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ABSTRACT

This research report describes strategies that can be used to enable students to appropriately use the scientific method to solve problems during labs and activities. The targeted population consists of middle school science students in a growing middle class suburban area. Evidence of their lack of understanding and application of the scientific method is documented by surveys of the teachers and students, a scientific method lab checklist completed by the teachers, and teacher observations. Analysis of probable cause data reveals that teachers and students report a lack of science-related experiences at home for many students, and that many students believe that science has little importance in everyday life. Solution strategies suggested by this research resulted in the selection of three areas of intervention: (1) an increase in hands on labs and activities; (2) an increase in the use of cooperative learning including utilization of reflection logs by the students to encourage metacognition of the scientific method; and (3) the addition of scientific method checklists for the student and teacher to complete on labs and activities. Post-intervention data indicated a significant improvement in the knowledge and completion of the scientific method. The researchers noted increased enthusiasm toward science, as well as test score improvements. (DDR)

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HELPING STUDENTS TAKE RESPONSIBILITY FOR COMPLETING THE SCIENTIFIC METHOD

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ABSTRACT

This report describes strategies used to enable students to appropriately use the scientific method to solve problems during labs and activities. The targeted population consisted of middle school science students in a growing middle class suburban area. Evidence of their lack of understanding and application of the scientific method was documented by surveys of teachers and students, a scientific method lab checklist filled out by the teacher, and teacher observations.

Analysis of probable cause data revealed that students and teachers reported a lack of science related experiences at home on the part of many students. The student survey reported that many students believe science has little importance in everyday life. Reviews of literature indicate that most science textbooks over-emphasize content, instead of finding a balance between science process and content. Also, teachers report pressure to finish the content of the required curriculum, sacrificing lab and activity time in the classroom.

Solution strategies suggested by a review of literature, combined with an analysis of the problem setting, resulted in the selection of three areas of intervention: an increase in hands-on labs and activities; an increase in the use of cooperative learning including utilization of reflection logs by the students to encourage metacognition of the scientific method; and the addition of scientific method checklists for the student and teacher to fill out on labs and activities.

Post intervention data indicated a significant improvement in the knowledge and completion of the scientific method. The researchers noted increased enthusiasm toward science, as well as test score improvements.

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CHAPTER 1

PROBLEM STATEMENT AND CONTEXT

General Statement of the Problem

The students of three classes of the targeted middle schools do not complete all the steps in the scientific method to solve problems. Evidence for the existence of the problem includes teacher observations and surveys, teacher-made surveys of targeted students, and student responses to lab questions.

Immediate Problem Context

Building C

Building C is a middle school, consisting of grades seven and eight, with a total student population of 815 (1996 School Report Card). Based on the 1996 School Report Card, the ethnic breakdown of Building C is as follows; White (79%), Black (5%), Hispanic (8%), Asian/Pacific Islander (8%). Seven percent of the student population was identified as low-income by the 1996 School Report Card. The attendance pattern indicates an attendance rate of 95%, a mobility rate of 9%, and a chronic truancy rate of 0% (1996 School Report Card).

Building C has 40 regular education teachers who teach in content area departments, 7 special education teachers, 4 itinerant therapists for special education, a social worker, a part-time counselor, a nurse, a librarian, a dean's assistant, a clerical aide, 3 custodians, 2 full-time secretaries, a part-time secretary, an assistant principal, and the principal. According to the 1996 School Report Card, the average teaching experience in the district is 16 years. Forty-four percent of teachers in the district have a bachelor's degree, fifty-five percent have a master's degree or above. The average district pupil-teacher ratio is 24:1.

Building C was built in 1978. It is a two story, U-shaped building divided into sections by departments. All classrooms (without doors) open into a common department hallway. Each department has a common teacher workroom. There are approximately 50 classrooms, a gymnasium, a cafetorium, a resource center, and 2 computer labs. The science department consists of four lab rooms and two lecture rooms.

The middle school program is made up of a heterogeneous mixture of seventh and eighth graders, with the exception of challenge math and challenge English. Some of the students are in interdisciplinary core groups, which consist of science, math, social studies, and English. Seventh graders also take speech, music, industrial arts, reading, and physical education. Eighth graders take six, twelve-week classes chosen from an elective list of fine and applied arts. The students who are not in cores, due to scheduling, enroll in the same courses as all other students. The school day begins at 9:00 A.M. and ends at 3:13 P.M. There are seven, 43 minute class periods in the day.

Beginning in the 1996-1997 school year, building C began housing a portion of the district's middle school bilingual program. There are about 80 bilingual students in self-contained classrooms that are mainstreamed into regular education classes when their communication skills are appropriate.

Seventh grade students study life science and eighth graders study physical and earth science. Although the content areas are designated by the district, teaching methods and areas of concentration vary from teacher to teacher. The science program is based on the text and lab series published by Prentice Hall. Teaching Integrated Math and Science (TIMS) is used by many teachers in the science department. Particles and Prairies, and Beauty and Charm are two other science programs for which the teachers have been in-serviced and use in the classrooms. Training for TIMS, Particles and Prairies, and Beauty and Charm took place at Fermi Lab National Accelerator Laboratory.

<u>Building E</u>

Building E was built in 1969 as a junior high school and closed due to low enrollment in 1986. In the fall of 1995, it reopened as a middle school with seventh grade only. The 1996-1997 school year had full enrollment with both seventh and eighth graders. The total student population is 396 (1996 School report Card). Based on the 1996 School Report Card, the ethnic breakdown of building E is as follows; White (87%), Black (3%), Hispanic (4%), Asian/Pacific Islander (6%). Seven percent of the student population was identified as low income by the 1996 School Report Card. The attendance pattern indicates an attendance rate of 96%, a mobility rate of 15%, and a chronic truancy rate of 0.3% (1996 School Report Card).

Building E has 53 regular education teachers who teach in content area departments, 3 special education teachers, 1.5 social workers, a nurse, a dean's assistant, a clerical aide, 3 custodians, 2 full time and 1 part time secretary, an assistant principal and a principal. According to the 1996 School Report Card the average teaching experience in the district is 16 years. Forty-four percent of the teachers in the district have a bachelor's degree, fifty-six percent have a master's degree or above. The average district pupil-teacher ratio is 24:1.

Building E is a two story, rectangular building divided by grade level on each side. The classrooms all have one door leading to the hall, with the exception of the science department. The six science classrooms are lab equipped and each has a second door that leads to a common science planning/storage room in the center. There are approximately 40 classrooms, a gymnasium, a cafeteria/commons with a stage, a library and a computer lab.

The middle school program in building E is a mixture of seventh and eighth graders (seventh grade only in 1995-1996). They are heterogeneously grouped in academic cores consisting of math, English, science and social studies. Challenge English and Algebra are the exceptions, as they are homogeneous ability groups. In addition to core classes, seventh graders take speech, music, industrial arts, reading and physical education. Eighth graders take physical education, and choose six, 12-week classes from an elective list of fine and applied arts in addition to their core classes. The school day begins at 9:00 A.M. and ends at 3:13 P.M. There are seven, 43 minute periods in the day, as well as a 15 minute all school sustained silent reading period.

Seventh grade students study life science and eighth graders study physical and earth science. Although the content areas are designated by the district, teaching methods and areas of concentration vary from teacher to teacher. The science program is based on the text and lab series published by Prentice Hall. Teaching Integrated Math and Science (TIMS) is used by many teachers in the science department. Particles and Prairies, and Beauty and Charm are two other science programs for which the teachers have been in-serviced and use in the classrooms. Training for TIMS, Particles and Prairies, and Beauty and Charm took place at Fermi Lab National Accelerator Laboratory.

The Surrounding Community

Buildings C and E are part of the second largest unit school district in the state with 31,000 students (1996 School Report Card). It is primarily suburban with some urban and rural areas. The district is currently building a new high school in community E. Building E will feed into this new high school, at least in part, pending the resolution of a boundary dispute. A boundary advisory panel has devised a boundary plan that divides community E students into three high schools. Community E wants all of its community to go to the new high school and is threatening to secede from the district if it does not.

The community that feeds into building C has a population of 32,000 and an average family income of $66,000. The average home value is $133,000 (Living in Greater Chicago, 1995). Of the students who attend building C, 7% are low income (1996 School Report Card). Some of the bilingual students in building C are bused in from other communities in the district.

The majority of building E students reside in a single community. However, due to the boundary lines in this large district, some students are transported from the edges of five nearby communities. The remainder of those surrounding communities are served by neighboring school districts. Community E has a population of 32,000 (1995 Special Census). It has an average family income of $70,000, and an average home value of $173,000 (Living in Greater Chicago, 1995). Of the students who attend building E, 7% are considered low income (1996 School Report Card).

National Context of the Problem

In recent years, Americans have become concerned about general scientific ignorance among young people. We have been unfavorably compared to other first and third world countries, most notably Japan, in science achievement. According to a study by the first International Assessment of Educational Progress, given to 24,000 students in 12 countries, the U.S. ranked last in science (as cited by Ahlgren, 1990).

Middle school students come to science class unwilling to follow through on the necessary steps of the scientific method. Students expect to be spoon-fed receivers of information rather than active thinkers of the information to be processed. There is no doubt that our world is rapidly advancing, both technologically and scientifically. Our scientific knowledge, at the least, doubles every 15 years (Stirling, 1992). Because of this, teachers are overwhelmed with the amount of information that must be covered in one school year. The students are losing the true process of science, which is the scientific method.

Students enter middle school expecting teachers to hand them a lab with "cookbook-like" instructions. They expect the teacher to pose literal questions, so they can quickly give simple answers and get the "A." They appear unwilling or unable to enter into the higher levels of scientific thinking. It is those higher levels of scientific thinking that are necessary for global competitiveness. As stated in A Nation at Risk (Baker et al.,1983), "The world is indeed one global village."

Mestre and Lockhead's study (as cited in Yager, 1994) found that nearly 85% to 90% of the most successful high school graduates (university physics majors and engineering students), cannot relate the concepts and processes they seem to know to real world situations. Since the inception of the science test in the Illinois Goal Assessment Program (IGAP), there has been no significant change in the number of students that do not meet science expectations in the state. If America is going to be a leading power in the global market,schools must produce adults that can use the scientific method in everyday real life situations.

CHAPTER 2

PROBLEM DOCUMENTATION

Problem Evidence

In order to document the extent of students' failure to follow through with the scientific method, student and teacher surveys were developed and administered in early September 1996 (Appendices A and B). A checklist was also developed by the researchers to grade student lab write-ups (Appendix C).

In the survey of 20 middle school science teachers, 90% reported that students often or sometimes skip the application or conclusion type questions in labs. These are the questions that reflect the essence of using the scientific method to its fullest extent, that is, to gain understanding and meaning of science. Sixty percent of the teachers also reported that students do not use the entire scientific method to solve problems in science.

When asked directly, 80% of the 66 students reported that they did not know how to write up a lab using the scientific method. The surveyed students consisted of 20 eighth grade physical science students and 44 seventh grade life science students. It should be noted that 60% of the surveyed students were incoming seventh graders and may not have been familiar with the term scientific method. Question number 10 (Appendix A) asked if the students use an orderly set of steps to solve problems in science, and 40% reported no.

One teacher out of 20 reported that students answer all the questions on labs, compared to 70% of the students reporting that they do complete all the questions on labs. On question 7 (Appendix B), 60% of the teachers indicated that the students do not use the scientific method in its completion to solve problems.

In early September 1996, the targeted students completed their first lab of the year. A checklist (Appendix C) was used by the researchers to assess the students' use of the entire scientific method in solving a problem. The results of the checklist are outlined in Table 1.

Table 1

Scientific Method Checklist on Lab 1 September 11, 1996

Steps in Scientific Method	Not Attempted	Not Yet	Developing	Mastered
Hypothesis	10	27	29	0
Experiment	0	64	2	0
Data Table	1	45	20	0
Analysis of Data	61	3	2	0
Conclusion	2	37	27	0
Critical Thinking	12	43	11	0

It was found that 83% of the 66 students who completed the lab had either not attempted, or were not yet exhibiting, critical thinking skills necessary to answer the conclusion/application questions. Ninety-six percent could not yet adequately write up a procedure for an experiment.

