THE EFFECTS OF TEACHER QUESTIONING
ON COGNITIVE ABILITIES

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CHAPTER I

INTRODUCTION

Recent efforts in educational reform reinforce the importance of the development of students' ability to act as independent, rational thinkers (Badger, 1989). One of the identifiable characteristics that distinguishes students from one another is their varied use of intellectual thinking abilities. Unfortunately, thinking skills too often remain undeveloped and the productive application of this innate potential fails to materialize (Parker, 1989).

Thinking skills constitute the foundation of learning. In his model of the human intellect, Guilford (1967) includes two operations that are types of thinking. Convergent production is the type of thinking that is most commonly required in the traditional school classroom. Contrary to a common misconception, convergent production is not the simple regurgitation of facts presented and memorized. Like divergent production, this skill requires the production of new information from given information. In convergent production, the emphasis is on the production of expected responses. Divergent production stresses the variety and quality of the response (Meeker, 1969), or unexpected response. The primary difference between convergent and divergent production cognition is focusing and branching out. Divergent production is particularly important in education because its open-ended nature encourages students to approach their potential more effectively than does convergent production (Parker, 1989).

Two methods that have been presented as strategies to encourage student thought are open-ended questions (Parker, 1989) and the use of discrepant events in science (Liem, 1987). Open-ended questions are thought to demand active intelligence as students are required to relate what they know to new and challenging situations. Parker (1989) contends that open-ended questions increase thinking skills.

In the teaching of science concepts, Liem (1987) has found the use of discrepant events as one of the most effective methods to accomplish the goal of increasing cognition skill as defined by both convergent and divergent production. The scientific events are presented in such a way that it poses open questions to the students requiring them to produce multiple explanations. Liem contends that students retain science concepts longer when they are engaged in experiencing such events. Asking the learner questions eventually leads students to the main reason for the occurrence. Through the use of discrepant events, the students are engaged in science inquiry and practicing the scientific processes of observation, measuring, inferring, predicting, interpretation, identifying and controlling variables, hypothesizing, and experimenting. It is anticipated that involving the learner in discrepant events reinforces the learning and retention of the science concepts.

If science were merely a set of explanations and a collection of facts, it could be taught with blackboard and chalk. Students could be assigned to read chapters and answer closed questions that followed. Closed questions have specifically right or wrong answers. Good students would take notes, read the text, turn in assignments, then repeat the information back to the instructor again on a final examination. Science is often taught in this traditional manner. Everyone in the class learns the same body of information at the same time in the same way. Class conformity is preserved. It has been found that long term retention and application of the concepts in science requires more than this mundane, traditional and factual-based approach (Marson, 1988).

Marson alleges that science is a process, a dynamic interaction of rational inquiry and creative play.

Scientists probe, poke, handle, observe, question, think up theories, test ideas, jump to conclusions, make mistakes, revise, synthesize, communicate, disagree, infer, and discover. Students can only learn these skills if they are free to think and act, like scientists, in a classroom that recognizes and honors individual learning differences. The use of open-ended questions and discrepant events is thought to provide the opportunities for divergent thinking to occur.

The purpose of this study was to compare the effects of a traditional instructional strategy and an innovative instructional strategy on divergent and convergent cognitive abilities and content knowledge. The research base of Hilda Taba (Maker, 1982) supports the effectiveness of the use of questioning techniques to increase higher levels of thinking skills in children. The Taba Strategies (Maker, 1982, Schiever, 1991) are a developmental program whereby the teacher leads students through a series of sequential intellectual tasks by asking open-ended, but focused questions that require children to verbalize reasoning. Extensive use of the Taba Strategies has shown that thinking skills have been developed in all children. Taba Strategies can be combined into a total approach that is comprehensive and based on research showing its validity. This research compared an innovative strategy with a traditional approach.

The innovative strategy is an adaptation of techniques from the Taba strategies using divergent questioning combined with the adaptation of a scientific discrepant event. The traditional approach is convergent questioning strategy combined with traditional assignments. The two instructional methods were compared by examining content knowledge and two types of cognitive abilities.

Significance of Study

In the search for ways to increase students' problem-solving and critical thinking skills, using the art of questioning becomes particularly important. One reason for involving open-ended questions is the value of information obtained. These types of questions call for the kind of thinking that science education requires. Too often educators pay lip service to the need for active learning but teach and test students in ways that demand passivity. By their actions, schools say to students, "We are not interested in your response, we are only interested in the correct response." It is the hope that this study will begin to show how students in two groups respond when they are challenged to retain science concepts when presented with either convergent or divergent questioning strategies.

Another rationale for this study was to show that questioning strategies act as a model for content development. This research attempts to show that this type of strategy yields important information about students' understanding of concepts and procedures, their ability to apply their learning to new situations, and their need for further instruction. This research attempted to show differences between questioning strategies.

Dillon (1984) indicates developing higher cognitive questions require students to engage in independent, divergent thinking. According to Parker (1989) convergent questions are those whereby responses are expected or conform to a predetermined pattern. The emphasis is on the production of expected responses. Divergent questions are those that allow many possible responses. Divergent production stresses the variety and quality of the responses. Brandwein (1962) has argued for years that emphasis on innovative strategies and discrepant events provides learners lasting and usable content knowledge as well as gives insight into the nature of how scientists work.

There are several reasons for employing discrepant events in the development of science education. Liem alleges it enhances the ability of students to use equipment and apparatus in science investigations. The strength and uniqueness of science is in the use of the senses as extended through physical tools that greatly enhance human powers of observation to gather evidence on how the world around us works.

Another reason to investigate the treatment questioning strategy is to heighten students' thinking skills. The use of questioning strategies and discrepant events in the teaching of science education are two of the best methods to arouse interest and curiosity (Liem, 1987). Innovative strategies are an excellent means to create in the student an eagerness to learn more about science. They capitalize on the students' own curiosity, already present within the person, helping them to gain a better understanding and retention of science concepts.

Selected for the review are research reports related to science teacher questioning behavior, with particular emphasis on those studies designed to help teachers change their questioning behavior. Many science education researchers have recently studied questioning and its relation to learning science principles and concepts. Some researchers have reported a positive and significant relationship between student's thinking ability and their performance on science tests. (Liem, 1987, Brandwein, 1968).

This study compared the differences between an innovative instructional strategy and a traditional instructional strategy on measures of content knowledge, divergent cognitive abilities, and convergent cognitive abilities. The focus reflected the need to formulate open-ended questions to increase thinking skills and attempted to show thinking processes were stimulated and developed by the use of open-ended questions and discrepant events.

Research Questions

The purpose of this study was to compare the differences between an innovative instructional strategy and a traditional instructional strategy on content knowledge and divergent and convergent cognitive abilities. Based upon the research design, the following questions are asked:

(1) Are there pre-existing differences between students when assigned to innovative and traditional methods of teaching?

(2) Is the impact of traditional and innovative programs on student scores dependent on pre-test or post-test conditions?

(3) At post-test, were there differences in students learning using traditional and innovative programs?

CHAPTER II

REVIEW OF RELEVANT LITERATURE

The purpose of this study was to compare the differences between a traditional instructional strategy and an innovative instructional strategy on divergent and convergent cognitive abilities and content knowledge. The review of literature supports the need to formulate open-ended questions to increase thinking skills and describes studies in which thinking processes are stimulated and developed by the use of open-ended questions.

Research on open-ended questions and instructional strategies based on the work of Hilda Taba (Schiever, 1991) are particularly relevant to this discussion. Additionally, the literature related to teaching strategies for elementary science is described. Particularly relevant is the research on the use of discrepant events. The chapter concludes with a discussion of research related to work done facilitating divergent and convergent thought processes in children.

Formulating Questions

Formulating the question that states the essence of a situation is considered one of the highest levels of intellectual functioning (Kratz, 1984). For most teachers, training and practice is necessary to develop this ability. Appropriate training will help individuals meet this need. The classroom is an environment within which both teachers and students practice the art of questioning.

The teacher, as a role model, helps students develop good questioning skills. The teacher needs to be aware of the purpose for which a question is being asked, its specific wording, and personal reaction to student responses. Dillon (1984) indicates that most teacher-posed questions are aimed at eliciting factual information from students about what they already know or are coming to know through questioning. The challenge for the teacher becomes one of getting students to use this base of information by developing higher cognitive questions which require students to engage in independent, divergent thinking. At the same time students need to be provided with the strategies they need to give good responses.

According to Dillon (1983), to conceive an educative question requires thought; to formulate it requires labor; and to pose it, tact. Dillon divides the educative classroom questions into two groups, those for recitation and those for discussion.

In the familiar form of recitation, teachers ask a series of questions, which require definite answers. Other questions or comments are not encouraged. This type of questioning can produce negative effects on students' cognitive, affective and expressive processes by increasing student passivity and dependence and by limiting student thought and response. Only a part of a student's understanding may be revealed.

Experience (Kratz, 1984) in questioning students has shown that those who were able to formulate good basic information questions moved easily into developing questions aimed at higher cognitive processing. At this point of development these students needed additional assistance in the more precise use of language. All students in a classroom do not reach this high level of development but all students will benefit from the thought processes that are developed.

Types of Questions

According to Pollack (1988), there are three types of questions that contribute to the development of critical thinking. Open-ended questions encourage independent critical thought as well as creativity. Students learn that all thoughtful responses to questions are valued. Deductive reasoning questions require students to put together clues to arrive logically at a conclusion. A third purpose of questioning is to guide children to gather facts to support their ideas.

The use of these types of questioning strategies can provide focus and raise the level of students' thinking. Questions can act as a catalyst, stimulate students' critical thinking processes, and give them a way to organize their ideas. In a study involving elementary students, Durkin (1979) observed that the emphasis on questioning seemed to be guessing the teacher's answer rather than recalling what was read. It was concluded that questions should be open-ended rather than seeking specific information. From that same study, Nessel (1987) concluded that directing students to predict and validate their responses enhance thinking and reasoning skills. Effective questioning strategies can serve in lifting the level of thought in the learning process.

