%	0%	7%	8%	5%	18%	6%	0%	9%	13%	0%	4%	0%	14%	0%	1%	100%
CLASS 28: SESSION 2			UNIT:			Buoyant Forces											
Raw Score	5	0	1	0	44	27	27	2	8	6	4	30	0	43	3	1	201
% Freq: Sessi	2%	0%	0%	0%	22%	13%	13%	1%	4%	3%	2%	15%	0%	21%	1%	0%	100%
CLASS 29: SESSION 1			UNIT:			Small Things											
Raw Score	27	0	1	0	0	45	7	0	3	9	0	2	2	44	5	9	154
% Freq: Sessi	18%	0%	1%	0%	0%	29%	5%	0%	2%	6%	0%	1%	1%	29%	3%	6%	100%
CLASS 29: SESSION 2			UNIT:			Small Things											
Raw Score	57	0	1	0	0	42	3	0	5	1	0	0	37	34	0	0	180
% Freq: Sessi	32%	0%	1%	0%	0%	23%	2%	0%	3%	1%	0%	0%	21%	19%	0%	0%	100%
CLASS 30: SESSION 1			UNIT:			Forces of Flying											
Raw Score	12	0	6	2	3	34	0	0	8	14	5	4	0	40	1	0	129
% Freq: Sessi	9%	0%	5%	2%	2%	26%	0%	0%	6%	11%	4%	3%	0%	31%	1%	0%	100%
CLASS 30: SESSION 2			UNIT:			Mystery Powders											
Raw Score	37	3	2	4	2	54	13	6	2	12	0	0	0	52	2	5	194
% Freq: Sessi	19%	2%	1%	2%	1%	28%	7%	3%	1%	6%	0%	0%	0%	27%	1%	3%	100%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIOI																	
SUMMARY SHEETS 1/2																	
			VERBALIZATION CATEGORIES														VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	DataC	OpDe	Quesl	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
MEAN % FREQ																	
Page 1	10%	4%	1%	1%	4%	21%	5%	1%	3%	7%	2%	3%	4%	25%	5%	4%	1614
Page 2	10%	4%	1%	1%	4%	25%	6%	0%	2%	2%	0%	3%	5%	24%	5%	8%	1419
Page 3	11%	6%	2%	2%	3%	18%	2%	0%	3%	3%	0%	2%	10%	29%	3%	6%	1278
Page 4	9%	5%	3%	2%	5%	17%	4%	0%	4%	9%	1%	3%	2%	24%	4%	8%	1365
Page 5	9%	5%	1%	2%	7%	15%	7%	0%	4%	7%	1%	2%	6%	27%	4%	4%	1105
Page 6	12%	5%	3%	2%	5%	11%	5%	1%	7%	10%	2%	2%	0%	27%	2%	7%	1380
Page 7	11%	2%	2%	3%	9%	14%	8%	0%	7%	9%	2%	3%	0%	23%	2%	5%	1224
Page 8	13%	2%	4%	2%	3%	12%	4%	0%	5%	9%	2%	1%	4%	27%	5%	8%	1036
Page 9	25%	1%	2%	1%	3%	19%	4%	0%	7%	7%	0%	1%	6%	21%	2%	3%	1211
Page 10	16%	0%	2%	2%	5%	23%	5%	1%	4%	7%	1%	4%	4%	23%	1%	2%	1048
																	12680
GRAND X % FRE	13%	3%	2%	2%	5%	17%	5%	0%	5%	7%	1%	2%	4%	25%	3%	5%	100.00%