Probable Cause

Based on data collected from teacher and student surveys (Appendices A and B) and colleague contacts, as well as current literature on science learning and teaching, six probable causes have been indicated. They are lack of motivation, excessive curricular requirements, lack of student background experience, lack of knowledge of what is expected on the part of the student, lack of application of learned science skills, and lack of concrete lessons/labs.

Lack of motivation on the part of students is a reason students do not follow through with the scientific method. Through personal experiences and contacts with colleagues, the researchers have noted that students are apathetic and indifferent toward science. This is supported by 3% of the students surveyed reporting science as their favorite subject. "As early as elementary and middle grades, students begin losing interest in science. By high school, students of all achievement levels find science hard, dull, and meaningless" (Glynn & Muth, 1994, p. 1058). Student attitude can be attributed as a cause for many educational problems today, but in science it is the apathy that is disconcerting; the fact that they do not see the purpose of school science (Glynn & Muth, 1994).

This attitude is linked to another probable cause which is lack of background experiences. Ninety percent of teachers reported that they do not feel their students have adequate background experiences and content knowledge, and 95% report that students are lacking in basic measurement skills and equipment use. On question #15 of the student survey (Appendix A), 86% of the students reported one or less science related experiences outside of school. The students see science as something done in school, not anywhere in the real world.

Ninety-five percent of teachers reported that their students skip the application or conclusion type questions on labs. These are usually the hardest questions on labs, but they are the ones that show that the student has completed all steps in the scientific method by internalizing and transferring new knowledge to real life. However, students avoid this active thinking phase. They stop short of applying new knowledge to what they already know to make it make sense. Students are not forging the connections between school learning and everyday life (Badger, 1990).

Ninety percent of teachers surveyed reported that there is too much content to teach in the course of one school year. According to Linn, Clement, Pulos, & Sullivan, (1989, p. 172), "Science books present enormous amounts of information with very little attempt to help students integrate their understanding..." The amount of scientific knowledge available in today's society is astounding, and growing every minute. In light of this, Stirling (1992) notes that the suitability of even trying to cover everything in a given textbook is questionable. Lab activities and experiments require planning time and learning time. The easiest way for a teacher to "hurry up and finish the book" is to emphasize content and limit the number of time consuming lab exercises, which leads to another probable cause for the student's lack of completion of the scientific method.

Inhelder and Piaget's study (as cited in Linn, 1976) reported that learners progress from a concrete operational stage to a formal operational stage. Today, this is often characterized as the concrete to abstract developmental levels. The concrete level is defined by the actual use or completion of a hands-on learning activity. Abstract is the level after concrete in which the learner uses what he or she experienced to anticipate possible results or reactions without the actual use of equipment. Linn goes on to state that only 30% to 50% of adolescents ever reach Piaget's formal operations level. "Hands-on experiences are part of a multi-sensory approach to learning that maintains that people learn through their senses, each with his or her unique sensory style" (Collins, 1994, p. 5). It follows that school teaching should be concrete and experience based, but the fact is that much science teaching is lecture/textbook/content based. Forty-five percent of teachers surveyed reported a lack of transfer from concrete to abstract as a reason for why students do not complete all steps in the scientific method.

One last probable cause for students not following through on all steps of the scientific method is that the students do not know exactly what each teacher expects of them regarding the scientific method. For the middle school curriculum it means an orderly, logical set of steps used to solve a problem. The researchers have observed that some teachers have students memorize their version of the scientific method as an end in itself. Other teachers never mention the scientific method at all. Results of the survey indicate that some students do not realize that there is a single, broad scientific method that may be written up in a variety of ways, and that certain steps are emphasized more on some experiments than others. Eighty percent of the students reported they could not write up a lab using the scientific method, yet 60% indicate when working on a science problem, they use an orderly set of steps to solve it. Students learn best when they know the instructional objectives and receive feedback on how well those objectives are being achieved (Helgeson, 1987).

After an analysis of both site based data and relevant literature, six probable causes are prominent. These include lack of motivation, excessive curricular requirements, lack of student background experiences, lack of knowledge of what is expected on the part of the student, lack of application of learned science knowledge and skills, and lack of concrete lessons/labs.

CHAPTER 3

THE SOLUTION STRATEGY

Literature Review

As noted in chapter 1, the future of science teaching and learning is heading towards new challenges in this age of technology. Today's students, tomorrow's leaders, need to be able to manipulate vast amounts of information into usable solutions for both local and global problems. Science is not information to be learned once and stored in memory. Rather, it needs to be used. Students must become scientifically literate. They must become life-long learners. The scientific method that will facilitate this is not a fixed, static set of steps that scientists follow. It is a logical pattern of scientific thinking that should be second-nature when encountering a problem (Ahlgren, 1990).

The historical development of science teaching began before the Sputnik crisis of the late 1950's. James B. Conant, then president of Harvard University, formed the physical science study committee in 1952 to address science education. The National Science Teachers Association (NSTA) was studying instruction and curriculum development. The launching of Sputnik was a catalyst for increased intensity nationwide, regarding the improvement of teaching science. In the 1960s, traditional instruction gave way to an emphasis on the ability to solve problems

(Helgeson, 1987). However, after 20 years, the interest produced by Sputnik fizzled out. Americans had gone to the moon in 1969, yet by the 1980's, science education was plagued by problems reminiscent of the early 1950's (Brandwein & Glass, 1991). Some examples are: lecture as the main form of instruction, textbook as curriculum, science lessons that are removed from the outside world, limited supplies, and lack of elementary experiences and instruction. In 1985, Project 2061 was developed by the American Association for the Advancement of Science (AAAS) with a goal of scientific literacy for all. The National Science Education Standards were published in 1996 to help chart the course of science education in the future. They have been in development since Project 2061 began. The solution strategies for this project are based on these standards.

"Studies show that in classroom settings adolescents learn more from each other about subject matter than they do from the teacher" (Lundgren, 1994, p. 6). Learning in cooperative groups capitalizes on adolescents' desire to interact with their peers. Due to the collaborative nature of science, cooperative learning is an effective way to teach and learn it. Scientists the world over are required to communicate their findings to their peers. When students share the responsibility of conducting an investigation, they generate ideas and understandings that are relevant to them. They cogitate on newly learned concepts and they have the opportunity to clarify misconceptions with each other (Collins, 1994). Working in cooperative groups, students will develop strategies and skills that can transfer to problems they encounter as adults. Cooperative learning forces students to internalize content that is transferred to real world problems (Collins, 1994). Cooperative learning gives students the nudge that they need to complete the scientific method, and often sparks discussion on a new related problem. When working in groups, the whole is worth more than the sum of its parts.

After students complete a cooperative investigation, they need time for individual reflection. Writing about observations requires students to think about how they approached their problem, which defines the scientific method. Students construct bridges of meaning between background knowledge and newly acquired knowledge. Science becomes real instead of rote (Glynn & Muth, 1994).

Research shows that when students are given criteria for acceptable levels of performance, the quality of their work improves. Awareness of instructional objectives and receiving feedback on progress regarding those objectives is necessary for an effective science classroom (Helgeson, 1987). It is common sense that students who know what is expected of them will be more likely to meet those expectations than those who do not know what is expected of them. "Research confirms what teachers have known for a long time---students learn best what they are tested on" (Badger, et al, 1990, p. 1). If students know that they are expected to go beyond the simple facts and apply the scientific method to problem solving, they will do so.

In order for children to learn science, they have to do it. They must question, inquire, and discover, not just cover the text. According to the National Research Council's National Science Education Standards (1996), teachers should emphasize active, hands-on investigations in order to develop the skills that are involved in solving problems and as well as increase scientific knowledge. Actively engaging students in scientific activities piques their interest in and makes them feel like a part of the process; it gives them ownership of their learning. Content is not to be overlooked for it is necessary, but engaging in the process ensures better understanding of the knowledge (Zemelman, Daniels & Hyde, 1993). Increasing the number of hands-on activities in the classroom will foster a permanent understanding of the scientific method and the possibility of its transfer to other situations.

In summary, three solution strategies are to be implemented as part of this study:

1. Cooperative learning will be used extensively with self-reflection at the end of labs.

2. The number of hands-on activities and experiments in the classroom will be increased.

3. A lab checklist outlining the criteria for evaluation will be given to the students at the beginning of each lab. The students will self-assess their lab using the checklist, and the teacher will also evaluate it using the same checklist.

Project Objectives and Processes

As a result of emphasizing cooperative learning during labs, from the period of September 1996 to January 1997, the students of the targeted middle schools will increase their ability to use the scientific method as measured by a lab checklist, post-test and teacher journal of observations.

In order to accomplish the terminal objective, the following three processes are necessary:

1. Activities that foster cooperative learning will be developed, including a metacognitive journal.

2. The number of science labs and activities related to the scientific method will increase.

3. A scientific method checklist will be developed and used to evaluate science labs and activities.

Project Action Plan

The targeted seventh grade life science and eighth grade physical science students will be exposed to increased lab experiences focusing on cooperative learning to increase completion of all steps in the scientific method. Data will be collected from one class period each week from each of three middle school teachers from September 1996 to January 1997. Class periods are 43 minutes long.

Assessment will be conducted through the use of a pre- and post- science lab test, teacher journals of observations, and scientific method checklist. The checklist will be used on five predetermined labs out of approximately 15 labs from September 1996 to January 1997.

This plan is organized by three main areas of intervention: cooperative learning, increasing lab activity time, and use of a lab checklist. Research shows that adolescents learn more and construct concepts and skills better when working cooperatively, than when taught by direct instruction only. Students will be exposed to more lab experiences focusing on the scientific method, which increases their understanding and use of it. Students learn best when they know exactly what is expected of them; the checklist is a reference for the students to use as they complete labs.

1. Cooperative Learning. Once a week a 20-30 minute session during a lab or activity will be documented in each of the three classes.

    A. building group identity

        1. people search (Appendix D)

        2. business cards (Appendix E)

        3. picture frames (Appendix F)

        4. creating team names, based on common attributes

    B. social skills

        1. zero, six inch and twelve inch voices (Appendix G)

        2. blindman drawings (Appendix H)

        3. science safety rules (Appendix I)

    C. collaboration

        1. portmanteau, vocabulary drawing in partners

        2. hypothetical problem solving, write up a plan using the scientific method

        3. chapter information webbing, semantic maps done in groups

    D. self-reflection/metacognition

        1. students will keep a reflection log writing about labs after they are completed (Appendix J)

2. Increasing lab activity time. Between 10 and 15 labs will be completed from September 1996 to January 1997. Five of the lab activities will be recorded and documented by each teacher for research purposes. Two of the five were the same lab for all three teachers.

A. Lab One - Gum, Two, Three

This is a lab in which the students will design an experiment to determine the best bubble gum out of several brands. All three classes will do this lab. (Appendix K)

B. Lab Two - Number of Drops on a Penny, (7th and 8th grade) and Number vs. Length (7th grade)

Number of Drops on a Penny is a lab in which the students will try to determine exactly how many drops of water can fit on a penny, nickel and dime. (Appendix L). In Number vs. Length the students study the relationship between the number and length of hex nuts lined up (Appendix M).

C. Lab Three - Pop/Diet Pop (8th grade), Testing a Hypothesis (7th grade)

The 20 eighth grade students are presented with a discrepant event in which regular pop sinks in water and diet pop floats and they experiment to try to find out why (Appendix N). In the seventh grade lab, the 46 students will form a hypothesis about bean seeds, test it, and draw a conclusion based on their observations (Appendix O).

D. Lab Four - Insulated Cup Lab (8th grade), Bouncing Ball Lab (7th grade)

In the insulated cup lab, the 20 eighth graders devise an experiment that tests the performance of different types of cups in keeping hot drinks hot (Appendix P). The 46 seventh graders will test how different drop heights of a rubber ball compare to the bounce heights. (Appendix Q).

E. Lab Five - Gum, Two, Three (8th grade), Paper Towel Absorbency (7th grade)

Lab One will be repeated for the final lab (Appendix K). This time the students will bring in their own gum. In paper towel absorbency, the students set up an experiment to decide which paper towel is the best (Appendix R).