The present study attempts to reflect that questioning strategies serve to raise the level of thought in the learning process. The thinking the children will communicate in response to the different types of questioning that occurs will indicate that their critical thinking processes are indeed stimulated and developed by the use of open-ended questions. The relationship between questioning strategies and content knowledge has led this author to believe that thinking abilities are an underlying factor that strongly influences the learning of a great deal of the course content in the science curriculum.

The Effects of Questioning Strategies

Winne (1979), in a descriptive summary of 18 studies, concluded that student achievement is not affected by the level of teacher questioning. However, a recent meta-analysis of experimental research on teacher-verbal questioning behavior (Rousseau & Redfield, 1980) showed that, regardless of the type of study or the degree of experimental validity, teachers' predominant use of higher cognitive questions has a statistically significant, positive effect on student achievement. The conclusion from the Redfield and Rousseau study was that when students participate in programs in which teachers are competent in questioning skills, in which the validity of program implementation is carefully monitored, and in which higher cognitive questions are used during instruction, gains in achievement can be expected.

Sampson (1986) examines Guilford's divergent productive thinking and reports an experimental study in which the divergent production of third-grade subjects was enhanced through instruction. His study concluded instructional techniques are needed to help students produce new, original ideas of the divergent production mode. Open-ended questions, when used as an instructional tool, is an example of such a technique. The findings of the study indicate that questioning was an effective technique to increase the divergent production of third-grade students.

In 1984, Moore examined the performance of entering college freshmen trained in thinking skills and the relationship of this training to the scores on the Wechsler Adult Intelligence Scale-Revised (WAIS-R) and to grade point averages. The program was designed to develop both convergent and divergent thinking. Measurement of the training was obtained from scores on a validated educational instrument based on the Taxonomy of Educational Objectives (Kropp, Stoker, & Bashaw, 1966). While subjects in each group made gains, the subjects in the divergent group made significant higher scores than did the subjects in the convergent group.

Measuring Cognitive Abilities

The Primary Test of Higher Processes of Thinking (PTHPT) is designed to determine a student's level of cognitive abilities in the higher level thinking processes (Williams, 1978). It is geared to students in grades two through four. The test consists of six subtests: Convergent Production, Convergent Analogies, Sequential Relationships, Logic, Deductive Reasoning, and Divergent Thinking. In addition to identifying high level thinkers, the test author suggests the test may be used to assess a child's strengths and weaknesses in creativity or as a research instrument to study giftedness.

In convergent production, one utilizes the knowledge possessed and applies it to new situations utilizing cognitive, memory, and recall to come out with the right answer. Convergent analogies is the utilization of present knowledge to determine the similarity or comparison which result in the most appropriate answer. Sequential relationships are a succession of related thoughts developing a single subject or thought. Logic measures the ability to infer when facts are presented. Deductive reasoning measures the use of logical reasoning to reach a valid conclusion.

The PTHTP shows promise, but must be studied further. The instrument can be used in its total form to assess general ability, or various subtests can be used to assess specific areas such as logic, deductive reasoning, or sequential relationships. Other ways to measure these abilites for this age level might include Guildford's Structure of the Intellect, the Torrance Tests of Creative Thinking, or the Wallach and Kogan battery. The PTHTP appeares to measure convergent and divergent production conducive to this design.

Science Education

According to Halkitis (1990), the past two decades have been characterized by a movement towards the emphasis of process in the science curriculum on both the elementary and secondary level. This movement was wholeheartedly accepted by scientific organizations throughout the United States because it captured the truer sense of science, incorporating all elements of the scientific method, and therefore, allowing students to gain a better understanding of the basic structure of the discipline. Discrepant events are particularly well suited for science for it involved levels of thinking that extended beyond basic knowledge and comprehension into thought processes that emphasize analysis, synthesis, and evaluation. It brings to science education the essence of science which is that of setting up problems and solving them through inquiry.

The use of questioning strategies and discrepant events in the teaching of science education are two of the best methods to arouse interest and curiosity (Liem, 1987). Innovative techniques are events set up in such a way that a question is posed to the student asking them to come up with the explanation through discovery. Asking the learner questions will eventually lead to the main reason for the occurrence while engaging in science inquiry and practicing the science processes of observing, measuring, inferring, predicting, interpreting data, identifying and controlling variables, hypothesizing, and experimenting.

Liem states that involving the learner in discrepant events reinforces the content knowledge and retention of the particular scientific concept.

Liem (1987) conducted studies on the effect of discrepant events on science concept retention. The control group of students were subjected to only discussion and reading of a text containing descriptions of discrepant events, whereas the experimental group were subjected to discrepant events demonstrated by the teacher and experienced by the students. Results revealed that discrepant events positively influences content achievement. The study showed that content achievement is affected by the arousal of student motivation, which is directed at the comprehension of the causes of the observed events.

Pre-test measures were administered to both groups. Post-test measures were administered immediately after the lessons, one month after the lessons, and three months after the lessons. Liem concluded that the larger the time lapse between the lessons and the administering of the post-test, the more significant the difference becomes between the mean score of the Experimental Group compared to that of the Control Group. The group taught using the discussion method whereby discrepant events were demonstrated by the teacher and experienced by the students retained the science concepts longer compared to the group taught using the discussion method whereby discrepant events were only read.

Suchman (1960) conducted a study involving teaching techniques with discrepant events. The study indicated discrepant events positively influence content achievement. The study showed that content achievement is affected by the arousal of student motivation, which is directed at the comprehension of the causes of the observed events.

Marlins (1973) studied upper elementary school students using a demonstration-discussion method integrating discrepant events. The findings indicated students involved in discrepant events had significantly higher retention scores compared to students taught without discrepant events.

Liem contends that the findings of the studies conducted thus far would seem to justify the use of discrepant events for teacher demonstration and student activities to increase retention and understanding of science concepts at the elementary level. He infers that the discrepant events lose their discrepancy or motivating effect on the student when they are merely described in a text and read by the student.

The present study will compare the effects of divergent and convergent questioning strategies on science concept learning and retention. This research will also attempt to show that content achievement is positively affected by the arousal of student motivation, which is directly related to the use of open-ended questions and discrepant events. Through questioning (Coolidge, 1989), teachers can develop and not merely assess comprehension. Effective questioning can expand student cognition from rote memory to higher critical thinking levels (Frager, 1986).

The importance of questioning techniques and strategies has received a great deal of attention from educators. The type of questions that a teacher poses can set the tone of a classroom and contribute significantly to the classroom climate. Questions asked can define a classroom as one where rote memory is valued or one where children are encouraged to be thoughtful and pursue ideas. Transference of academic skills to life situations can result from certain questioning strategies for the ability to ask effective questions is necessary for quality teaching that will enable students to participate fully in the world.

CHAPTER III

METHODOLOGY

The purpose of this study was to compare the differences between an innovative teacher questioning strategy and a traditional questioning strategy on divergent and convergent cognitive abilities and content knowledge. The independent variable is the two treatment groups of teaching strategies, one innovative and one traditional. The dependent variable for the first analysis is divergent cognitive abilities. The dependent variable for the second analysis is convergent cognitive abilities. Additionally, the study will attempt to show what differences the independent variable has on content knowledge, the dependent variable in the third analysis.

Subjects

The sample for this study was comprised of 83 fourth grade students enrolled in public elementary school in one of the largest cities in Oklahoma. The students are generally from white middle income families. There were 40 boys and 43 girls who participated in the study. After securing permission from the school district and approval from appropriate Institutional Review Boards for use of human subjects (Appendix A), each student received a permission to test form (Appendix B) describing the study to students and to parents, ensuring confidentiality, anonymity and right to refuse to participate at any time in the study. Only those students whose parents signed the permission form participated in the cognitive abilities test. The test on science content (volume) is a part of the regular curriculum and all students participated. The data from the instrument was used only for those subjects who offered permission.

The students comprised four sections of elementary science taught by the same instructor, who is the researcher. The sections are heterogeneously grouped by random assignment in the beginning of the year. The school principal was responsible for the assignment to classrooms.

Instruments

The score for cognitive abilities was determined using the Primary Test of Higher Processes of Thinking (PTHPT) (Williams, 1979). The PTHPT can be found in Appendix C and was used to arrive at a pre-test and post-test score. The PTHPT yields convergent production, convergent analogies, sequential relationships, logic, deductive reasoning, divergent thinking subtests, and presents a divergent, convergent, and composite score. The divergent and convergent scores were used to measure students' gains in cognitive ability.

The PTHPT was located in the Educational Testing Service Test Collection which provides microfiche copies of certain unpublished tests as a service to educators and psychologists. Permission to reproduce this instrument in its original form was granted by ETS.

The test manual is well-written. Administration and scoring standards are detailed clearly and applied easily. In general, the PTHPT is user friendly.

Raw scores can be converted to percentiles and standard scores. Item analysis data are reported thoroughly in the manual. The manual reports reliability data is promising, but sparse. Exact correlation is not reported in the manual. Content validity is not addressed adequately in the manual.

The aim of this measure is to reveal a students level of cognitive abilities in the higher levels of thinking. In convergent production one utilizes the knowledge possessed and applies it to new situations utilizing cognitive, memory, and recall to come out with the one right answer. Convergent analogies is the utilization of present knowledge to determine the similarity or comparison which results in the most appropriate answer. Sequential relationships is a succession of related thoughts developing a single subject or thought. Logic is a science of correct reasoning. When facts are presented positive inferences can be made through hypothesizing. Deductive reasoning is the use of logical reasoning to reach a valid conclusion. Divergent thinking is an intellectual operation which allows for a large number of possible associations of problem solutions.