X %				VERBALIZATION CATEGORIES												
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesl	Expe	Mode	Resu	SciEq	Teac	Discij	Other
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A
Artemia Salina	26%	3%	3%	1%	3%	19%	3%	0%	6%	6%	0%	1%	7%	22%	1%	1%
Buoyant Force:	7%	3%	1%	2%	8%	16%	9%	0%	5%	8%	2%	4%	0%	24%	4%	6%
Buoyant Force:	11%	2%	3%	4%	9%	13%	7%	0%	5%	10%	2%	4%	0%	22%	3%	5%
Buoyant Forces	9%	3%	2%	3%	8%	14%	8%	0%	5%	9%	2%	4%	0%	23%	3%	6%
Forces of Flyin	9%	1%	7%	4%	3%	15%	1%	0%	9%	14%	2%	3%	0%	26%	3%	2%
Mystery Powd	22%	10%	1%	1%	2%	16%	6%	2%	4%	6%	0%	0%	0%	24%	3%	2%
Small Things	11%	5%	1%	1%	2%	21%	2%	0%	2%	3%	0%	1%	9%	27%	4%	9%
Small Things	17%	0%	0%	0%	2%	20%	5%	0%	4%	6%	0%	1%	9%	28%	4%	4%
Small Things	14%	3%	1%	0%	2%	21%	4%	0%	3%	4%	0%	1%	9%	27%	4%	6%
Sessions 1 (1-	10%	5%	1%	2%	4%	18%	4%	1%	3%	6%	1%	3%	6%	25%	4%	7%
Sessions 1 (16	14%	1%	3%	3%	5%	16%	5%	0%	6%	10%	2%	2%	1%	24%	2%	6%
Sessions 2 (1-	10%	4%	1%	2%	5%	20%	5%	0%	3%	5%	0%	2%	4%	27%	5%	6%
Sessions 2 (16	17%	3%	3%	1%	5%	15%	5%	1%	6%	7%	1%	2%	4%	25%	2%	3%
X % Freq Sess'	12%	3%	2%	2%	4%	17%	5%	0%	5%	8%	1%	3%	4%	24%	3%	6%
X % Freq Sess'	13%	4%	2%	2%	5%	18%	5%	0%	4%	6%	1%	2%	4%	26%	4%	5%
Grand X % Frec	13%	3%	2%	2%	5%	17%	5%	0%	5%	7%	1%	2%	4%	25%	3%	5%

APPENDIX H: VERBALIZATIONS: % FREQUENCY OF PROCESS SCIENCE SKILLS--RAW SCORES & PERCENTS BY UNIT, CLASS, & SESSIO																	
SUMMARY SHEET: STANDARD DEVIATIONS																	
				VERBALIZATION CATEGORIES													VERBALIZATIONS
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Ques	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
STANDARD DEVIATION: SESSIONS 1 AND 2																	
X % Sessions 1	12%	3%	2%	2%	4%	17%	5%	0%	5%	8%	1%	3%	4%	24%	3%	6%	
X % Sessions 2	13%	4%	2%	2%	5%	18%	5%	0%	4%	6%	1%	2%	4%	26%	4%	5%	
StDev: Skills	1.17	0.29	0.10	0.42	0.76	0.60	0.28	0.03	0.31	1.49	0.33	0.55	0.08	0.87	0.36	1.16	

RELIABILITY: Standard Deviation, by Skill Categories, from Identical Sessions Tallied One Week Apart (Tallied by Investigator)																	
					PROCESS SCIENCE OBJECTIVES												
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Quesi	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
Rating Session 1-1																	
Raw Score	12	0	6	3	3	34	0	0	8	14	5	4	0	40	1	0	130
% Session 1-1	9%	0%	5%	2%	2%	26%	0%	0%	6%	11%	4%	3%	0%	31%	1%	0%	100%
Rating Session 1-2																	
Raw Score	11	0	5	2	2	36	0	0	7	12	5	4	0	42	2	0	128
% Session 1-2	9%	0%	4%	2%	2%	28%	0%	0%	5%	9%	4%	3%	0%	33%	2%	0%	100%
St.Dev./Skill	0.45	0	0.50	0.52	0.52	1.39	0	0	0.48	0.98	0.04	0.03	0	1.44	0.56	0	
Rating Session 2-1																	
Raw Score	51	29	0	0	3	78	17	1	8	13	0	0	65	88	10	12	375
% Session 2-1	14%	8%	0%	0%	1%	21%	5%	0%	2%	3%	0%	0%	17%	23%	3%	3%	1
Rating Session 2-2																	
Raw Score	54	28	0	0	2	74	16	2	7	12	0	0	66	90	9	14	374
% Session 2-2	14%	7%	0%	0%	1%	20%	4%	1%	2%	3%	0%	0%	18%	24%	2%	4%	1
St.Dev./Skill	0.59	0.17	0	0	0.18	0.71	0.18	0.18	0.18	0.18	0	0	0.22	0.42	0.18	0.38	