3. Use of a lab checklist. From September 1996, to January 1997, the students will complete checklists for their labs. (Appendix C)

A. students

1. used as a reference guide to check for completion of the scientific method when doing lab reports and activity write-ups

2. used as a tool to evaluate mistakes to be corrected for future labs

B. teacher

1. used as a measurement tool in assessment of lab reports and activity write-ups

2. used as a long term evaluation of progress in completing all steps in the scientific method during the research period

Methods of Assessment

The effects of the intervention will be assessed using a variety of data collection methods. A science pre-test will be administered in September 1996, and again in February of 1997, to show improvement in science process skills (Appendix S). A scientific method checklist will be used to track student progress on completion of labs. After completing labs in cooperative groups, the students will fill out journal entries in which they reflect on what they did, how they did it, and what progress they made. The teachers will also reflect on student performance, behavior, and achievement during the planned lessons.

CHAPTER 4

PROJECT RESULTS

Historical Description of Intervention

The terminal objective for this project addressed the student's lack of ability to carry out the scientific method. Increased use of cooperative learning with self-reflection, increased number of hands-on activities, and the utilization of a lab checklist were the strategies used to foster development towards attainment of this objective.

Cooperative learning was used to deliver content matter as well as increase the use of the scientific method. When working with their peers, students tend to learn more from each other by talking and interacting about the process and content, as opposed to teacher-directed instruction or individual completion of assignments. Once a week, for the first ten weeks, an activity was conducted in each of the targeted classrooms to develop cooperative learning skills. Lesson plan samples can be found in Appendices D - J.

Each week the targeted classes participated in hands-on labs and activities. Five of these experiences were documented for research purposes by using a lab checklist. A sample checklist can be found in Appendix C. The lab checklist was used by students to guide them in the completion of the scientific method when doing a lab.

It also helped the students evaluate the mistakes they made to improve performance on future labs. The teacher used the rubric portion of the checklist to assess the students lab reports. A master checklist was used by the teacher to assess long term progress in completing all steps of the scientific method during the research period. A sample master checklist is in Appendix C.

A teacher survey (Appendix B) completed by middle school science teachers in the district in which the targeted schools are located was administered in September, 1996, to reveal the existence of the problem. The main focus of this survey was the scientific method. A student attitude survey (Appendix A) was administered in September, 1996, to reveal problem evidence and probable causes.

A pretest was administered to each of the students in the targeted seventh and eighth grade classes in September, 1996, to determine the current level of functioning. A copy of the pre/post test is in Appendix S. The same test was given in February, 1997, to document any changes in the students' understanding of the scientific method.

Presentation and Analysis of Results

In order to assess the effects of the planned intervention, scientific method pre-tests (Appendix S) were administered in September, 1996, and the same test was given in February, 1997, as a post-test. The student scores were tabulated and analyzed in Figure 1.

PRE AND POST TEST STUDENT SCORES

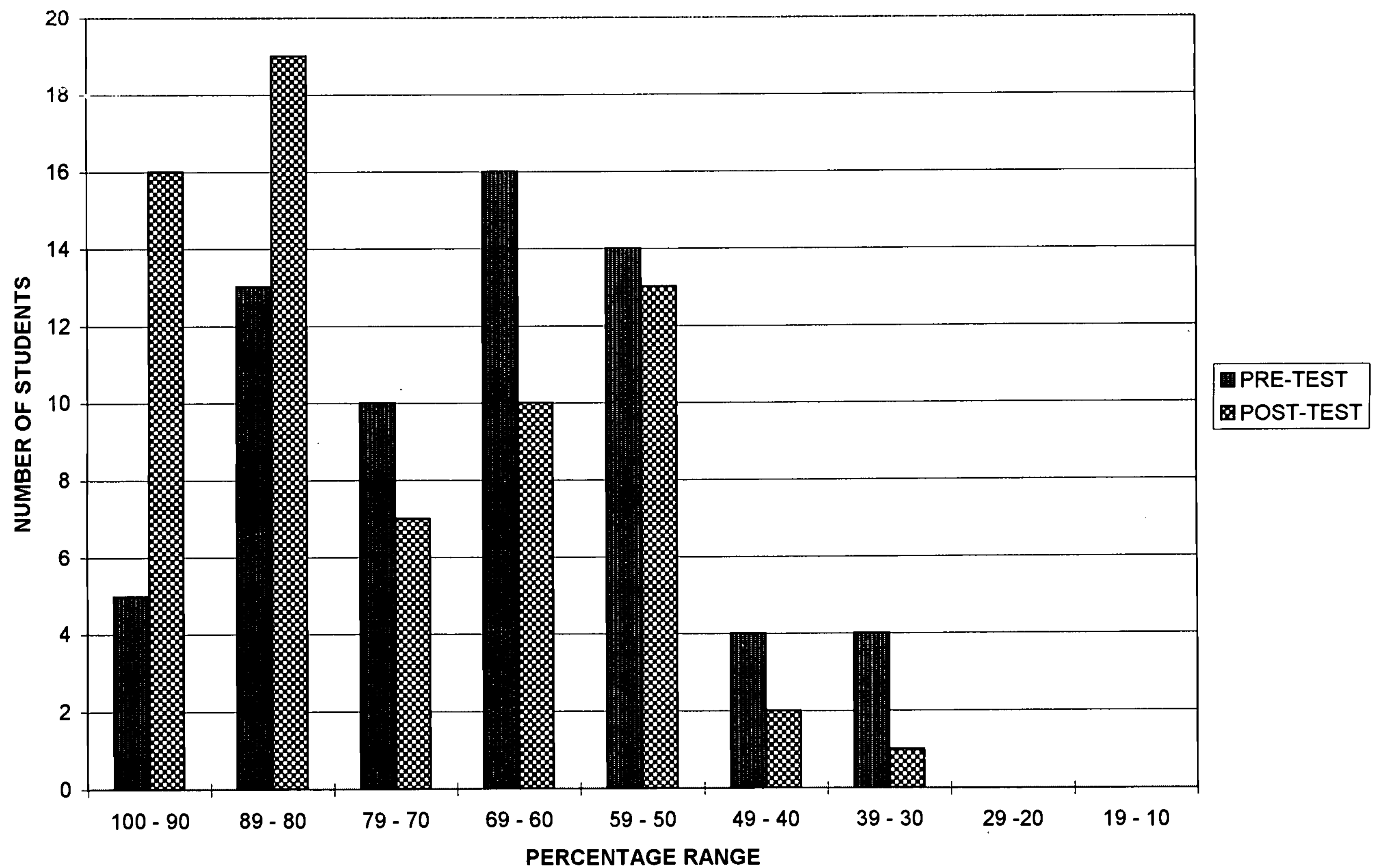


Figure 1

The intervention appears to have had a positive effect on the students' understanding of the scientific method. There has been a definite shift towards higher percentage scores from the pre-test to the post-test. Of particular note is the number of students that moved from below 80% on the pre-test to above 80% on the post-test. Of the 66 students that took the pre-test, only 18, or 27% of them scored 80% or above. Of the 68 students who took the post-test, 35 or 51% of them scored 80% or above. Five of 66 students, or 8%, were at or above 90% on the pre-test, while 16 of 68 students, or 24%, were at or above 90% on the post-test.

There were significant changes in six of the pre-post test questions answered correctly by the students. Table 2 below shows the results of questions 6, 7, 11, 12 , 14, and 25.

Table 2

<u>Scientific Method Pre/Post Test Question Analysis</u>

Question Number	Pre-test Answered Correctly	Post-test Answered Correctly	Difference
6	23	44	21
7	44	58	14
11	43	57	14
12	36	48	12
14	34	47	13
25	32	54	22

Questions six and seven relate to the students' understanding of controlled variables. This is an important aspect of using the scientific method for problem solving. Question 11 asks students what is the main goal of science. Question 12 asks students to logically sequence four parts of an experiment. Question 14 asks students to identify the purpose of science. Question 25 requests that the students choose the best plan to test a given hypothesis.

Not only did these questions show the most significant improvement, but they also show the greatest growth of understanding in the use of the scientific method. They range from the general, main goal of science; to the specific, identifying variables. The students showed improvement on all post-test questions. When comparing the correct answers on the pre/post tests, the six questions in Table 2 were those that showed the most significant increase.

Table 3

Scientific Method Checklist on Lab 1 September 11, 1996

Steps in Scientific Method	Not Attempted	Not Yet	Developing	Mastered
Hypothesis	10	27	29	0
Experiment	0	64	2	0
Data Table	1	45	20	0
Analysis of Data	61	3	2	0
Conclusion	2	37	27	0
Critical Thinking	12	43	11	0

Table 4

Scientific Method Checklist on Lab 5 February 24, 1997

Steps in Scientific Method	Not Attempted	Not Yet	Developing	Mastered
Hypothesis	0	6	21	36
Experiment	0	5	33	25
Data Table	0	4	23	36
Analysis of Data	1	7	32	23
Conclusion	2	10	37	14
Critical Thinking	1	10	26	26

Table 3 shows that in September, 1996, 56% of the targeted students could not or did not attempt to begin a lab investigation with a hypothesis. Table 4 shows that in February, 1997, only 9% still could not or did not attempt to begin a lab investigation with a hypothesis.

Ninety-six percent of the targeted students in September, 1996, had not attempted or could not adequately write up a procedure for an experiment. By February, 1997, only 8% still had either not attempted or inadequately wrote up a procedure for an experiment.

In September, 1996, the data table was not correctly constructed or was not attempted by 70% of the targeted students. In February, 1997, only 6% of the students could not or did not attempt to construct a data table when doing a lab.

Ninety-seven percent of the targeted students did not attempt or were not yet able to analyze data in September, 1996. By February, 1997, only 13% did not attempt or were not yet able to analyze data.

A conclusion was not reached or not attempted by 59% of the targeted students in September, 1996, when doing lab investigations. In February, 1997, only 19% were not or could not reach a conclusion when doing a lab investigation.

In September, 1996, 83% of the targeted students did not attempt or were not yet exhibiting critical thinking skills on the first lab conducted. In February, 1997, only 17% of the targeted students did not attempt or were not yet exhibiting critical thinking skills.

Figure 2 is a summary of the percentage of the number of scores in each of the four areas graded on the lab checklist. As the labs progress, there is a shift towards the mastery end of the rubric.

Figure 3 shows a decrease in the percentage of zero scores received on labs one through five. A zero score on a lab represents skills or parts of the scientific method not attempted. It also demonstrates a progression of increased scores of three. A three on a lab indicates that the skill has been mastered or that part of the scientific method has been completed adequately. These percentages were calculated from totals of all scores of all criteria from all five labs.