Responses are marked directly in the test booklet. Each item counts one point in the first five sections. In scoring a student's divergent thinking, the examiner needs to be cognizant of fluency (number of responses), flexibility (adapting to change), and elaboration (expression in great detail). Fluency scores are determined by the amount of responses related to the subject. Flexibility scores are determined by how often ideas change. Elaboration scores are determined by how much detail students use to expand upon their responses. One to four responses earn one-half point, five to eight responses earn one point, nine to twelve responses earn one and one half points and 13 or more responses earn two points.

The assessment of content knowledge consisted of the facts, concepts, instruments, and procedures involved in measuring volume of solids, liquids, and irregularly shaped objects. It was a teacher-made evaluation that assumed a variety of forms including multiple choice, sequencing, and true or false questions. The 10-item test was a combination of the chapter test questions on volume provided in the fourth grade Silver Burdett Company science textbook. The reliability or validity is not apparent.

Content knowledge was scored on a 100-point scale. Each item weighed the same amount. This assessment was useful in assessing recall of factual information and sequential reasoning, is easy to score, and is efficient and objective.

Procedure

The study was conducted over a four week period during the fourth quarter of the school year. This study was designed to use four testing sessions and eight lessons of 30 minutes. Each treatment group received eight 30 minute lessons on volume. Before any intervention was received, students participating in the study were given the PTHPT to determine divergent cognitive abilities and convergent cognitive abilities. The volume test was administered following the cognitive abilities measure. It took approximately to take 45 minutes to administer both tests.

After the last lesson on volume, subjects were administered the Primary Test of Higher Processes of Thinking to arrive at a post-test score for divergent and convergent thinking skills. The content test was administered to obtain differences in learning about volume.

The traditional treatment group received instruction according to the lesson plans in Appendix E. Each lesson consisted of directing students to read silently and orally the story of Archimedes and his solution in the third century to the problem of the composition of King Hiero II's crown. Closed questions included: Who was Archimedes? What was his discovery? What is displacement? After closed questions of Archimedes' discovery of displacement, discussion was developed about practical applications of his theory to modern day science. Similarly, students spent Lesson 2 reading the Silver Burdett text on volume silently and orally.

In lesson 3 students participated in a closed-question discussion involving units of measurement. Emphasis included tools for measuring volume and comparisons of milliliters and cubic centimeters. Closed questions included: What instrument is used to measure volume of a solid? What instrument is used to measure volume of a liquid? What instrument is used to measure volume of an irregularly shaped solid? What unit of measure is used to identify solids? What unit of measure is used to identify liquids? What unit of measure is used to identify irregularly shaped solids? Students were invited to collect empty one- and two-liter containers to make a display.

Lesson 4 invited students by closed questions to predict how to measure the volume of the containers they collect. Questions included: Which container has the greatest volume? Which container has the least volume?

Lesson 5 invited students to read about measuring volume of irregular objects using displacement. Closed questions included: What is the water level of the graduate with the water? When the marble is placed in the graduate and the water, what happens to the water level? What is the difference between the starting level and the rising level? What is the volume of the irregularly shaped solid? Lesson 6 challenged students through closed questions to identify the materials and procedures Archimedes needed to conduct his study. Lesson 7 invited students to present their scientific methods to the class. In Lesson 8, students sequenced the steps needed to find the volume of regular objects and irregular objects.

The innovative strategy treatment group included Lesson 1 (Appendix F) reading silently and orally about Archimedes and his solution in the third century to the problem of the composition of King Hiero II's crown. Open questions included: Who was Archimedes? What was his theory of displacement? In whats way did Archimedes arrive at his theory of displacement? In what ways is the discovery of displacement applied to modern day science? For what reason did Archimedes experiment with displacement? After discussion of Archimedes' discovery of displacement, discussion was developed about practical application of his theory to modern day science.

Lesson 2 differentiated from the traditional strategies through the use of open questions between measuring the volume of solids and liquids. Open questions included: In what ways do we measure length, area, and volume? In what ways are the instruments and units of measurement different in length, area, and volume? Students used cubigrams to create solid cubes for the next lesson. The discrepant event at the onset of Lesson 3 involved students in measuring the dimensions of a Rubik's cube, a sugar cube, and dice. The lesson invited students to measure the three dimensions of their various sized cubes constructed from the cubigrams to discover the volume of each. Open questions included: How many cubes are in each solid block? In what ways might one find the volume of a solid? For what reasons might we find the volume of solids?

The discrepant event that introduced Lesson 4 involved the comparison of the volumes of solid matter with the same mass using displacement. The lesson involved measuring the volume of solids with different masses using displacement. Open questions included: In what ways are the three objects similar? Different? What changes occured when the matter was placed in the graduate of water? In what ways does the volume of the solids compare? In what ways are the solids different? In what ways might we define displacement?

Lesson 5 involved students in measuring irregular objects using displacement. The discrepant event at the onset introduced students to the theory of displacement by measuring one half cup of shortening in one half cup of water. Open questions included: In what ways does the water level change when you add an irregularly shaped solid to the graduate? What is the difference between the starting level and the rising level? In what ways might we find the volume of an irregularly shaped solid? Lesson 6 challenged students to compare measurements of dry volume and liquid volume. Students were asked in what ways can the volume of an unlabeled container be measured.

Lesson 7 invited students to differentiate between length, area, and volume of objects as well as their units of measurements. Students identified examples of each. Open questions included: What examples can be found of length in the room? Of area? Of volume? In Lesson 8, students listed steps needed to find the volume of regular objects and irregular objects. Open questions included: What steps are needed to find the volume of a solid? What steps are needed to find the volume of an irregularly shaped solid? What steps are needed to find the volume of a liquid? Innovative strategy questions were opened and allowed multiple responses, whereas, in the traditional strategy, questions were closed and required specifically correct answers.

Data Analysis

The design for this study utilized three separate two-way analyses of variance (ANOVA). The dependent variables were divergent cognitive abilities, convergent cognitive abilitites and content knowledge. The independent variables in each analysis included pre- and post-test scores, the repeated factor, and treatment, the between factor, with two levels.

To insure that both groups started the same, t-tests on the mean were run for both groups on the pre-test scores. A t-test of the means examined the degree of similarity for the intact groups used for the two treatments of science instruction.

The factorial design was a mixed model two-way analysis of variance (ANOVA) with students nested in teaching method (traditional or innovative) and crossed with test (pre- and post-). Students' divergent production, convergent production, and content knowledge scores served as the measures in the current study.

To measure post-test differences in students learning, t-tests on the means were run for both groups on post-test scores. A t-test of the means compared the degree of difference for the intact groups used for the two treatments of science instruction.

Summary

The purpose of this research was to compare the differences between an innovative teaching questioning strategy and a traditional teaching strategy on content knowledge, divergent cognitive abilities, and convergent cognitive abilities. The null hypotheses for this study are:

(1) There will be no pre-test differences in the innovative and traditional treatment groups across any of the three measures (convergent production, divergent production, content knowledge).

(2) There will be no interactive effects of test (pre, post) and method (innovative, traditional) upon student scores (convergent production, divergent production, content knowledge).

(3) There will be no post-test differences in the innovative and traditional treatment groups across the three measures (convergent production, divergent production, content knowledge).

CHAPTER IV

REPORT OF RESULTS

The purpose of this study was to compare the differences between an innovative teacher questioning strategy and a traditional teaching strategy on convergent and divergent cognitive abilities and content knowledge. A t-test on the means were run for both groups on the pre-treatment scores to examine the degree of similarity for the groups. A two-way analysis of variance with students nested in teaching method and crossed with test was conducted. A t-test on the means were run for both groups on the post-treatment scores to compare the degree of difference for the intact groups used for the two treamtents of science instruction.

Results

To insure that both groups started the same, t-tests on the means were run for both groups on the pre-test scores. In order to examine the degree of similarity for the intact groups used for the two treatments of science instruction, a t-test was conducted on the means of the pre-test scores on the PTHPT convergent production, PTHPT divergent production, and content knowledge test. The pretest mean scores on the respective measures are shown in Table I.

After calculating t to be .613 for convergent production, .762 for divergent production, and .595 for content knowledge, the Values of t at .01 Levels of Significance Table for 81 degrees of freedom was consulted. The t value of ±2.639 marks off the 1% region of rejection. Since the calculated values were well within the central region, the null hypothesis was not rejected. The obtained difference in mean scores was not significant, thus both groups started the same.

Analysis of variance was used for determining the significance of the interactive effect of teaching method (traditional and innovative) and test (pre- and post-) in divergent production. In order to compute an ANOVA, simple statistics were tabulated which included the total of all the scores, sums of squares for each group, the mean score of each group, and the sample size. The results of the computational efforts in calculating the variance are summarized in the typical ANOVA summary table shown in Table II. Thus, F=.412 with 1 and 81 degrees of freedom. Assuming p=.01, these two degree of freedom values intersect on the F-table at 7.08, the value of F required for significance to reject the null hypothesis. Since the calculated F value of .412 is less than the F table value of 7.08, the F is not significant and the null hypothesis is not rejected. There is not a statistically significant interactive effect in divergent production.

Analysis of variance was used for determining the significance of the interactice effect of method and test in convergent production. The results of the computational efforts in calculating the variance are summarized in the typical ANOVA summary table shown in Table III. Thus, F=.3691 with 1 and 81 degrees of freedom. Since the calculated F value of .3691 is less than the F table value of 7.08, the F is not significant and the null hypothesis is not rejected. There is not a statistically significant interactive effect in convergent production.