COMPARISON: % OF EACH SKILL AS A PART OF THE TOTAL PROCESS SCIENCE (SKILL) OBJECTIVES																	
VS % FREQUENCY OF OCCURRENCE OF EACH SKILL																	
					PROCESS SCIENCE OBJECTIVES												
																	OBJECTIVES
(Cue)	Obse	Class	Infere	Predi	Meas	Comr	Data(	OpDe	Ques	Expe	Mode	Resu	SciEq	Guida	Regu	Other	
(Code)	O	C	I	P	M	T	D	N	H	E	F	V	U	G	R	A	
No. of Objectiv	30	17	23	13	21	17	35	6	11	55	22	18	31				299
% of Total Pr(	10%	6%	8%	4%	7%	6%	12%	2%	4%	18%	7%	6%	10%				1
Grand X % Fre(	13%	3%	2%	2%	5%	17%	5%	0%	5%	7%	1%	2%	4%				66.37%

PERCENT FREQUENCY OF OCCURRENCE	
PROCESS SCIENCE SKILLS VS (DIRECTION, DISCIPLINE, OTHER)	
Guidance: Direction	25%
Regulation: Discipline	3%
Apart: Other	5%
Process Science Skills	66%

APPENDIX I

APPENDIX I																
FREQUENCY DISTRIBUTIONS OF "OBSERVATION": BY UNIT AND BY CLASS																
BY UNIT																
	Number of Classes															
% Freq	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Artemia Salina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buoyant Forces	0	3	2	3	0	1	0	1	1	2	3	0	2	0	0	1
Forces of Flying	0	0	0	1	0	0	0	0	0	2	2	0	1	0	0	0
Mystery Powders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Things	0	0	0	0	0	0	0	3	0	6	1	3	0	0	1	2
	Number of Classes															
% Freq	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Artemia Salina	0	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0
Buoyant Forces	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Forces of Flying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mystery Powders	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0
Small Things	2	0	0	3	0	0	1	1	0	0	0	0	0	0	0	0
	Number of Classes															
% Freq	30	31	32	33	34	35	36	37	38	39	40					
Artemia Salina	0	0	0	0	0	0	0	0	1	0	0					
Buoyant Forces	0	0	0	0	0	0	0	0	0	0	0					
Forces of Flying	0	0	0	0	0	0	0	0	0	0	0					
Mystery Powders	0	0	0	0	0	0	0	0	0	0	0					
Small Things	0	0	1	0	0	0	0	0	0	0	0					
BY CLASS																
% Freq	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of Classes	0	2	2	4	0	1	0	4	1	10	6	3	3	2	4	3
% Freq	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Number of Classes	3	2	1	2	1	0	1	2	2	0	0	0	1	0	0	0
% Freq	30	31	32	33	34	35	36	37	38	39	40					
Number of Classes	0	0	1	0	0	0	0	0	1	0	0					

APPROVAL SHEET

The dissertation submitted by Shelley Ann Lipowich has been read and approved by the following committee:

Dr. Diane P. Schiller, Director
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Stanford University

The final copies have been examined by the director of the dissertation, and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the dissertation is now given final approval by the Committee with reference to content and form.

The dissertation is therefore accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Nov. 8, 1988 — Diane Schiller

Date — Director's Signature