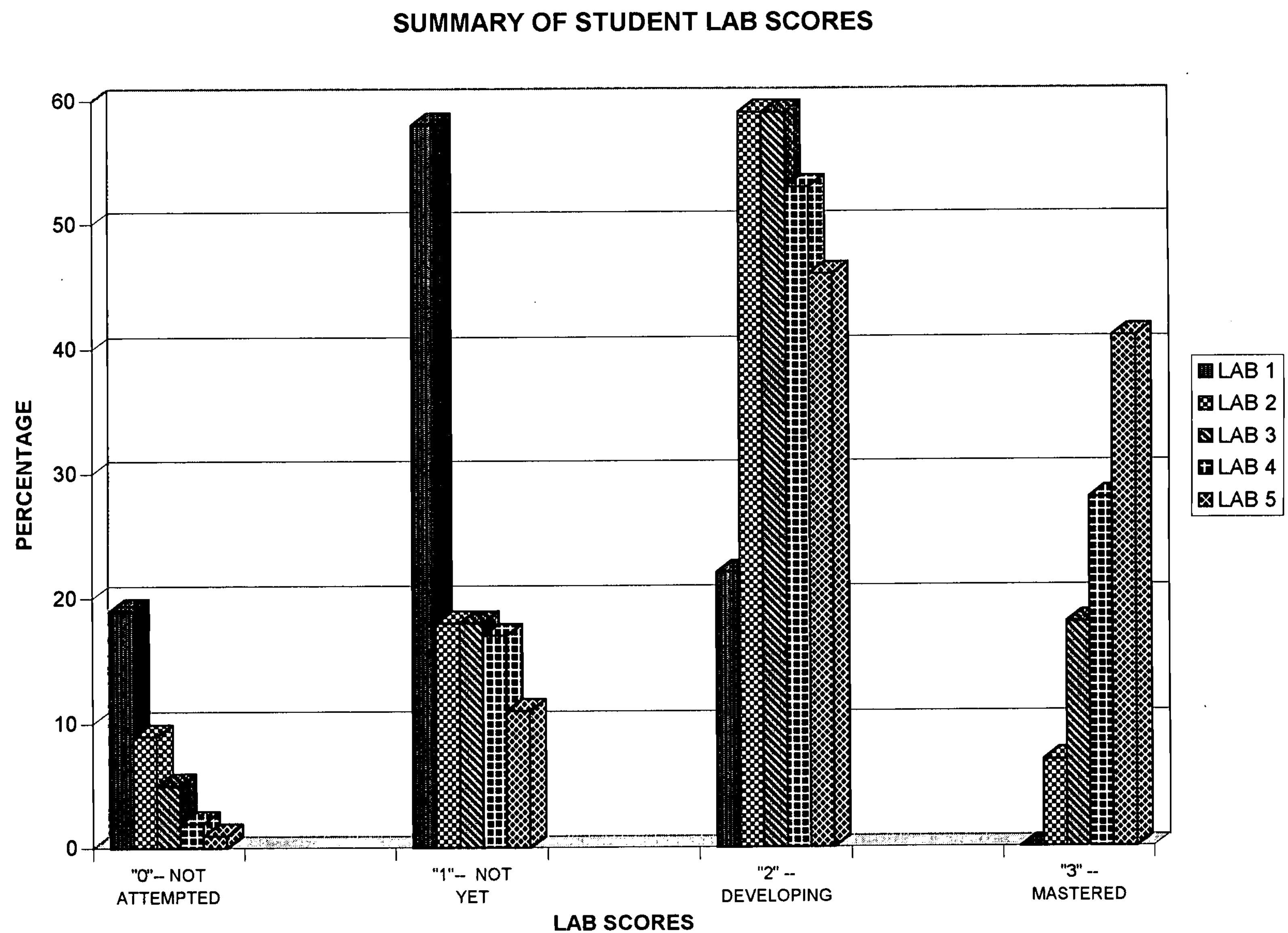
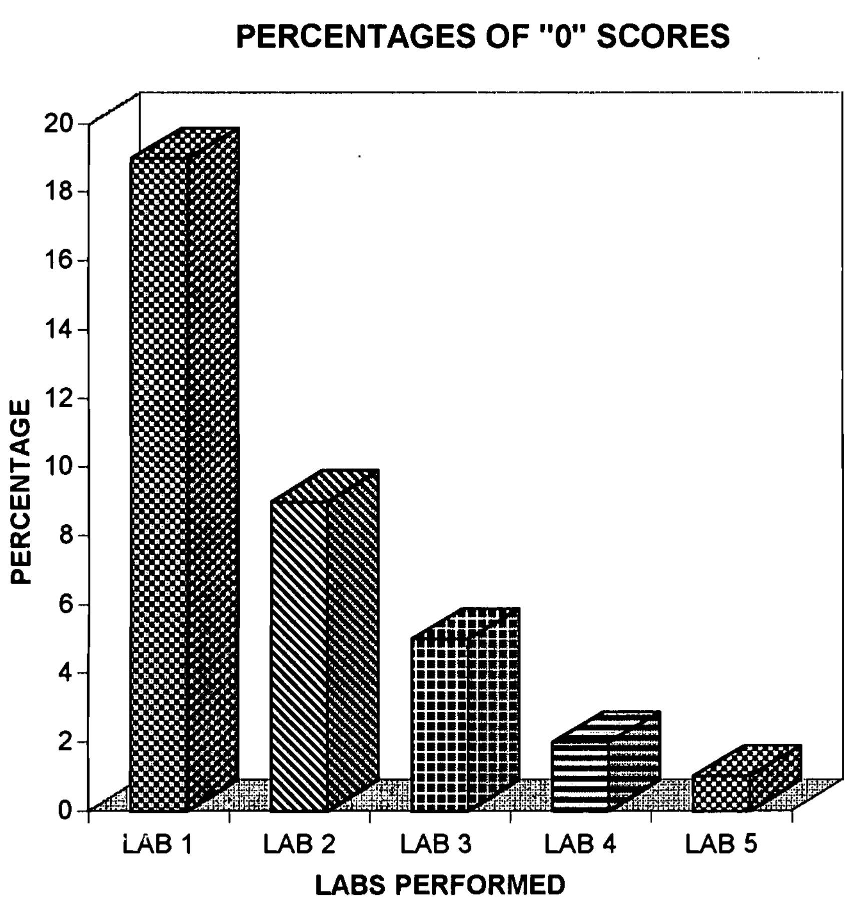

SUMMARY OF STUDENT LAB SCORES
PERCENTAGE
60
50
40
30
20
10
0
"0"-- NOT ATTEMPTED
"1"-- NOT YET
"2" -- DEVELOPING
"3" -- MASTERED
LAB SCORES
LAB 1
LAB 2
LAB 3
LAB 4
LAB 5

Figure 2


PERCENTAGES OF "0" SCORES
PERCENTAGE
20
18
16
14
12
10
8
6
4
2
0
LAB 1
LAB 2
LAB 3
LAB 4
LAB 5
LABS PERFORMED

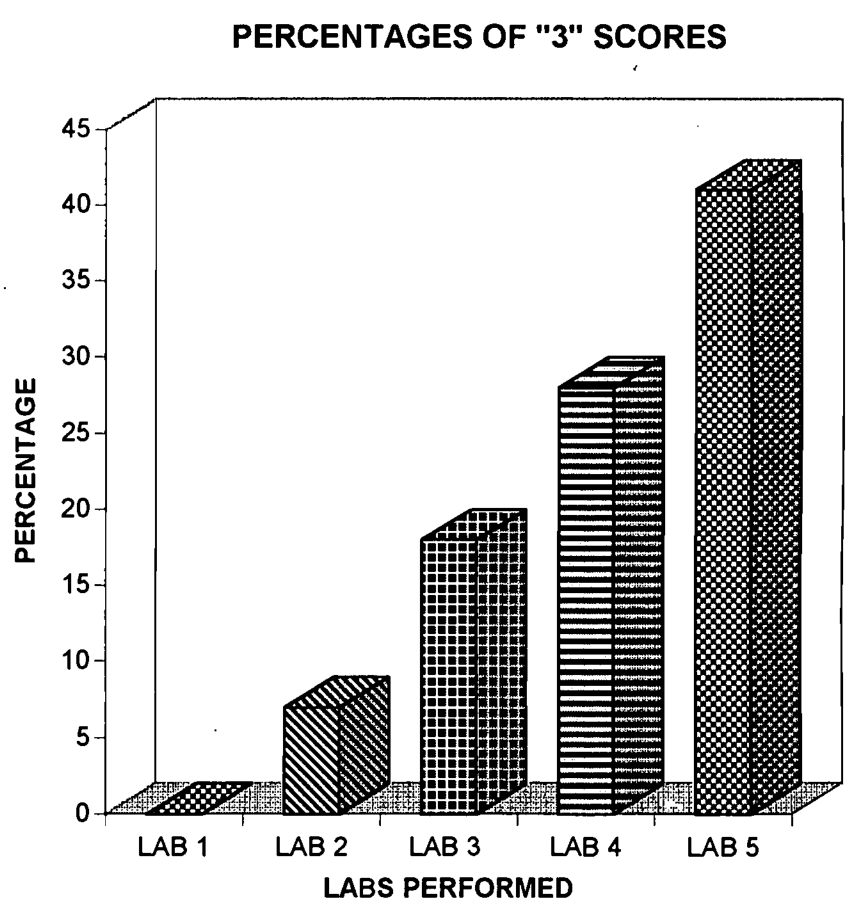

PERCENTAGES OF "3" SCORES
PERCENTAGE
45
40
35
30
25
20
15
10
5
0
LAB 1
LAB 2
LAB 3
LAB 4
LAB 5
LABS PERFORMED

Figure 3

A final reflective journal was given to the targeted students at the end of the implementation period (Appendix T). Question one asked the students about their feelings regarding working in groups compared to working alone. The vast majority of responses indicated that they preferred to work with others. If one person was confused or needed help, the other one could usually help out. Question three asked what the students have learned about the scientific method this year. Many indicated that the scientific method can and is used on a daily basis to solve problems in real life, not just in school for a grade.

Question five asked the students if journaling after an investigation in science helped them to learn. Many responded that being forced to think about how they thought through a lab and write it down helped to solidify scientific understandings. Some also reported that journaling helped review the whole process of the investigation from start to finish.

Conclusions and Recommendations

The data suggests that the intervention program designed to aid students in the completion and understanding of the scientific method be continued. The data showed significant improvement in the knowledge of and ability to complete the scientific method.

The use of cooperative learning appeared to enhance the content understanding in both the seventh and eighth grade classrooms. The eighth grade researcher noted that the students benefited right at the beginning of the year from cooperative learning in that they were on task and were often found helping each other without direction from the teacher. However, the researchers supervising seventh grade classrooms found off task behavior was prevalent, especially at the beginning of the year. All three researchers agreed that eighth graders have had a year of the middle school experience behind them, so they are already a step ahead of the seventh graders in September. The seventh graders had a hard time knowing when to stop socializing and when to start working compared to the eighth graders. The students' reflections indicate that an overwhelming number of students feel that working in groups is beneficial because they can always ask each other to explain things when and if confusion sets in. It should be noted that the students did not choose their own groups. When students wrote that groups were preferred, it was because of the support of peer knowledge, not just because they wanted to socialize with their friends.

Students indicated on reflections that the increased opportunities to practice using the scientific method through labs helped them learn it. This is also evidenced by the data collected in the intervention assessments by the researchers. Having students write reflections on labs often helps them to remember not only the content learned, but the process used to learn that knowledge. However, some students seem to stagnate on reflection writing. Understandings are expressed for the basic content at hand, but there is hesitation to go beyond literal knowledge. They express what they think the teacher would accept, not that with which they really struggled. The students seemed so used to just getting the right answer that they do not know what to write in a reflection.

The data indicated a trend towards understanding the scientific method on the lab checklists. It was a tool for student guidance in completing all steps in the scientific method when doing a lab. The checklist was used effectively. Both grade levels showed growth in completing their labs, but it should be noted that the seventh graders started out the year with a more elementary understanding of the scientific method than the eighth graders. More eighth graders are able to think in an abstract manner. Many seventh graders are still very concrete in their thinking and have a difficult time carrying out the scientific method to its fullest. The master checklist was an effective way for the researchers to evaluate the progress of the students from September, 1996, to February, 1997. It showed areas of strengths and weaknesses on which to focus.

Although our implementation was successful, the researchers feel that students would benefit from some modifications in the plan. The master checklist was helpful, but tedious for the teacher to complete. The students could fill out their own master checklist and keep it in a folder or portfolio to assess their own progress. The students would develop an ownership in their accomplishments. To do this, more specific criteria should be listed for the students to know the expectations for attaining mastery.

To make student journals more worthwhile, the researchers recommend practicing how to journal with oral brainstorming, whole group reflecting and pair-share reflecting for the purpose of preventing low level, teacher-pleasing responses. Most journal entries were appropriate; however, inadequate reflections were a problem with some students in both grade levels, but more so in seventh grade. Modifying the reflection part of the implementation by adding practice sessions at the beginning of the intervention would benefit all students.

Because the seventh graders are unaccustomed to doing full laboratory investigations, it is suggested that some time be spent teaching each step in the scientific method through examples and activities before completing labs to be assessed for research or assessment purposes. It is too overwhelming for a seventh grader to complete an entire lab with minimal instruction, while an eighth grader is less likely to have difficulty. The seventh graders were at a disadvantage near the end of the intervention due to three weeks of standardized testing.

A recommendation to the cooperative learning aspect of our intervention is to suggest flexibility in how much cooperative grouping is best. At the middle school age, socialization is such a high priority that it can interfere with the process of learning. The researchers noted that there are times when an activity would be better completed individually with a certain class than within cooperative groups. Teacher discretion in all activities and labs should be based on the group dynamics of that particular class.