Analysis of variance was used for determining the significance of the interactive effect of method and test in content knowledge. The results of the computational efforts in calculating the variance are summarized in the typical ANOVA summary table shown in Table IV. Thus, F=.444 with 1 and 81 degrees of freedom. Since the calculated F value of .444 is less than the F table value of 7.08, the F is not significant and the null hypothesis was not rejected. There is not a statistically significant interactive effect in content knowledge.

In order to compare the difference for the intact groups used for the two treatments of science instruction, a t-test was conducted on the means of the post-test scores on convergent production, divergent production, and content knowledge. The post-test mean scores on the respective meansure are shown in Table V.

After calculating the t to be .097 for convergent production, .907 for divergent production, and .118 for content knowledge, the Values of t at .01 Levels of Significance Table for 81 degrees of freedom was consulted. The t value of ±2.639 marks off the 1% region of rejection. Since the calculated values were well within the central region, the null hypothesis was not rejected. The observed differences in mean scores was not significant, thus there was no difference in the innovative and traditional treatment groups across the three measures.

CHAPTER V

SUMMARY AND CONCLUSION

This investigation compared teacher questioning strategies and their impact of implementation upon cognitive abilities and content knowledge. One treatment group received a traditional questioning strategy involving closed questions while another group received an innovative questioning strategy involving discrepant events and opened questions. Measurements made of cognitive abilities and content knowledge prior to and following the questioning techniques were compared.

Inspection of the results in the ANOVA summary table for divergent production revealed that the main effect of instruction is not statistically significant. The mean scores exhibited minimal increases as measured by pre- and post-test scores, however, the increase is relatively the same for each group.

Inspection of the results in the ANOVA summary table for convergent production revealed that the main effect of instruction is not statistically significant. The mean scores exhibited minimal increases as measured by pre-and post-test scores, however, the increase is relatively the same for each group.

Inspection of the results in the ANOVA summary table of content knowledge revealed that the main effects of instruction is not statistically significant. The mean scores imply there was not much difference in the performance of the two groups as measured by the pre-test scores. At the onset the traditional group demonstrated slightly more knowledge about volume than the innovative group. There was not much difference in the performance of the two groups as measured by post-test scores, however, the content knowledge of the innovative group had a greater increase than the content knowledge of the traditional group.

The results of this study validate the original hypothesis that there were no pre-test differences between the traditional and the innovative treatment groups for divergent cognitive abilities, convergent cognitive abilities, and content knowledge. The results likewise support the original hypothesis that there were no interaction effects of test and method across any of the three measures. The results further endorse no posttest differences between the traditional and the innovative treatment groups for the respective abilities.

Based on the research design employed, data collected, and analysis, the findings of this study contribute that the innovative teaching strategy is no more effective than the traditional strategy for increasing the convergent production, divergent production, and content knowledge of fourth grade students.

Various reasons might be attributed to why the findings did not show significant differences. One reason may be the effort to maintain a high degree of control for the sake of internal validity. Another reason is the two groups may have felt in competition with the other, therefore, outdoing themselves and performing beyond what would normally be expected.

It appears that a plateau is reached at the end of second grade (Caldwell, 1987), with little or no measured academic progress during the next year. This deceleration in the achievement curve is known as third-grade slumping. Kids seem different. Spontaneous expressions of attention diminish. Discipline based on the educational version of withdrawal of love seem less effective. Being considered "cool" is more important than being considered good. Social and emotional ferment occurring at this age could disrupt previous cognitive and academic gains.

This research attempted to compare an adaptation of techniques from one of several of the Taba strategies that uses divergent questioning combined with the content of a scientific discrepant event to a convergent questioning strategy combined with traditional assignments. Analysis of the data collected does not support Taba's concept of open-ended questioning techniques used to increase higher levels of thinking skills in children (Maker, 1982). Nevertheless, Brandwein (1962) has argued for years that emphasis on innovative strategies and discrepant events provides learners lasting and usable content knowledge as well as gives insight into the nature of how scientists work.

Procedures designed to insure equivalent groups on all relevant variables included specific teacher lesson plans which were strictly followed. The students met for the same amount of time each day. They were treated the same except for the levels of the independent variable. Each group was taught by the same instructor to insure a controlled teacher variable.

Limitations of Study

Limitations of the study that may have negatively affected the results might include unequal sample sizes for each of the groups, the length of the study, the location in which the traditional treatment group was instructed, or the time of day in which the students were instructed. Though the sample size might be small, it may have had an affect on the outcome. Ideally, the subjects should have been exposed to treatment for a longer period of time in order to more accurately assess its effectiveness. The traditional treatment group were instructed in a classroom where the physical setting was much different from the science lab. One traditional treatment group and one innovative treatment group were instructed during the fourth period of the day after having been exposed to three other classes, unlike the other traditional and innovative treatment groups who met first period of the day. In this experimental research, the independent variables typically manipulated included method of instruction, type of reinforcement, frequency of reinforcement, arrangement of learning environment, type of learning materials, and size of learning group.

Need for Further Studies

The more the results are replicated, the more confidence obtained in the procedures that produced the results. The study has high ecological validity in that the results can be replicated in other environments by other researchers. Further studies might compare the same subjects with subjects from another school taught by the same instructor. Further studies might compare the same subjects with subjects from another school taught by different instructors. Such variables should enable one to study the topic with varying degrees of randomness.

The hypotheses of the study determined the design which in turn determined the statistical analysis. The analysis technique selected was dependent on a number of factors. They included how the groups were formed, how many groups were involved, how many independent variables were involved and the kind of data that was collected. This experimental study represents the most valid approach to truly testing these hypotheses concerning these cause-and-effect relationships.

Alternative measuring instruments may result in a different assessment of performance. Data might be collected through observation of cognitive abilities. However, observers may not be observing or evaluating behavior the same way at the end of the study as at the beginning. Researchers need to carefully select experimental designs that control for measuring instruments and observers.

There are various means for measuring the knowledge, skills, feelings, intelligence, or aptitude of the subjects or groups. Achievement tests measure the current status of individuals with respect to proficiency in the area of knowledge or skill. Tests of personality measure characteristics of individuals and assess feelings and attitudes toward one's self or others. Attitude scales attempt to determine what an individual believes, perceives, or feels. Tests of creativity are designed to measure personality characteristics related to creative behavior such as divergent thinking. Aptitude tests measure how well someone is likely to perform in a future situation. Numerous instruments are available which yield a wide variety of data for a wide variety of purposes.

In addition to comparing the effects of questioning strategies, this study carries a message about the evaluation that goes on in the classroom. The short objective tests of closed questions, standard fare in most classrooms, are too slight a vehicle to convey the true purpose of evaluation. Unless teachers take the time to discover for themselves how students understand concepts, they will be unable to adjust their teaching in appropriate ways. This kind of assessment, involving student discussion and explanation, should be a continuous and constant part of student evaluations

Evaluations (Badger, 1989) can, and do, affect students' learning. It is a signal to students to be aware of the content areas that teachers consider important. It gives a message about the kind of thinking that is considered valuable. Short objective questions on evaluations that require a single answer, gives the message that facts are what really counts. When questions encourage all students to think, to ponder over material, and to integrate different aspects of learning, the message is much different. Open-ended questions indicate to students it is the quality of thought that is important, not the correctness of an answer. The diversity of answers invites all students in the discussion, argumentation, and intellectual excitement of learning. This is the message we want to convey.

Assessing students' learning in science can not only be done through multiple-choice tests. Such tests are useful in assessing recall of factual information and some deductive reasoning skills, are efficient, easy to score and objective, but they do not address such important goals as learning to understand how scientists think and why they think what they think, applying science knowledge to individual and societal problems, designing ways of addressing unfamiliar and puzzling situations, and constructing solutions. At any level of science knowledge, students should be able to exercise these complex skills, appropriate to their age and development. Including open-ended questions on an assessment results in a more effective estimation of student achievement than what would be obtained if the assessment was limited to multiple-choice items.

Questions can act as a catalyst, stimulate students' critical thinking processes, and give them a way to organize their ideas. Pollak (1988) suggests that effective questioning strategies can serve in lifting the level of thought in the learning process. The questioning that took place in the innovative strategies was designed to achieve this purpose. Examples of the thinking that the students wrote in response to the different types of questioning that occurred in the class indicated that their convergent production and divergent production were indeed stimulated and developed by the use of open-ended questions, though the difference was not significant.

Researchers should continue investigations that include the variables addressed in this study. Measurement of abilities and knowledge, as well as the implementation of the teaching strategies, should be considered when sampling the population in order to affect student responses and to arrive at a significant difference in thinking skills and content knowledge.

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APPENDIXES

APPENDIX A

HUMAN SUBJECT APPROVAL

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
FOR HUMAN SUBJECTS RESEARCH

Date: 04-08-93 IRB#: ED-93-082

Proposal Title: EFFECTS OF TEACHER QUESTIONING ON COGNITIVE ABILITIES

Principal Investigator(s): Diane Montgomery, Roxianne Vincent

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

APPROVAL STATUS SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING.
APPROVAL STATUS PERIOD VALID FOR ONE CALENDAR YEAR AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL. ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

Comments, Modifications/Conditions for Approval or Reasons for Deferral or Disapproval are as follows:

MODIFICATIONS RECEIVED AND APPROVED.

Signature: Maria L. Tilley
Chair of Institutional Review Board

Date: April 23, 1993

TO: Roxianne Vincent
Eliot Elementary School

FROM: Jerry Roger

DATE: April 19, 1993

I am pleased to report that our Research Review Committee has approved your thesis proposal, contingent on obtaining parental permission.