The results of this intervention should be shared with faculty members in the buildings represented, all district middle school science teachers, and the math/science coordinator for the district. It should also be offered as an inservice to the upper elementary teachers in the district to expose them to the middle school science program. With the modifications listed above, the researchers plan to continue the intervention. This intervention has confirmed for us that an effective way to teach the scientific method may include a curriculum rich in scientific investigations, cooperative learning with student reflection, and the use of a checklist to guide the students through the process.

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Appendices

Appendix A

Science Attitude Survey

Please read the following questions carefully and answer honestly. Don't put your name on this paper. Complete both sides.

1. What is your favorite subject in school?
   a. language arts b. social studies c. math d. science
   e. foreign language f. gym g. music h. other

2. What is your least favorite subject in school?
   a. language arts b. social studies c. math d. science
   e. foreign languages f. gym g. music h. other

3. Who does more science experiments/activities in your science class?
   a. the teacher b. the students

4. How good are you in science?
   a. very good b. somewhat good c. average d. poor

5. The most important thing in science is:
   a. reading the science book
   b. doing science experiments
   c. listening to the teacher explain science

6. Would you like to learn a lot about science this year?
   a. yes b. no

7. How important do you think science is in everyday life?
   a. important b. somewhat important c. not important

8. How often do you recognize science happening in everyday life?
   a. never b. rarely c. sometimes d. often

9. Do you know how to write up a lab using the scientific method?
   a. yes b. no

10. When working on a science experiment or problem, do you use an orderly set of steps to solve it?
  a. yes b. no

11. When working on a science experiment or lab do you finish all the questions in the lab write-up?
  a. yes b. no

12. Do you feel confident that you could safely and correctly use basic scientific measurment devices (balance, graduated cylinder, thermometer, etc...)?
  a. yes b. no

13. I learn science best by...

14. The most difficult part of learning science is...

15. Tell about any science related activities you experience outside of school.

Appendix B

Middle School Science Survey-Teachers

We are completing a research project on improving students learning the scientific method through the St. Xavier University Field-Based Masters Program.

The purpose of this brief, anonymous, voluntary survey is to determine how middle school science teachers in our district perceive the teaching and learning of the scientific method. Please answer these questions and return the form in the addressed envelope through school mail by this Friday, August 30, 1996.

Thank-you,

Ann Cournaya
Peggy Hernandez
Frankie Valenzia

1. Do you feel there is too much content to teach in the course of one school year?
   a. yes b. no

2. By circling the letter below, indicate the approximate ratio of process vs. content teaching that actually takes place in your class.

process content
A----------------------B----------------------C-----------------------D-------------------E
100% 50% 100%

3. By circling the letter below, indicate the approximate ratio of process vs. content teaching that you think should take place in your classroom.

process content
A----------------------B-----------------------C----------------------D--------------------E
100% 50% 100%

4. Do you feel that your students have adequate background experiences and content knowledge?
   a. yes b. no

5. Do you feel your students enter middle school with adequate science process skills?
   a. yes b. no

6. Do your students ever skip the application or conclusion type questions on labs?
   a. never b. rarely c. sometimes d. often e. always

7. Do your students use the scientific method in it's completion to solve problems in science?
   a. yes   b. no

8. Who usually does science experiments in your class?
   a. teacher   b. students   c. combination of teacher/student   d. neither

9. Do you think our text series is well balanced between content matter and processes of the scientific method?
   a. yes   b. no

10. Does a lack of materials/equipment reduce the amount of labs/hands-on activities you do?
   a. yes   b. no

11. Are your students lacking in basic measurement skills and equipment use?
   a. yes   b. no

12. How many days of an average school week are your students engaged in science labs and activities?
   a. never   b. once or less   c. two to three   d. more than three

13. How many days of the average school week do you use cooperative learning groups?
   a. never   b. once or less   c. two to three   d. more than three

14. When students do not complete lab questions or skip parts of a lab write-up, what do you think is the problem?
   a. too difficult for the student
   b. not understanding what to do
   c. lack of transfer from concrete to abstract
   d. other____

15. The most difficult part of teaching science is...

16. My students learn science best by...

Appendix C

Name ______________________ Period __________ Date__________

LAB: ____

Scientific Method Checklist

Student: Use the space provided to check for a completed lab.					
Teacher: **0** Not Attempted **1** Not Yet **2** Developing **3** Mastered					
	Student	**Teacher**			
		0	**1**	**2**	**3**
Problem					
Background Information					
Hypothesis					
Experiment (Variables)					
Materials Used Properly					
Data Table					
Analysis of Data					
Conclusion					
Critical Thinking Questions					

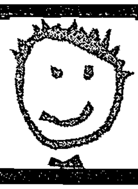
Student______________________

Scientific Method Checklist Master

0 Not Attempted **1** Not Yet **2** Developing **3** Mastered

	LAB 1				**LAB 2**				**LAB 3**				**LAB 4**				**LAB 5**			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
Problem																				
Background Information																				
Hypothesis																				
Experiment (Variables)																				
Materials Used Properly																				
Data Table																				
Analysis of Data																				
Conclusion																				
Critical Thinking Questions																				

Appendix D



People Search

Find someone who:

1. Plays a musical instrument ____________________
2. Was born on a holiday ____________________
3. Was born in another state ____________________
4. Has more than three pets ____________________
5. Cries at movies or TV shows ____________________
6. Had a weird dream lately ____________________
7. Refuses to walk under a ladder ____________________
8. Plays on a sports team ____________________
9. Speaks a foreign language ____________________
10. Is in two more of your classes
11. Has a large family ____________________
12. Was born in the same month as you ____________________
13. Has a stupid or funny pet story ____________________
14. Went to camp this summer ____________________
15. Has done a science project ____________________
16. Has used an outhouse ____________________
17. Likes roller coasters ____________________
18. Refuses to ride a roller coaster ____________________
19. Is a good artist ____________________
20. Got lost going to a class today ____________________

Appendix E

Cooperative Learning Activity -- Group Bonding

Business Cards

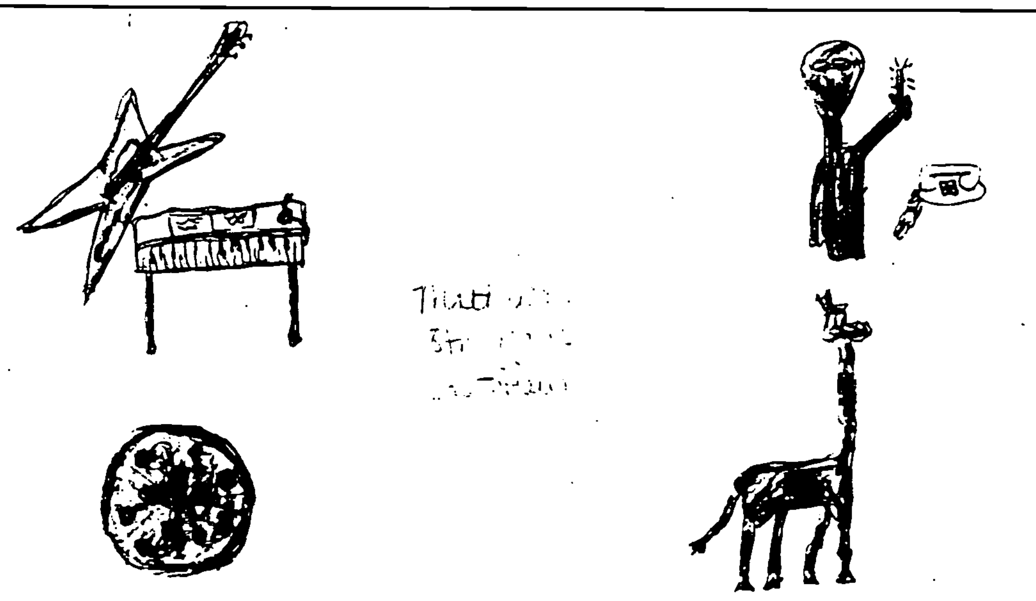
Business Cards are used as a group bonding activity. Each student is given an index card and markers, colored pencils, or crayons may be used. Explain to students that the business cards will be used to help introduce themselves to other students.

Give the students the following instructions as they begin their cards:

1. Write down your first and last names in the middle of the card.
2. In the upper left hand corner, draw a symbol that represents your favorite subject.
3. In the upper right hand corner, draw a symbol that represents your favorite book.
4. In the lower left hand corner, draw a symbol that represents your favorite TV show or movie.
5. In the lower right hand corner, write a word that describes you.

After all cards are complete, put students in pairs to share them. Tell students to try to guess what the symbols represent, see how many symbols they have in common, and tell why they have chosen the things they have drawn.

SAMPLE

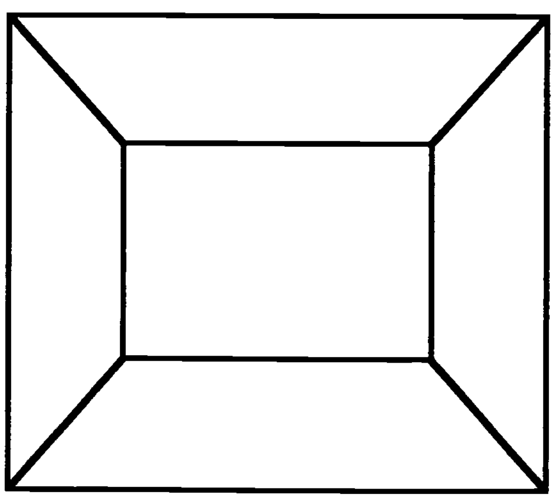


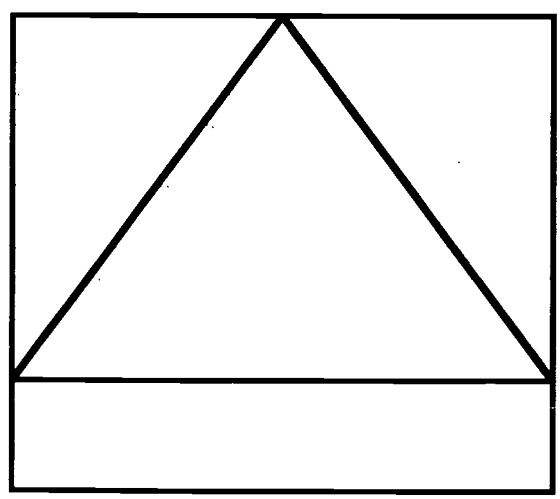
Appendix F

Cooperative Learning Activity -- Group Bonding

☆ Picture Frames ☆

1. Each group of 3 or 4 students needs a large piece of newsprint and 4 markers.
2. In one section of the "Frame" a student writes his name and personal characteristics or interests.
3. After the allotted time, the group identifies any common characteristics or interests and writes these in the center.
4. After 5 - 10 common areas are recorded, groups make up a name for their group.
5. Each group shares their frame with the rest of the class.





Appendix G

Cooperative Learning Activity -- Social Skills

☆ Different Level Voices ☆

The Hook: Tell students that in order to do group work as well as individual work, they need to be familiar with the different levels of voices that are appropriate for the classroom.

Teach: Discuss social skills with the students and inform them of the skills that we will be concentrating on in science class. Tell them that today we will be working on appropriate level of voice. Have students work in their base groups to create T-charts for 0", 6", and 12" voices. T-charts are then shared with the whole class.

0" Voice		6" Voice		12" Voice	
Looks Like	Sounds Like	Looks Like	Sounds Like	Looks Like	Sounds Like

Practice:

1. Have students get into groups according to eye color using 12" voices.
2. Have students get in order according to the last two numbers of their phone number using 6" voices.
3. Have students get in order according to their birth date using 0" voices.
4. Have students get in order from shortest to tallest using 0" voices.
5. Discuss what level of voice would be appropriate to use for labs, activities, and individual work.

Observe: Observe the methods that the students choose for getting into order. Time the students to see how quickly they could get into order or into the groups. Observe the students to see that they are using the indicated voices.

Reward: Give the students five minutes of free talk time if they were able to use the appropriate level of voices.

Appendix H

NAME________________________________PERIOD_____________DATE______

Blindman's Drawing

PURPOSE: To illustrate the importance of good verbal directions.

OBJECTIVES: You will:

1. Recognize the importance of good verbal directions.
2. Improve your ability to give and receive verbal directions.

MATERIALS: Design Cards
Paper
pen or pencil

PROCEDURE:

1. You will work back to back with a partner.
2. One member of the pair obtains a Design Card. Note the number on the card. The student not given the card is to look ONLY at the drawing paper.
3. The student with the Design Card will verbally describe the design while the other student draws his/her interpretation.
4. When completed, compare card and drawing.
5. Reverse roles with another card.

DISCUSSION
QUESTIONS:

1. Were you effective in describing the design? Why or why not?
____
____
____

2. Did being the first or second describer make a difference on your effectiveness? Explain.______________________________________
____
____
____

3. Were you effective in drawing the design? Why or why not?
____
____
____
____

4. How could you have done a better job of being either describer or artist?____
____
____
____

5. In what ways is it necessary for a scientist to be a good "describer?" A good receiver of directions?___________________
____
____
____
____

Appendix I

COOPERATIVE LEARNING LESSON PLAN

Grade, Subject 7th and 8th Grade Science

LESSON OBJECTIVE

The students will become aware of the science safety rules.

HOOK

I told students that next week we would be working with the Bunsen burners. Before they were allowed to use them, we had to cover science safety and they had to pass the science safety quiz.

ROLES

1. READER - Reads safety rules to the group
2. LEADER - Keeps group on task and makes sure everyone is working
3. MATERIALS PERSON - obtains needed materials and puts them away
4. INSTRUCTOR - Instructs class on safety rules and explains poster

MATERIALS FOR STUDENTS:

- sheet of drawing paper
- markers or colored pencils
- safety rules on pg. 599-600 in book

FOR TEACHER:

NONE

ROOM CONFIGURATION, TYPE OF GROUP, NUMBER IN EACH GROUP

ROOM CONFIGURATION - two tables pushed together

TYPE OF GROUP - random

NUMBER IN EACH GROUP - Three or four

TASK DIRECTIONS

1. Each group was assigned a set of safety rules to discuss and illustrate on a poster.
2. The reader read the safety rules to the group.
3. The group was then to design a poster to illustrate each of the rules.
4. After each group finished their poster, the instructor taught the safety rules to the whole class and explained the poster.
5. The following day there was a quiz on science safety.

BUILDING IN HIGHER ORDER THINKING

TRANSFER OF KNOWLEDGE IN A LAB SITUATION

UNIFY THE TEAMS

The groups created a single product - the science safety poster.

INSURE INDIVIDUAL ACCOUNTABILITY

- Roles were assigned.
- A quiz followed the activity.

LOOK OVER AND DISCUSS

MRS. POTTER'S QUESTIONS

DEVELOP SOCIAL SKILLS

The students worked on using six inch voices.

APPLICATIONS

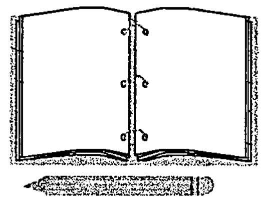
The science safety rules are important for the students to be aware of in every lab we do throughout the year.

BEST COPY AVAILABLE

Appendix J
Reflection Logs

Name____________________________________Period______Date__________

Science Journal



1. What were you supposed to do?

2. What did you do well?

3. What was your least favorite part?

4. What key things did you learn?

5. If you did this task over, what would you do differently?

Appendix J cont.

Cooperative Learning Activity -- Metacognition

☆ Mrs. Potter's Questions ☆

1. What were you expected to do?

2. In this assignment, what did you do well?

3. If you had to do this task over, what would you do differently?

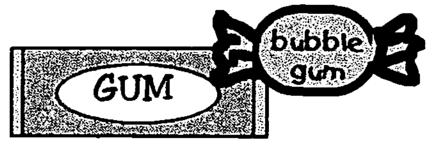
4. What help do you need from me?

Appendix K

Name________________________________Period________Date______

Team members: ____

GUM, 2, 3...



memo

To: Science Students
From: Cafeteria Manager
Re.: Researching gum

As of next week we will be adding gum to the snack line in the school cafeteria. We will be limited to the addition of one brand and flavor of gum. In order to satisfy the students of -------- Middle School, we are asking for your help. As a student research team, it will be your task to choose the **best** gum.

Problem: ____

____

____

General Information: ____________________________________

____

____

____

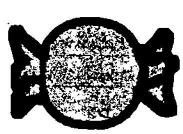
____

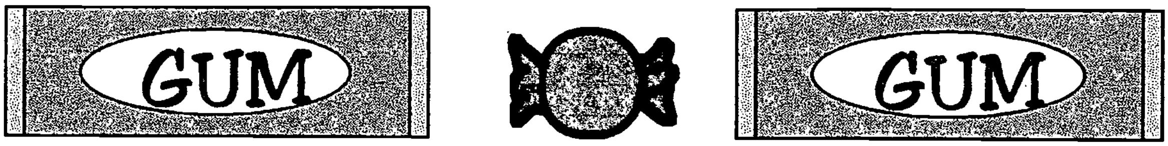
____

Hypothesis:

Procedure:

Data:





Data Analysis:

Conclusion: ____

____
____
____
____
____
____
____
____

Critical Thinking Questions

1. How might this activity be useful in a real life situation?

2. What kind of job or profession might be related to this type of investigation?

3. What factors influenced the results of your experiment?

4. What factors did you control in your experiment?

Appendix L

Name____Period______Date______

Number of Drops on a Penny

Background Information:

An important skill in science is predicting--the forecasting of future events. To understand predicting, it is important to remember that science is based on several assumptions or beliefs about the natural world. Scientists believe that there are cause-and-effect relationships in the natural world that control the world in a somewhat orderly manner. For example, predators (mountain lions) can cause a decrease in a prey (rabbits) population. This is a cause-and-effect relationship. Each time an apple releases from its branch, it will fall toward the center of the earth, regardless of the type of apple or its location on earth, because of orderly forces at work. The belief in cause-and-effect and orderly forces leads to the assumption that events in the natural world can be predicted.

However, some events are more accurately predicted than others. Predictions are based on past observations or available data. The amount of data available and the accuracy of the data can have a profound effect on the accuracy of the prediction. Eclipses and planet location, for example, can be predicted to the minute of occurrence. Predictions of weather or population changes, however, cannot be made as accurately. The assumption that the world behaves in an orderly manner helps scientists use available and accurate data to forecast future events.

In this activity you will be placing drops of water on various coins with a medicine dropper. First you will predict how many drops each coin can hold. Then you will count the number of drops each coin holds before the water runs off.

Problem:

To what extent does the size of coins affect the number of drops of water the coin will hold?

Manipulated Variable____

Responding Variable____

Controlled Variables____

____

Hypothesis:

____
____
____
____

Materials:

1 penny, 1 nickel, 1 dime, 1 quarter
water
medicine dropper
paper towels

Procedure:

1. Predict how many drops of water the penny will hold. Record your prediction on the table below.
2. Drop water on the penny. Record how many drops the penny held.
3. Dry the penny and repeat step 2 two more times. Record your findings below.
4. Average your three trials for a more accurate idea of how many drops of water a penny will hold.
5. Do the investigation again using the different coins. Record your results below.

Data:

Number of Drops of Water Held on Different Types of Coins

Type of Coin	Prediction	Trial #1	Trial #2	Trial #3	Average
Penny					
Nickel					
Dime					
Quarter					

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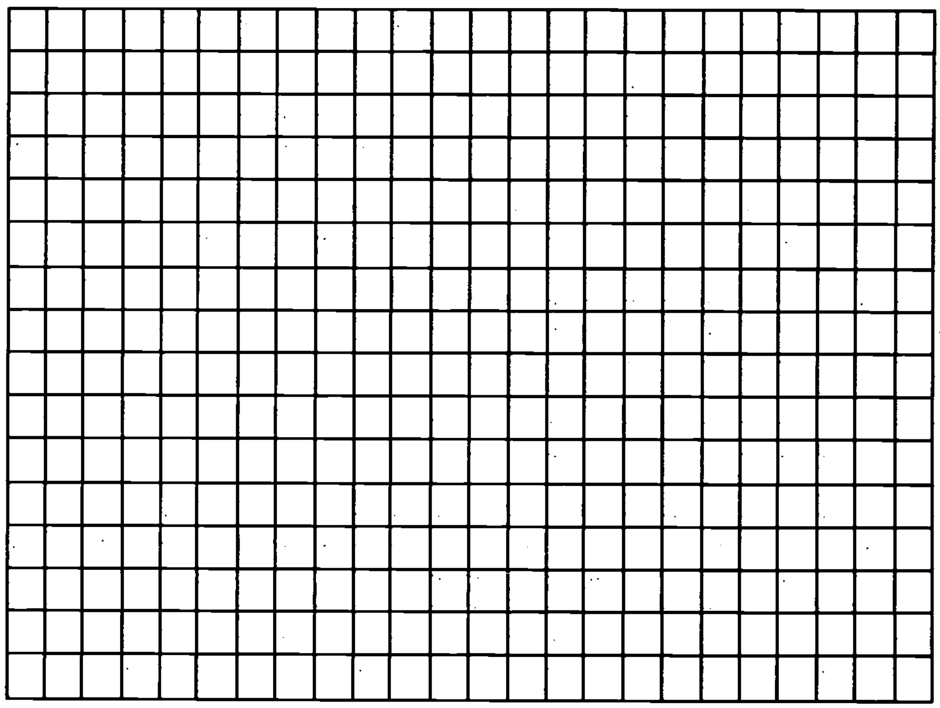
Data Analysis:

Construct a bar graph of the data you collected so that you will be better able to interpret it.

Number of Drops of Water Held on Different Types of Coins

Number of Drops Held



Type of Coin

Conclusion:

Critical Thinking:

1. Did your ability to predict become more accurate as you performed the investigation with coins than the penny? Explain.

___
___
___

2. Meteorology is a profession based almost entirely on prediction. Can you give an example of another profession that is similarly based on prediction?

___
___
___

3. Can you give an example of a prediction that is easily made based on past observation and available data?

___
___
___

4. What would be an example of a prediction which would be difficult to make based on past observation and available data?

___
___
___

Science Journal:

1. What were you supposed to do?

___
___
___

2. What did you do well?

___
___
___

3. What was your least favorite part?

___
___
___

4. What new science skills have you learned since the last lab?

___
___
___

5. If you did this task over, what would you do differently?

___
___
___

Appendix M

Name______________________________Period__________Date__________

Group Members____

Number vs. Length

Problem:

Is there a relationship between the number of hex nuts and the length of them?

Hypothesis:

____

____

Experiment:

Manipulated Variable: ________________________________
Responding Variable: ________________________________
Controlled Variables: ________________________________

____

Materials:

Procedure:

Data Table:

Graph: (use graph paper provided)

Conclusion:

Comprehension Questions:

1. If you had zero objects to measure, how would you show that in your data table?____

2. What does this data point mean? ______________________________

3. Are the variables that you measured quantitative or qualitative?

4. What type of graph will give us the best picture of this data?________________

5. Make a prediction about what you think the length of 15 hex nuts would be? (Explain)

6. How do you think you could use your line on the graph to find the length of 15 objects?

7. Check your method by measuring the length of the 15 objects. What did you get? ______

This method is called INTERPOLATION, making predictions between the data points.

8. Use your graph to predict the length of 27 hex nuts. What did you get? ____________

This is called EXTRAPOLATION, making predictions beyond the data that you have collected.

9. Check your prediction by measuring the length of 27 hex nuts. What did you get? ______

Appendix N
Pop Lab

Regular Pop vs. Diet Pop

1. In a large, clear bucket have on display a regular pop and a diet pop in water. The diet floats, while the regular sinks. Discuss the discrepancy and determine the problem.

2. In groups of two, the children will come up with a hypothesis on why one sinks and one floats. Each group will get a regular pop and a diet pop to test their hypothesis.

3. Each group must write up their data and analyze it to come to a conclusion. Graduate cylinders, beakers and balances will be available.