Congratulations on reaching this stage of your program and continued good luck.

cc: Mr. Carr
Dr. Young
Dr. West
Dr. Nelson
Dr. Montgomery, OSU

APPENDIX B

PARENT PERMISSION TO TEST

April __, 1993

Dear Parents,

I am working on a Masters thesis and have permission from Tulsa Public School District to conduct a study on the effects of teacher questioning on content knowledge and cognitive abilities. I will attempt to compare the differences between an innovative teacher questioning strategy and a traditional teaching strategy on content knowledge, divergent cognitive abilities, and convergent cognitive abilities. The study will be conducted during fourth quarter. The experiment is designed to use eight 30-minute lessons involving innovative techniques about the concept of volume. The Primary Test of Higher Processes of Thinking (PTHPT) will be administered prior to the lessons to arrive at a pretest score and following the series of lessons to arrive at a posttest score.

Participation is voluntary, there is no penalty for refusal to participate, and students are free to withdraw consent and participation in the pretest and posttest evaluations at any time without penalty after notifying the project director. The students who do not receive permission will simply not participate in the pretest and posttest evaluations. The lessons taught are a part of the planned curriculum.

The PTHPT will be kept only long enough to record the scores. I will be the only one who has access to them and they will be destroyed once scores have been recorded. Student names will be eliminated and codes will be substituted following completion of the testing. Please consider allowing your child to participate in this study.

Thank you,

Roxianne Vincent

- -

I hereby authorize Mrs. Vincent to administer the Primary Test of Higher Processes of Thinking prior to and following the lessons on volume to ___________________________.
I have read and fully understand the consent form. I sign it freely and voluntarily.

______________________________ ____________________________

signature of parent date

April __, 1993

Dear Parents,

I am working on a Masters thesis and have permission from Tulsa Public School District to conduct a study on the effects of teacher questioning on content knowledge and cognitive abilities. I will attempt to compare the differences between an innovative teacher questioning strategy and a traditional teaching strategy on content knowledge, divergent cognitive abilities, and convergent cognitive abilities. The study will be conducted during fourth quarter. The experiment is designed to use eight 30-minute lessons involving traditional techniques about the concept of volume. The Primary Test of Higher Processes of Thinking (PTHPT) will be administered prior to the lessons to arrive at a pretest score and following the series of lessons to arrive at a posttest score.

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The PTHPT will be kept only long enough to record the scores. I will be the only one who has access to them and they will be destroyed once scores have been recorded. Student names will be eliminated and codes will be substituted following completion of the testing. Please consider allowing your child to participate in this study.

Thank you,

Roxianne Vincent

- -

I hereby authorize Mrs. Vincent to administer the Primary Test of Higher Processes of Thinking prior to and following the lessons on volume to ____________________________.
I have read and fully understand the consent form. I sign it freely and voluntarily.

______________________________ ______________________________
signature of parent date

APPENDIX C

PRIMARY TEST OF HIGHER
PROCESSES OF THINKING

PRIMARY TEST OF HIGHER PROCESSES OF THINKING

by

Winnie V. Williams
Central Wesleyan College
Central, S.C.

Designed for use
with gifted students
grades 2 - 4

Student's name ____________________

Date ____________________

		SCORE	
Section I	Convergent Production	______	
Section II	Convergent Analogies	______	
Section III	Sequential Relationships	______	
Section IV	Logic	______	
Section V	Deductive Reasoning	______	
Total score items I - V			______
Section VI	Divergent Thinking		
	Item 51	______	
	Item 52	______	
	Item 53	______	
	Item 54	______	
	Item 55	______	
Total score items 51 - 55			______
GRAND TOTAL			______

ADMINISTRATION

The test may be administered either to a group or to an individual.

TIME LIMITS

Aproximate time required is 45 minutes, which does not include a recommended 10 minute break after completion of Section IV. Additional time may be required between each section for instruction. The established time limits allows most students an opportunity to try all of the items. Each student is to close his booklet if he completes a section before time is up.

At the completion of a section, before time is called, a student must not be allowed to go back to a previous section. If all students complete a test section in les than the specified time, the examiner should proceed to the next section.

CAUTION AGAINST COACHING

Instructions are read at the beginning of each section. It is necessary that students understand clearly the directions before timing begins. The correct response should in no way be indicated for items other than the example.

BREAK PERIOD

A break period of 10 minutes or more is recommended between Section IV and Section V. This could be a lunch period, recess, or a regular class activity. The booklets should be collected before a break period and distributed at the beginning of Section V.

SCORING

Responses are marked directly in the test booklet (answers are on page ____). Each item counts one point in Section I through Section V. Section VI assesses a student's divergent thinking. In scoring this section of the test one needs to be cognizant of fluency (number of responses), flexibility (adapting to change), and elaboration (expression in great detail). Points are awarded to Section VI in the following manner.

<u>Fluency</u>

1 to 4 responses related to subject - ½ point
5 to 8 responses related to subject - 1 point
9 to 12 responses related to subject - 1½ points
13+ responses related to subject - 2 points

Flexibility

The student's score is determined by how often he changes ideas in his responses. Example item number 51:

splint for leg - 1 idea		This student would receive 5 points for flexibility.
use as a staff - 1 idea		
fishing pole - 1 idea		
build a hut		
build a house - 1 idea		
make a fire - 1 idea		

1 to 4 changes in ideas - ½ point
5 to 8 changes in ideas - 1 point
9 to 12 changes in ideas - 1½ points
13+ changes in ideas - 2 points

Elaboration

Following are examples from each item:

51. Make a sling shot and send a note calling for help. Make a ladder and climb into a tree and look for nearest house.

52. Make an underground cave and put tent over it. Make a spear to kill animals to eat.

53. Glue them together into styrofoam to stretch needle work before framing. Build car and trailor with help of papier mache.

54. Make it with dividers so no one could see your work. Have special sides to close o big, heavy notebooks won't fall out.

55. The Scared Moments of Sam and Tom in the Swift River Current. Rescue of Two Boys in Danger by the Riverboat.

1 to 4 items with elaboration - ½ point
5 to 8 items with elaboration - 1 point
9 to 12 items with elaboration - 1½ points
13+ items with elaboration - 2 points

Total number of points that may be awarded on Section VI is 30 (maximum of 6 points for each item 51 - 55). The entire test has a grand total of 80 points. A provision is made on cover sheet for recording the scores.

SECTION I

Select the word in the box that best goes with each set of words. Do not use any word more than once.

Example: ___J___ rake, shovel, pick

Time limit - 4 minutes

______ 1. hand, foot, hair

______ 2. bed, sheet, sleep

______ 3. orange, bread, soup

______ 4. jar, bottle, pitcher

______ 5. sofa, box, stool

______ 6. button, cloth, needle

______ 7. school, book, pencil

______ 8. yield, stop, railroad

______ 9. petal, root, bark

______10. hot, sun, bright

a.	eyes
b.	stem
c.	exit
d.	quilt
e.	cream
f.	scissors
g.	paper
h.	chair
i.	fire
j.	hoe
k.	frame
l.	cup

S T O P! Please close your text book. Your teacher will tell you when to turn to the next section.

SECTION II

Place the letter in the blank that best completes the sentence.

Example: _____ Button is to shirt as handle is to _____.
(a) dress (b) door (c) paper (d) book

Time limit - 5 minutes

_____11. Puppy is to dog as kitten is to _____.
(a) chicken (b) cat (c) calf (d) bird

_____12. Light is to day as dark is to _____.
(a) moon (b) night (c) blink (d) brown

_____13. Lion is to circus as bed is to _____.
(a) doll (b) window (c) dog (d) house

_____14. Heat is related to fire as cold is related to ___.
(a) ice (b) winter (c) jacket (d) eskimoes

_____15. Leaf is to tree as toe is to _____.
(a) snake (b) body (c) hand (d) shoe

_____16. Shirt is to clothing as corn is to _____.
(a) girl (b) garden (c) road (d) seed

_____17. Peeling is to apple as skin is to _____.
(a) snake (b) tree (c) hair (d) bed

_____18. Cage is to bird as fence is to _____.
(a) road (b) cow (c) gate (d) flower

_____19. Author is related to paper as painter is to ____.
(a) oil (b) brush (c) tree (d) canvas

_____20. Wing is to bird as leg is to _____.
(a) foot (b) pillow (c) dog (d) house

S T O P ! Please close your test book. Your teacher will tell you when to turn to the next section.

SECTION III

Read all of the section "Taking a Trip". The sentences are not in correct order. Place a "1" beside the sentence that tells what happened first. Place "2" by what happened second and so forth. There are 6 sentences that complete the story. Complete "Plant a Garden" in the same way.

Time limit - 4 minutes.

Taking a Trip

______21. Play games while riding.

______22. Stop at motel.

______23. Pack suitcases.

______24. Go swimming at hotel pool.

______25. Load car.

______26. Lock house.

______27. Unpack suitcases.

______28. Plan where to go.

Plant a Garden

______29. Harvest the vegetables.

______30. Plant the seed.

______31. Decide when and where to plant a garden.

______32. Hoe around the small plants.

______33. Buy the seed.

______34. First decide what you want to grow.

S T O P ! Please close your text book. Your teacher will tell you when to turn to the next section.

SECTION IV

Read each problem and decide if there are enough facts given to solve the problem. Check "yes" or "no". You do not have to work the problem.

Example: Sam had 7 dogs and he wanted to give 2 dogs to each of his friends. Did he have enough dogs to do so?

______yes

______no

time limit - 5 minutes

35. A horse weighs 3 times as much as a dog. How much does the dog weigh?

______yes

______no

36. There are 12 children to go in cars to the circus. All girls want to ride together. How many cars are needed?

______yes

______no

37. Jane sold 25 glasses of lemonade. Large glasses were 10¢ each and small glasses were 7¢ each. How much money did she make?

______yes

______no

38. Sam had 24 worms. It took 2 worms to catch each fish. Three fish go away. How many fish were left?

______yes

______no

(CONTINUES ON THE NEXT PAGE)

SECTION IV
CONTINUED

39. There wer 10 girls at the school party. Twice as many boys came as girls. Half as many parents came as did girls. How many people were present?