4. A conclusion is written up and possible new problems are explored.

Appendix O

Name______________________________ Period_______ Date___________

Testing a Hypothesis

Background Information:

To seek answers to problems, scientists use a systematic, orderly procedure called a scientific method. Scientists ask a question, form a hypothesis, devise an experiment, record observations, and arrive at conclusions in this process. The information that they receive from each experiment is applied to other similar types of experiments.

In this investigation, you will form a hypothesis, test it, and draw a conclusion based on your observations.

Problem:

Is water needed for seeds to grow?

Manipulated Variable____

Responding Variable____

Controlled Variables____

____

Hypothesis:

____

____

____

Materials:

4 pinto bean seeds
4 lima bean seeds
Beaker
Blotter paper (paper towels)
Medicine dropper
2 plastic sandwich bags
Scissors
Water

Procedure:

1. Fill the beaker one-fourth full of water.
2. Place two lima bean seeds and two pinto bean seeds in the beaker of water for five minutes.
3. While the seeds are soaking, cut the blotter paper into two 15 cm x 7 cm pieces with scissors. **CAUTION:** *Be careful when using scissors.*
4. Place one piece of blotter paper in each bag.
5. Write "A" on one bag with the initials of one member of your group. Write "B" on the other bag along with the same initials.
6. With the medicine dropper, add enough water to moisten the blotter paper in bag A. Do not add water to the blotter paper in bag B.
7. Place the two bean seeds and the two pinto bean seeds that were soaking in the water on the moist blotter paper in bag A. Space the beans an equal distance from each other.
8. Fold the open end of the plastic bag over the beans and staple the open end to the sealed end. See Figure 1.
9. Place the remaining bean seeds on the dry blotter paper in bag B. Space the beans on equal distance from one another and then follow the directions in step 9.
10. Place both plastic bags in a place where they will remain undisturbed.
11. Observe the bags each day for the next five days. Record your observation in the data table.

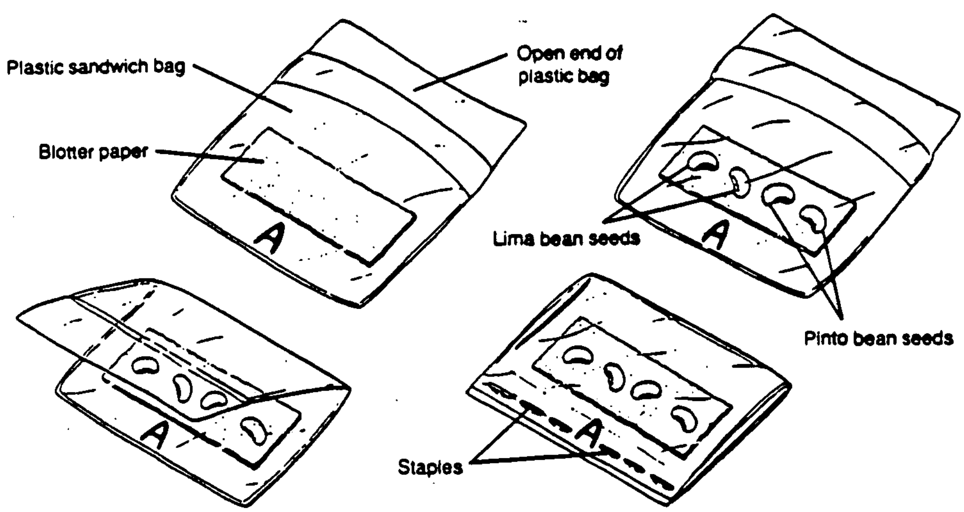


Figure 1

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Data:

Observations of Bean Seeds

Day	Date	Seeds in Bag A	Seeds in Bag B
1			
2			
3			
4			
5			

Conclusions:

How do the seeds in bag A and bag B compare? How does your hypothesis compare with your results after doing the experiment? What have you concluded after doing this experiment?

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Critical Thinking:

1. Why is it necessary to have a control setup when doing an experiment?
2. Why is it necessary to observe the seeds over a five-day period?
3. Why were the plastic bags sealed?
4. How do farmers who live in dry areas get water to their seed crops?
5. Suppose after five days you added water to the blotter paper in bag B. What would happen?

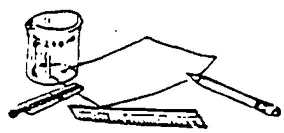
Science Journal:

1. What were you supposed to do?
2. What did you do well?
3. What was your least favorite part?
4. What new science skills have you learned since the last lab?
5. If you did this task over, what would you do differently?

Appendix P

BEYOND Paper Pencil

Insulation



Introduction

Although laboratory activities may form part of the most eighth graders' science instruction, there is little chance for experimentation. The purpose of most laboratory work is to confirm results or to provide experiences for concepts introduced previously. Seldom do students have a chance to plan and carry out a real experiment that has no clear "right" answer.

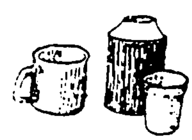
Insulation gave them this chance. It set forth an interesting question in a practical context. No special materials or laboratory equipment were involved. There was nothing to signal that this was a science test. Yet, both scientific concepts and procedures were evaluated as students investigated the relative heat loss of different hot drink containers.

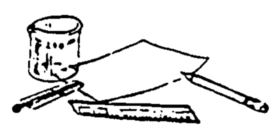
Description

Students were asked to evaluate the insulating capacity of three hot drink cups and to come to a decision based on their findings. They were provided with the materials necessary to carry out and record such an investigation. The role of the administrators was limited to observing students' procedures although, at the conclusion of the experiment, they discussed the students' decisions with them.

Materials:

- an insulated plastic cup
- a plastic mug
- a styrofoam cup
- 3 thermometers
- rulers
- 1 large container filled with hot water
- a stopwatch
- plain paper
- 250 ml beakers
- a graduated cylinder





Massachusetts Educational Assessment Program

Massachusetts Department of Education January 1990

In the spring of 1989 over 2000 pairs of fourth and eighth grade students were assessed on their ability to apply mathematical and scientific concepts. This series of reports describes and discusses the results of these assessments. Prepared by Elizabeth Badger, Brenda Thomas, and Elizabeth McCormack.

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Appendix Q

Name____________________Period________Date________

Group Members______________________________

The Bouncing Ball Lab

Problem:

Does the height from which you drop a ball affect how high it will bounce?

Hypothesis:

____

____

Experiment:

Labeled Drawing of the Experiment:

(Call the drop height D and the bounce height B. Label D and B in your drawing.)

Manipulated Variable: ______________________________

Responding Variable: ______________________________

Controlled Variables: ______________________________

____

Materials:

Procedure:

Experiment 1: Tennis Ball

Data Table

Graph:
Plot the data from the experiment on a sheet of graph paper.

Use your graph to answer the following questions.

1. If the drop height of the tennis ball is 60cm, what is the bounce height? ____________
   Did you use interpolation or extrapolation? ______________________________

2. If the drop height of the tennis ball is 160 cm, what is the bounce height? ___________
   Did you use interpolation or extrapolation? ______________________________
   Check your prediction experimentally. Was your answer approximately correct? ________
   ____

3. If the tennis ball rebounds to a height of 55cm, from what height was it dropped? _____
   Did you use interpolation or extrapolation? ______________________________

Experiment 2: Super ball
Data Table:

Graph:
Plot the data from this experiment on the same graph as the tennis ball.

Use your graph to answer the following questions.

1. Why did you redo the experiment with a different ball? _______________________
   ____

2. If the drop height of the super ball is 1 meter, what is the bounce height? ____________
   Did you use interpolation or extrapolation? ____________________________________

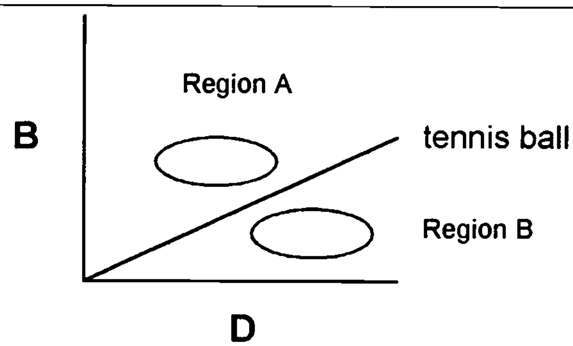
3. If the super ball rebounds to a height of 1 meter, from what height was it dropped? ____
   How did you determine your answer? ____

General Comprehension Check

1. Based on the information in the graphs, do the variables D and B appear to be related?
   ____
   Explain. ____
   ____

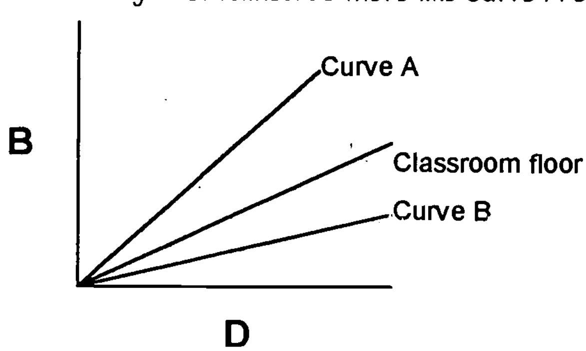
2. You find a strange-looking ball on the playground. Because you have been investigating bouncing balls, you decide to drop the ball from a height of 50cm and discover that it rebounds to a height of 18cm. Is it more like the super ball or the tennis ball?__________

3. You bring in a ball which you believe is not as lively as a tennis ball. In what region of the graph do you expect the curve to lie, relative to the curve for the tennis ball? Would it be region A or region B?____



   Explain, ____
   ____

4. If you performed you experiment with the tennis ball on a soft rug instead of on your classroom floor, would the curve you obtained be more like curve A or curve B? _________



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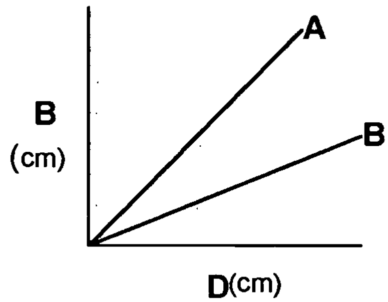
5. Wooden tennis courts are supposed to produce a higher bounce than clay courts. Which curve of bounce height versus drop height, curve A or curve B, represents the data taken on a wooden court? ______________________________



6. Fill in this table for an experiment using the rubber ball.

D(cm)	B(cm)
40	30
	60
100	

7. Plot the data you obtained from problem 6 on another sheet of graph paper. Fit a curve to the data points. From the curve, find the ratio B/D for:

B = 20cm, $\frac{B}{D}$ = ____________

B = 40cm, $\frac{B}{D}$ = ____________

B = 50cm, $\frac{B}{D}$ = ____________

Is the ratio always the same? ______________________________
Using just the ratio, find D when B is 90 cm. ______________________

8. A ball is dropped from a height of 30cm. It rebounds to a height of 10cm. If the ball was dropped from a height of 60cm, how high would it rebound?____________________
If the ball rebounds to a height of 25cm, from how high was it dropped? ____________

Appendix R

Name________________________________Period__________Date________

Team members: ____

? ? ? Which Paper Towel Should I Buy? ? ? ?

1. State the Problem

____
____
____

2. Gather Information on the Problem

____
____
____
____
____
____
____
____

3. Form a Hypothesis

____
____
____

4. Experiment

Manipulated Variable:____
Responding Variable:____
Controlled Variables:____
____

? ? ? ? ? ? ? ? ?