______yes

______no

40. A dog catches 16 rabbits in a week. How many does he average catching a day.

______yes

______no

41. Mary is shorter than Sue. Sue is taller than Amy. Who is the shortest?

______yes

______no

42. John has 27¢ in coins. He has 2 pennies and 1 dimes. What other coins does he have?

______yes

______no

S T O P ! Please close your text book. Your teacher will tell you when to turn to the next section.

SECTION V

You are to pretend that A and B are true statements. Since A and B are true, is C a good conclusion? Check "yes" or "no".

Example: A. All peaches are pink.
B. Pink peaches are good to eat.
C. Therefore, all peaches are good to eat.

______yes

______no

Time limit - 5 minutes

43. A. All flowers bloom.
B. All roses are flowers.
C. Therefore, all roses bloom.

______ yes

______ no

44. A. Ann likes to eat corn; Jenny likes to eat fish.
B. Both girls are blond.
C. Therefore, all blonds like fish and corn.

______ yes

______ no

45. A. A lady bug can fly.
B. A lady bug is an insect.
C. Therefore, all insects can fly.

______ yes

______ no

46. A. All boys have red hair.
B. Boys with red hair are smart.
C. Therefore, all boys are smart.

______ yes

______ no

SECTION V
CONTINUED

47. A. The wardos in the box are square.
    B. Square things are sticky.
    C. Therefore, all sticky things in the box are square.

______ yes

______ no

48. A. All cats are yellow or brown.
    B. Yellow is a beautiful color.
    C. Therefore, all cats are beautiful.

______ yes

______ no

49. A. All birds like parmons.
    B. Parmons come from the desert and are yellow.
    C. Therefore, all yellow parmons are eaten by birds.

______ yes

______ no

50. A. No one can make an A without studying.
    B. All students who are intelligent study.
    C. Therefore, all students who study make A's.

______ yes

______ no

S T O P ! Please close your test book. Your teacher will tell you when to turn to the next section.

SECTION VI

Read each of the following statements and list as many unusual answers as you can with one or more words. You will have 3 minutes to complete each item.

Example: List different ways brick could be used for building a house.

Build a toy box in child's room.

Build a brick oven with metal door for baking bread.

Box beside fireplace to store firewood.

Patio porch with holders for flower pots.

Round fireplace with very large brick.

Love seat.

51. You are lost in the woods. List ways you could use sticks to help you.

S T O P ! Please close your test book. Your teacher will tell you when to turn to the next section.

SECTION VI
CONTINUED

52. You are sleeping in a tent. The wind and rain causes your tent to fall down. List ways to keep dry.

Time limit - 3 minutes

<u>S T O P !</u> Please close your test book. Your teacher will tell you when to turn to the next section.

SECTION VI
CONTINUED

53. List ways to build somethings using toothpicks as one of your supplies.

Time limit - 3 minutes

S T O P ! Please close your test book. Your teacher will tell you when to turn to the next section.

SECTION VI
CONTINUED

54. List ways you could improve your school desk.

Time limit - 3 minutes

S T O P ! Please close your test book. Your teacher will tell you when to turn to the next section.

SECTION VI
CONTINUED

55. Sam and Tom, while fishing from a boat, drift into the main current of the river and are quickly in great danger. Struggling with paddles they are unable to row out of the current. Suddenly they see a large river boat which comes to their rescue. Give titles that fit the story.

Time limit - 3 minutes

S T O P ! Please close your test book. Your teacher will tell you when to turn to the next section.

APPENDIX D

CONTENT KNOWLEDGE TEST
ON VOLUME

NAME ______________________________

CHAPTER TEST (VOLUME)

In the blank on the left write the letter of the instrument you would need to answer each question.

__A__ 1. What is the volume of the shampoo in a bottle?
a. graduate b. ruler

__B__ 2. What is the volume of a box?
a. graduate b. ruler

__A__ 3. What tool is used to measure the volume of a liquid?
a. graduate b. ruler

Sequence the five (5) steps needed to find the volume of a marble.

__3__ 4. Record the new level of the water, which is 52 mL.

__4__ 5. Subtract the original level.

__1__ 6. Fill the graduate to 50 mL with water.

__5__ 7. Volume = 2 mL

__2__ 8. Drop the marble into the water.

In the blank on the left write T if the statement is true or F if the statement is false.

__F__ 9. A balance is used to measure volume.

__F__ 10. Density is the amount of space an object takes up.

APPENDIX E

TRADITIONAL STRATEGY LESSON PLANS

APPENDIX E

TRADITIONAL LESSON 1

I. Generalization

Volume is a measure of the amount of space that matter takes up. It is measured in units called cubic centimeters.

II. Concept

The volume of water shifted because of a solid is displacement.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
		Provide story of Archimedes.
		Have students remove books from desk or sit in a circle to listen to the story.
Students will identify Archimedes' solution in the third century to the problem of the composition of King Hiero II's crown.	Who was Archimedes?	Request students speak clearly and one at a time to answer questions.
	What was his discovery?	Accept all answers.
Students will define displacement.	What is displacement?	
	How is Archimedes' discovery of displacement applied to modern day science?	How did Archimedes' discovery occur?

TRADITIONAL LESSON 2

I. Generalization

Volume is a measure of the amount of space that matter takes up.

II. Concept

The volume of regular solids, liquids, and irregular objects are measured.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will read the text about volume silently and orally. Students will define the term volume.	Define the term volume.	Silver Burdett pg 100-113 Emphasize the states of matter as solids, liquids, and irregular solids.
	What are the names of some kinds of cubes?	Emphasize cubes have three dimensions... height, width, length V = cm x cm x cm
	What liquids to you buy that are measured in liters?	soft drinks, milk, juice, gasoline,
	What are some irregularly shaped solids?	marble, jars, bottles, vases, rocks, butter,

TRADITIONAL LESSON 3

I. Generalization

Volume is a measure of the amount of space that matter takes up.

II. Concept

The volume of regular solids are measured in cubic centimeters. Liquids and irregular solids are measured in milliliters.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
		Provide graduates and rulers (cm).
Students will identify the unit of measurement used to identify volume.	What instrument is used to measure volume of a solid?	
	What units of measurement are used to identify solids?	solids: cm^3 liquids: mL irregular: mL
Students will compare the units of measure for various states of matter.	What instrument is used to measure the volume of a liquid?	The curve of the liquid measured in a graduate is called the meniscus. The most accurate way to measure volume is to read the unit closest to the bottom of the meniscus.
	What unit of measurement is used to identify liquids?	
	What instrument is used to measure the volume of an irregularly shaped solid?	Milliliters are small units of volume. Large units of volume are measured in liters. 1 L = 1,000 mL
	What units of measurement are used to identify the volume of irregularly shaped solids?	A mL is the same amount of volume as the cube. $1\ mL = 1\ cm^3$
		Invite students to collect empty containers at home to make a display of various volumes for the next lesson.

TRADITIONAL LESSON 4

I. Generalization

Volume is a measure of the amount of space that matter takes up.

II. Concept

The volume of liquid can be measured using graduates.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
		Display the containers: Observe the containers:
Students will hypothesize which containers have the greatest volume.	Which container has the greatest volume? Least?	
Students will determine which containers have the greatest volume?	How will you measure the volume of the different containers?	ON THE BOARD: Hypothesis: Container Volume
Students will use graduates to measure the volume of liquids.	Which container had the greatest volume? Least?	#1 #2 #3 : #8
	Was your prediction accurate?	My hypothesis was ___.

TRADITIONAL LESSON 5

I. Generalization

Volume is the measure of the amount of space that matter takes up.

II. Concept

The volume of irregularly shaped solids can be measured using displacement.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will use graduates to measure the volume of irregularly shaped solids.	Observe irregularly shaped solids. How might you measure the volume of irregularly shaped solids?	Provide irregularly shaped solids (rocks, marbles,...) Emphasize that displacement is a good method for determining the volume of an irregularly shaped solid.
Students will determine which objects have the greatest volume.	What is the water level of the graduate? When the marble is placed in the graduate, what happens to the water level? What is the difference between the starting level and rising level? What is the volume of the irregularly shaped solid?	Demonstrate measuring the volume of irregularly shaped solids using displacement. ON THE BOARD SOLID — START LEVEL — RISE LEVEL — VOL

TRADITIONAL LESSON 6

I. Generalization

Volume is a measure of the amount of space that matter takes up.

II. Concept

Materials and procedure are two steps to the scientific method that are necessary to complete an experiment.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
		Provide a story about Archimedes and a lab report.
Students will research Archimedes' experiment.	What materials did Archimedes use to conduct his experiment?	Circle the materials in the story.
Students will identify the materials and the procedure necessary for Archimedes to conduct his experiment.	What steps did Archimedes follow to conduct his experiment?	Identify the steps Archimedes used with capital letters.

Name ____________________

CHALLENGE / CRITICAL THINKING

Over 2000 years ago a scientist named Archimedes lived in Greece. Archimedes was asked by a king to determine whether his crown was made of pure gold. After much thought, Archimedes developed an experiment.

Use reference books to find out about Archimedes' experiment. Then use the space below to list the materials and steps needed to copy the experiment. Identify the steps with capital letters.

Materials ____________________

____

Procedure

____

____

____

____

____

____

____

____

____

____

____

____

TRADITIONAL LESSON 7

I. Generalization

Volume is a measure of the amount of space matter takes up.

II. Concept

Oral presentations develop listening and communication skills. Oral communication and the ability to listen and attend are essential skills for effective leadership.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will present the scientific method Archimedes' used to the class.	Who will present the scientific method? Were all the steps to Archimedes' procedure mentioned?	Listen to each student respectfully. Use one's own scientific method as an outline for listening to presenters.

TRADITIONAL LESSON 8

I. Generalization

Volume is the measure of the amount of space matter takes up.

II. Concept

Using terminology appropriate to science, the technical writing provides information about the comprehension of content.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will list the steps needed to find the volume of solids and irregularly shaped solids.	What steps are needed to find the volume of a solid? What steps are needed to find the volume of an irregularly shaped solid?	List the steps. Number the steps. Listen respectfully to all students.

APPENDIX F

INNOVATIVE STRATEGY LESSON PLANS

INNOVATIVE STRATEGY 1

I. Generalization

Volume is the measure of the amount of space matter takes up.

II. Concept

Archimedes discovered the volume of an irregularly shaped object through displacement.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
		Provide the story of Archimedes.
		Have students remove books from desk or sit in a circle to listen to the story.
Student will identify Archimedes' solution in the third century to the problem of the composition of King Hiero II's crown.	Who was Archimedes? What was his discovery?	Request students speak clearly and one at a time to answer questions
		Accept all answers.
Students will define displacement.	What is displacement?	
	How is Archimedes' discovery of displacement applied to modern day science?	How did Archimedes' discovery occur?
	For what reason did Archimedes experiment with displacement?	

INNOVATIVE STRATEGY 2

I. Generalization

Volume is the measure of the amount of space matter takes up.

II. Concept

The measure of one dimension is length, the measure of two dimensions is area, and the measure of three dimensions is volume.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will make various three-dimension shapes using cubigrams.		Provide cubigrams.
		Extend arms and explain distance between hands as length (one dimension). Bend arms at elbows and explain area (two dimensions). Move arms around and explain volume (three dimensions). Present a definition for each dimension.
	What instruments are used to measure length? area? volume?	
	What units of measurement are used for length? area? volume?	length = cm area = cm x cm = cm^2 volume = cm x cm x cm =cm^3
	How many different shapes can you create in order to measure volume of various objects?	Have students snap together cubes representing 2 x 3 x 4, 2 x 2 x 2, and 3 x 3 x 3.

INNOVATIVE STRATEGY 3

I. Generalization

Volume is a measure of the amount of space matter takes up.

II. Concept

Finding the volume of a solid is a matter of counting cubes.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
		Draw a 5 x 4 grid of squares on the board. Extend this grid backward into 3 dimensions turning the squares into cubes. Call the length of each cube one unit. Show how to find the volume of the block by (1) counting all cubes (2) multiplying L x W x
Students will count cubic units to find the volume of solid cubes.	How many cubes are in each solid block?	
Students will multiply length, width, and height of solid blocks to find the volume.	In what ways might one find the volume of a solid?	Emphasize find the volume is simply counting or multiplying L x H x W. Try multiplying one dimension by another, to find the number of cubes in a single layer, then multiply the result by the total number of layers.
Students will measure the volume of solid cubes created previously.	What are the volumes of the various solid blocks?	
Students will use cubic centimeters as a unit of measurement for volume.	For what reasons do we find the volume of solids?	Ask for reasoning.
Students will justify why we find the volume of objects.		ON THE BOARD <u>OBJECTS LENGTH VOLUME</u> 2x3x4 2x2x2 3x3x3 ON WORKSHEET chart results

INNOVATIVE STRATEGY 4

I. Generalization

Volume is the measure of the amount of space matter takes up.

II. Concept

Volume can be measure through displacement.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will observe objects with the same volume made of different matter.		Provide aluminum, brass, and acrylic blocks.
Students will compare the similarities in the volume of differing matter.	In what ways are the three objects similar? Different?	Measure and chart the length of the three sides of each object. ON THE BOARD OBJECT L x W x H VOLUME
	What changes have occured when the matter was placed in the graduate of water? In what ways does the volume of the solids compare? In what ways are the solids different?	Fill a graduate with water to as close to 50 mL as possible. Make sure your eye is level with the top when reading the volume of the liquid in a graduate. Tilt the graduate and slide one of the solids into it. Observe.
Students will define displacement in their own terms.	In what ways might we define displacement?	Read the water level again. Chart the result. ON THE BOARD OBJECT GRAD/WATER WATER/SOLID VOL List steps to finding volume of a solid through displacement.

INNOVATIVE STRATEGY 5

I. Generalization

Volume is the measure of the amount of space matter takes up.

II. Concept

Displacement is a good method for determining volume of irregularly shaped solids.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will find the volume of irregularly shaped solids.	In what ways does the water level change when you add an irregularly shaped solid to the graduate?	Provide irregularly shaped solids (marble, rocks, butter, etc.)
Students will measure and chart the volumes of irregularly shaped solids.		Measure and chart the volume of several irregularly shaped solids.
	What is the difference between the starting level and the rising level?	ON THE BOARD
	What is the volume of the irregularly shaped solid?	<u>OBJECT</u> <u>GRAD/ WATER</u> <u>WATER/ SOLID</u> <u>VOL</u>
	In what ways might we find the volume of an irregularly shaped solid?	Chart results. List the steps necessary to measure the volume of irregularly shaped solids.
		Collect various size jars for display in the next lesson.

INNOVATIVE STRATEGY 6

I. Generalization

Volume is the measure of the amount of space matter takes up.

II. Concept

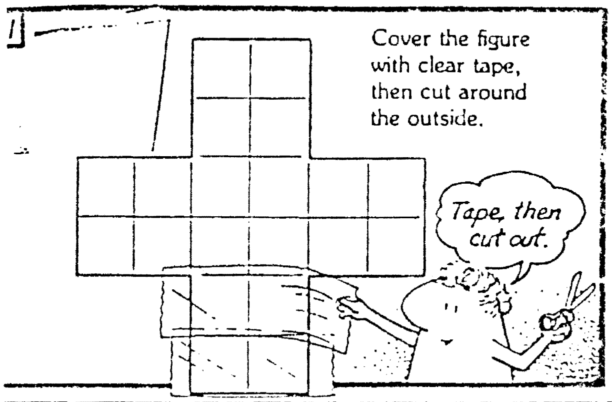
Volume can be measured in unlabeled jars.

III. Discussion Plan

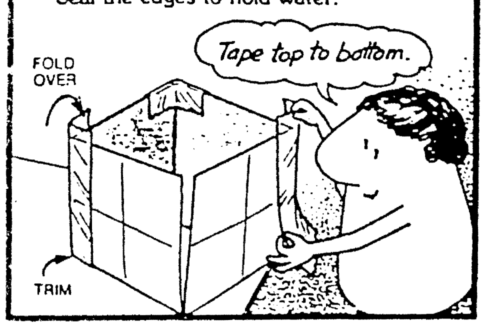
BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will measure the volume of unlabeled containers.		Cover the pattern with clear tape. Fold up all four flaps to make a block. Seal the edges to hold water. Make several for students who have difficulty. Bend a paper clip at a right angle and afix it to the side of the box to make a handle.
	How many boxes of water are used to measure 100mL?	Explain measuring 100mL of water ito a small jar and mark the water level with masking tape.
	In what ways can the volume of an unlabeled container be measured?	

DRY MEASURE / LIQUID MEASURE

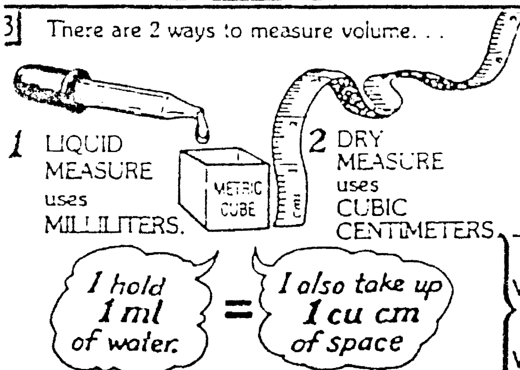
1 Cover the figure with clear tape, then cut around the outside.

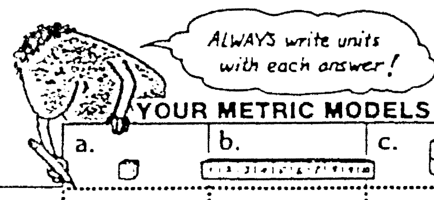


2 Fold up all 4 flaps to make a box. Seal the edges to hold water.



3 There are 2 ways to measure volume. . . . . . Understand this, and you can fill in the table.

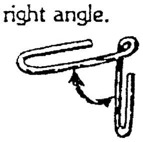




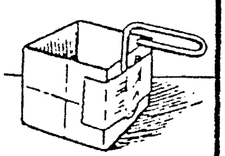
YOUR METRIC MODELS

	a.	b.	c.
DRY VOLUME?			
LIQUID VOLUME?			

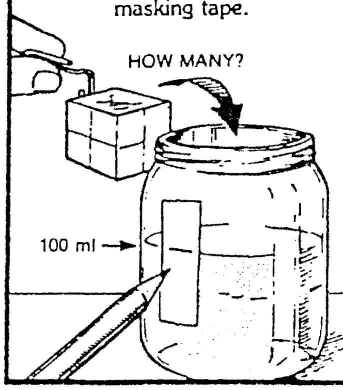
4 Bend out a paper clip at a right angle.



Tape it to the side of the box you made.



5 Measure 100 ml of water into a small jar. Mark the water level on masking tape.



Tell how you measured the water.

Tape your name to the box and jar, and save them.

INNOVATIVE STRATEGY 7

I. Generalization

Volume is the measure of the amount of space matter takes up.

II. Concept

Length measures one dimension, area measures two dimensions, and volume measures three dimensions.