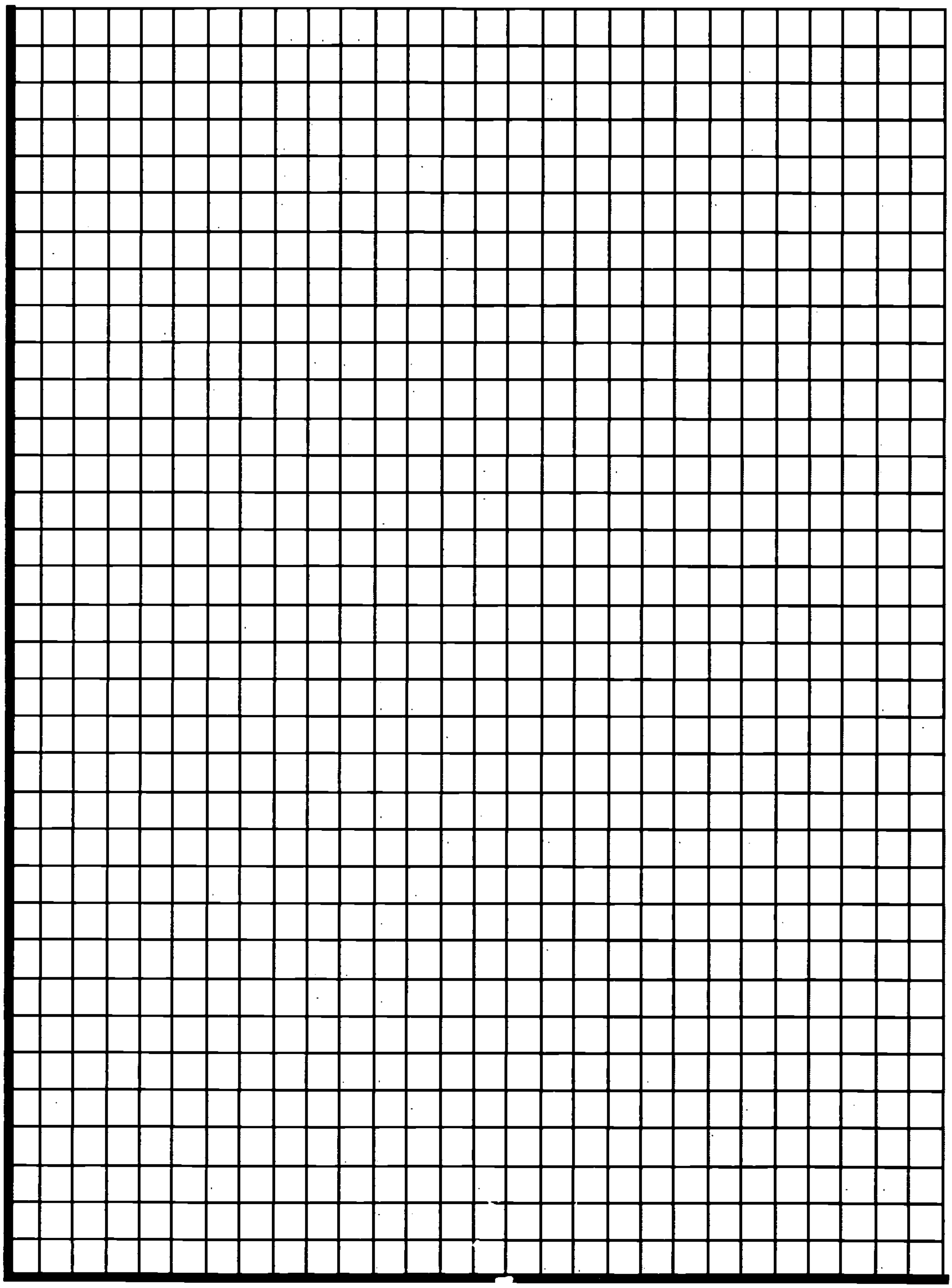
Materials:

Procedure:

5. Record and Analyze Data

Data Table:

Analyze Data:



6. Conclusion

Which Paper Towel Should I Buy?

? ? ? ? ? ? ? ? ?

Critical Thinking Questions

Answer the following questions in complete sentences.

1. How might this activity be useful in your life?

2. What kind of job or profession might be related to this type of investigation?

3. What is the price of each paper towel per square foot?

4. Which paper towel is the best value? Why?

5. What factors did you control in your experiment? Why?

6. List two other household products and tests you can run to determine the best product for the money. (Don't use things you did in S.S.)

Appendix S

Name______________________________Period ________Date__________

Science Pre/Post Test

Directions: This is a test to find out what you know about science and the scientific method. Read each problem carefully. Choose what you think is the BEST answer, and circle the answer. Try hard to answer all of the questions.

1. After scientists think they have found the solution to a problem by thinking it through and doing an experiment, they almost always
   a. use the solution to make an invention.
   b. see that the results of the experiment have led to new questions.
   c. have difficulty finding another problem to work on.
   d. feel that the problem is solved once and for all.

2. When new information is discovered that conflicts with a theory, scientists will usually
   a. throw out the theory, since the new evidence does not fit in.
   b. change the evidence a little so that it will fit the existing theory.
   c. keep the theory as it is, since this new evidence does not support it.
   d. change the theory a little so that this new evidence is explained by it.

Questions 3 through 6 refer to the following situation.
A fire destroyed a large forest, and the soil is being washed away by rain. So, the forest rangers want to test how different types of grasses affect soil erosion. They choose ten plots of ground that are the same size. These plots receive the same amount of sun. They also have the same kind of soil. The rangers plant each plot with a different type of grass. Measurements of soil erosion are made every week of the entire summer.

3. What hypothesis is being tested in this study?
   a. Some types of grass reduce soil erosion more than others.
   b. Soil erosion is effected by the slope of the land.
   c. Burned over areas have greater erosion than forested areas.
   d. Planting grass will reduce the amount of soil erosion.

4. What is the manipulated variable?
   a. the size of the plots
   b. the types of grasses
   c. the amount of soil erosion
   d. the type of soil in the plots

5. What is the responding variable?
   a. the size of the plots
   b. the types of grasses
   c. the amount of soil erosion
   d. the type of soil in the plots

6. Which of the following variables is NOT controlled in this study?
   a. the size of the plots
   b. the type of soil in the plots
   c. the amount of soil erosion
   d. the amount of sun the plots received

Questions 7 - 9 refer to the following situation.
John wanted to find out which laundry soap was best for removing grass stains. He tested four soaps. He mixed 1 tablespoon of each soap with 1 quart of warm water at 20 degrees Celsius. Each soapy mixture was then used to scrub a piece of grass-stained cloth for 1 minute. Then the amount of stain left on the cloth was measured.

7. Of the following variables, which one was NOT controlled in this experiment?
   a. amount of stain left on the cloth
   b. amount of water
   c. amount of time scrubbing
   d. amount of laundry soap

8. Why did John need to control variables?
   a. He wanted the conditions of each test to be the same so that he could see if the variables he was testing made a difference.
   b. By controlling variables, he would get exactly the same outcome for all four test.
   c. He needed to control only the variables that he was trying to test.
   d. He needed to control things so that he would not make a mess.

9. Why was it important that John measured amounts, time, and temperature in his experiment?
   a. He wanted to find out if using more laundry soap would make the stain come out faster.
   b. If he had not made measurements, he could not be sure that the controlled variables were the same for each test.
   c. He needed to practice measuring variables accurately.
   d. It did not matter if he measured the other variables, but one must always measure the responding variable.

10. Scientists predicted that an experiment would come out a certain way. When they did the experiment, they got an unexpected result. What should they do next?
    a. They should continue experimenting until they discover the experiment that proves their prediction.
    b. They should repeat the same experiment until they get the result they predicted.
    c. They should repeat the experiment and if they get the same result, they should think about why their prediction was wrong.
    d. They should stop doing any more experiments since their prediction was wrong.

11. There are many goals in doing scientific work, but the main goal of science is
    a. to do experiments.
    b. to discover all of the facts about nature.
    c. to make new inventions.
    d. to build better explanations of things in nature.

12. Margaret saw some fussy green stuff on a rock she found in the park. When she asked her science teacher about it, the teacher said that it was a kind of plant called moss. Margaret was curious about why the moss grew on the rock. She remembered that the rock was in a dark, damp place. In order to study why moss grows on rocks, what should Margaret do?

Number the following items 1 through 4 in the order you think Margaret <u>should</u> do them.

___ Do an experiment that changes one variable but controls all the other variables.

___ Come up with a hypothesis about how either moisture or light affects the growth of moss.

___ Look at the result of her experiment and think about what it means.

___ Think about what she already knows about light, moisture and the growth of other plants.

13. Margaret has an idea that moisture is necessary for moss to grow, so she designs an experiment where she puts one rock on a pot of wet dirt and another rock on a pot of dry dirt. Before she begins her experiment, should Margaret think about what the results might be?
    a. Yes, because she wants to prove that she has the right plan for her experiment.
    b. No, because she cannot possibly predict what the results might be.
    c. Yes, because she must think about what different possible results will mean for her idea.
    d. No, because she must wait until after she gets the results to think about what different possible results will mean for her idea.

14. The main reason for doing experiments in science is:
    a. to come up with new cures or inventions.
    b. to try something new because it has never been done before.
    c. to explore and test the ideas of scientists.
    d. to see what happens when things are mixed together.

Questions 15 - 18 refer to the following situation.
Fred's family had a farm where spotted cows were raised. He was responsible for taking care of a calf. He noticed that the calf went to its own mother for milk. He wondered how the calf could tell its mother from all the other spotted cows on the farm. Fred had the following idea to explain how a calf could tell which cow was its mother.

IDEA: A calf recognises its mother by the particular pattern of spots the mother has.

For each of the following observations, circle whether you think the observation SUPPORTS or DOES NOT SUPPORT Fred's IDEA.

15.	SUPPORTS	DOES NOT SUPPORT	The calf did not go to a cow that had a different pattern of spots than the calf's mother.
16.	SUPPORTS	DOES NOT SUPPORT	Fred painted a picture of a cow that had the same pattern of spots as the mother cow and the calf went to it for milk.
17.	SUPPORTS	DOES NOT SUPPORT	The calf went looking for milk from a cow that had no spots.
18.	SUPPORTS	DOES NOT SUPPORT	Fred added lots of extra spots to the mother cow using washable paint, and the calf did not go to the mother for milk.

In the following questions, circle whether you think each statement is TRUE or FALSE.

19. TRUE FALSE Scientists usually do not have any ideas about how something works before they start experimenting on it.

20. TRUE FALSE For the entire time they spend investigating something, scientists are always working on the exact same question that they started out with.

21. TRUE FALSE Scientists sometimes need to create a laboratory version of an event in nature so that they can observe it.

22. TRUE FALSE Scientists can only investigate an object if they can see or touch it.

23. TRUE FALSE As they investigate things in nature, sometimes scientists have to change basic ideas that they had once believed to be true.

24. Scientists decide what variables to test in an experiment
    a. by using the variables that are given in the problem.
    b. by trying every variable that can be tested.
    c. by considering all the information available and their ideas about what is happening.
    d. by choosing any variable since it doesn't matter which one they start with.

25. Alice grows violets. She has six red and six white violets. She heard that violets produce more flowers when they receive morning sunlight. She made this hypothesis:

    Hypothesis: When violets receive morning sunlight rather than afternoon sunlight, they will produce more flowers.

    Which of the following is the BEST plan to test this hypothesis?
    a. Set all of her violets in the morning sun. Count the number of flowers produced by each. Do this for a period of four months. Then find the average number of flowers produced by each kind of plant.
    b. Set three white violets in the morning sun. Set the other three white violets in the afternoon sun. Do not study the red ones at all.
    c. Set all of her plants in the morning sun for four months. Count the number of flowers produced during this time. Then set all of the plants in the afternoon sun for four months. Count the number of flowers produced during this time.
    d. Set three red and three white violets in the morning sun. Place the other three red and three white violets in the afternoon sun. Count the number of flowers produced by each plant for four months.

Appendix T

SCIENCE JOURNAL

NAME: ____________________

PER.: ________

DATE: ____________

1. DO YOU FEEL LEARNING THE SCIENTIFIC METHOD BY WORKING IN GROUPS WAS BETTER THAN WORKING ALONE? (EXPLAIN)

2. DO YOU THINK YOU KNOW MORE ABOUT THE SCIENTIFIC METHOD NOW THAN YOU DID IN SEPTEMBER? (EXPLAIN)

3. WHAT IS IT THAT YOU LEARNED ABOUT THE SCIENTIFIC METHOD?

4. WHAT IN THE SCIENTIFIC METHOD DO YOU FEEL YOU STILL HAVE DIFFICULTY WITH?

5. DOES JOURNALING ABOUT WHAT YOU DID HELP YOU TO LEARN IT?

6. IF WE WERE TO DO THIS OVER AGAIN WHAT WOULD YOU CHANGE?

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