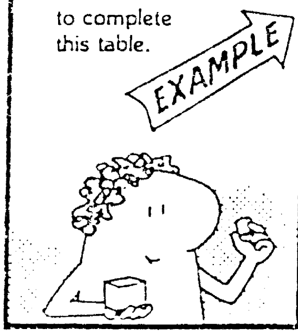
III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will differentiate between length, area, and volume of matter while completing a table.	Using the given pattern, what is being measured? What dimensions are being measured?	Have several patterns made for students who find it difficult.
Students will find the length, area, and volume of matter.	What are the dimensions of the different measures?	
Students will identify the unit of measurements for length, area, and volume.	What are the units of measurements used in the various dimensions?	
Students will cite examples of length, area, and volume visible in the room.	What examples can be found of length in the room? of area? of volume?	

WHICH DIMENSION?

1 Cut, fold, and tape the box pattern.

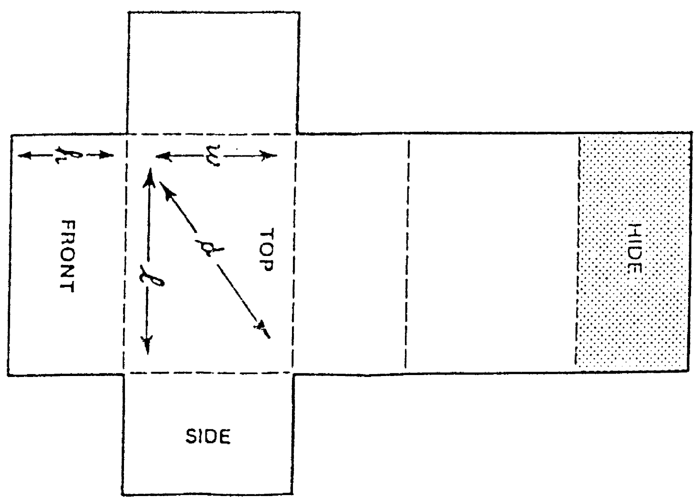
Then use your metric models to complete this table.



Measure what?	Length, Area, or Volume?	Answer? Units?
h	*length*	*2 cm*
w		
top		
front		
whole box		
l		
side		
d		

2 Look around your room. Find 3 examples of each.

LENGTH (1 dimension)	AREA (2 dimensions)	VOLUME (3 dimensions)
a. *the edge of a door.*	d.	g.
b.	e.	h.
c.	f.	i.



INNOVATIVE STRATEGY 8

I. Generalization

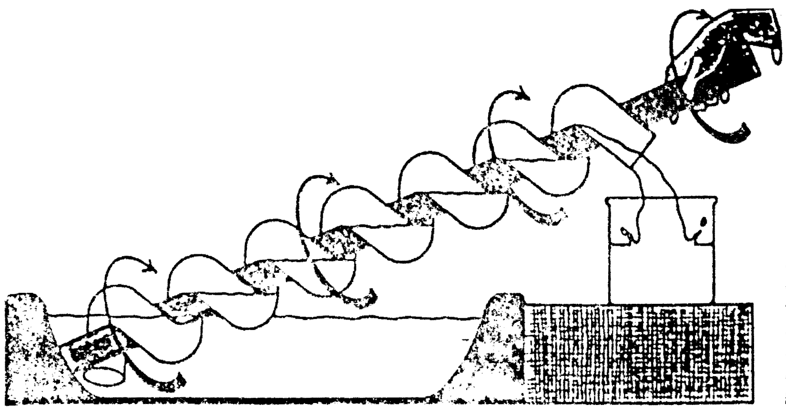
Volume is the measure of the amount of space matter takes up.

II. Concept

Using terminology appropriate to science, the technical writing provides information about the comprehension of content.

III. Discussion Plan

BEHAVIORAL OBJECTIVES	FOCUS QUESTIONS	SUPPORT PROCEDURES
Students will list the steps needed to find the volume of solids and irregularly shaped solids.	What steps are needed to find the volume of a solid? What steps are needed to find the volume of an irregularly shaped solid?	List the steps. Number the steps. Listen respectfully to all students.



One of Archimedes' many clever inventions is the water screw. As it turns, water is scooped into the lower end and moves upward through the coils. You can make this simple device with a few feet of flexible tubing, a sturdy rod such as a broomstick, and some cloth tape to hold the top and bottom ends of the tubing in place.

ARCHIMEDES (287?–212 B.C.)

"Give me a place to stand, and I can move the world." The man who is supposed to have spoken those words was Archimedes, a Greek mathematician and inventor who lived some 2,200 years ago. It was not an idle boast. Archimedes was one of the first people to develop the science of mechanics. He understood that a person with a mechanical device such as a lever could move many times his or her own weight. Challenged by the king to prove his point, Archimedes did so. He arranged a device that allowed the king to move a large ship all by himself.

Archimedes was born about 287 B.C., in Syracuse, a Greek settlement on the island of Sicily. Little is known about his personal life except that his father was an astronomer and may have been related to the king of Syracuse. Also, at some time in his life, Archimedes studied in Alexandria, Egypt, a center of Greek culture.

Archimedes is best known for his many inventions. Among other things, he invented a compound pulley; a sphere that imitated the motions of the heavenly bodies; and a water screw to raise water. He himself most valued his work in mathematics and scientific theory. But his fame rests on inventions and the legends that grew up around him.

One legend tells how Archimedes made his most important discovery. The king, it seems, had ordered a new crown. It was supposed to be made of solid gold, but the king suspected the jeweler of cheating. He asked Archimedes to tell him if the crown was solid gold.

At first Archimedes could not think how to do this. Then one day the answer came to him as he was getting into his bath. Legend has it that he rushed naked into the streets shouting, "Eureka [I have found it]!"

What had happened was very simple. The bath was full, and it overflowed as Archimedes climbed into it. This started him thinking about the way objects displace water. And he suddenly saw how to solve his problem.

First he took a quantity of gold and a quantity of silver, each equal in weight to the crown. The weights of gold and silver were equal, but their volumes were not. The silver, being less dense, was bulkier than the gold.

Next Archimedes took two vessels filled to the brim with water. He placed the gold in one and the silver in the other. The silver, being bulkier, caused more water to overflow. Archimedes concluded that when a solid sinks in water, it displaces its own volume of water.

Finally he tested the crown against the equal weight of gold. When placed in water, the crown caused more overflow. Therefore, the crown had to contain metal other than gold. This metal made it bulkier and caused the greater overflow.

Further experiments resulted in what is now known as Archimedes' principle: An object in a fluid is buoyed up by a force equal to the weight of the displaced fluid.

When Archimedes was an old man, the Romans attacked Syracuse. He turned his creative mind to defense and invented several weapons that held off the enemy. It is claimed that he built a huge system of mirrors that burned Roman ships by concentrating the sun's rays on them. Syracuse, however, was defeated in 212 B.C., and Archimedes was killed. The story goes that he was drawing mathematical figures in the sand when a Roman soldier struck him down. But Archimedes was so highly respected that the Roman commander buried him with full honors.

JOHN S. BOWMAN
Author, *Prehistory and Early Civilization*

TRADITIONAL STRATEGY WORKSHEET

LESSON #3

VOLUME	UNIT OF MEASURE	INSTRUMENT
solid		
liquid		
irregular object		

LESSON #4

HYPOTHESIS: ____

____

____

# OF JAR	VOLUME	RANK ORDER

My hypothesis was ______________________________________.

LESSON #5

SOLID	GRADUATE & WATER	WATER & SOLID	VOLUME

VOLUME

Lesson #8

List the steps necessary for finding the volume of the following objects.

SOLID

1.

2.

3.

4.

5.

LIQUID

1.

2.

3.

4.

5.

IRREGULAR OBJECT

1.

2.

3.

4.

5.

APPENDIX G

TABLES

TABLE I

PRE-TREATMENT t-TEST

Sample	TRADITIONAL		INNOVATIVE		t-score
	Mean	Standard Deviation	Mean	Standard Deviation	
CONVERGENT PRODUCTION	37.21	4.50	37.83	4.52	.613
DIVERGENT PRODUCTION	7.12	2.19	6.77	1.94	.762
CONTENT KNOWLEDGE	65.58	452.56	63.00	17.34	.595

significance, $p > .01$

TABLE II

TWO-WAY ANOVA SUMMARY TABLE
FOR DIVERGENT PRODUCTION

Sources of Variance	Degree of Freedom	Sums of Squares	Mean Squares	F
Method	1	27.379	27.379	1.0597
Test	1	400.838	400.83	18.85262
M X T	1	8.765	8.765	.412
S/M	81	2092.671	25.835	
T X S / M	81	1722.195	21.261	

significance, p < .01

TABLE III

TWO-WAY ANOVA SUMMARY TABLE
FOR CONVERGENT PRODUCTION

Sources of Variance	Degree of Freedom	Sums of Squares	Mean Squares	F
Method	1	4.674	4.674	.1673
Test	1	361.618	361.618	41.0113
M X T	1	3.217	3.217	.3691
S/M	81	2263.289	27.941	
T X S /M	81	714.218	8.817	

significance, $p < .01$

TABLE IV

TWO-WAY ANOVA SUMMARY TABLE
FOR CONTENT KNOWLEDGE

Sources of Variance	Degree of Freedom	Sums of Squares	Mean Squares	F
Method	1	49.54	49.54	.1178
Test	1	24901.27	24901.27	120.538
M X T	1	91.79	91.79	.444
S/M	81	34043.25	420.2871	
T X S /M	81	16733.47	206.586	

significance, $p < .01$

TABLE V

POST-TREATMENT t-TEST

Sample	TRADITIONAL Mean	TRADITIONAL Standard Deviation	INNOVATIVE Mean	INNOVATIVE Standard Deviation	t-score
CONVERGENT PRODUCTION	40.44	3.88	40.50	4.00	.097
DIVERGENT PRODUCTION	10.697	8.63	9.43	2.50	0.907
CONTENT KNOWLEDGE	88.60	16.50	89.00	13.75	0.118

significance, $p > .01$

VITA

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