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CONCEPTUAL DEVELOPMENT AND RETENTION WITHIN THE LEARNING CYCLE

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Abstract

This research was designed to achieve two goals: (1) examine concept development and retention within the learning cycle and (2) examine how students' concept development is mediated by classroom discussions and the students' small cooperative learning group. Forty-eight sixth-grade students and one teacher at an urban middle school participated in the study. The research utilized both quantitative and qualitative analyses. Quantitative assessments included a concept mapping technique as well as teacher generated multiple choice tests. Preliminary quantitative analysis found that students' reading levels had an effect on students' pretest scores in both the concept mapping and the multiple-choice assessment. Therefore, a covariant design was implemented for the quantitative analyses.

Quantitative analysis techniques were used to examine concept development and retention, it was discovered that the students' concept knowledge increased significantly from the time of the conclusion of the term introduction phase to the conclusion of the expansion phase. These findings would indicate that all three phases

of the learning cycle are necessary for conceptual development. However, quantitative analyses of concept maps indicated that this is not true for all students. Individual students showed evidence of concept development and integration at each phase. Therefore, concept development is individualized and all phases of the learning cycle are not necessary for all students. As a result, individual's assimilation, disequilibration, accommodation and organization may not correlate with the phases of the learning cycle. Quantitative analysis also indicated a significant decrease in the retention of concepts over time.

Qualitative analyses was used to examine how students' concept development is mediated by classroom discussions and the students' small cooperative learning group. It was discovered that there was a correlation between teacher-student interaction and small-group interaction and concept mediation. Therefore, students who had a high level of teacher-student dialogue which utilized teacher led discussions with integrated scaffolding techniques where the same students who mediated the ideas within the small group discussions. Those students whose teacher-student interactions consisted of dialogue with little positive teacher feedback made no contributions within the small group regardless of their level of concept development.

CHAPTER 1

INTRODUCTION

In the past decade, science educators have begun to shift from an emphasis on factual knowledge to an emphasis on the processes involved in how a student constructs knowledge (Tobin & Espinet, 1989; Tobin, Espinet, Byrd & Adams, 1988; Tobin & Gallagher, 1987). As a consequence of this shift, research has begun to focus on learners' conceptual development and organization (Tobin, Tippens, Gallard, 1994). However, in order to fully understand learners' conceptual development and organization, students' interactions with their learning environment which may influence these processes should be an important research consideration.

The nature of a laboratory-based science classroom, including the students' interactive role with the whole class, a cooperative learning laboratory group, and the classroom teacher, as well as the students' concrete experience with an experimental procedure, provides an ideal opportunity for this type of research. How these classroom discussions, collaborative cooperative learning groups, and teacher interactions may influence and mediate the students' conceptual development and organization is a significant research area. These interactions should be further studied in order to better understand how a student develops science concepts within the classroom. Therefore, cooperative learning and its various components of collaborative and mediating roles have become significant factors in science education research (Anderson, 1994; Kelly & Crawford, 1996; Richmond & Striley, 1996; Roth, 1996).

Considering the importance of the these collaborative and mediating roles in science classrooms, it is surprising that more is not known about these processes. Tobin, Tippins, and Gallard (1994) pointed out that a review of the literature found little empirical research on the teacher's mediatory role in cooperative learning, the roles of negotiation and consensus building in the collaborative process, or how collaborative learning develops. Tobin (1990) noted that, although cooperative learning studies in the science education field abound, the focus of these studies has not been on the learning process itself. Therefore, the studies that are most needed involve close examination of the negotiated processes, how students construct and reconstruct ideas, test them with their peers, and transform them as a result of negotiation (Tobin, Tippins, and Gallard, 1994).

In order to study these processes, the classroom organization and teaching methodology must be conducive to cooperative learning. One type of teaching methodology that easily lends itself to this type of research in the field of science is the learning cycle. The learning cycle is composed of three phases that include: (a) an experimental exploration phase, (b) a teacher facilitated term introduction phase, and (c) an expansion phase. In the learning cycle exploration phase the students are given the opportunity to manipulate materials and observe the results with teacher directions. In the term introduction phase the teacher introduces the terms that refer to the patterns discovered during the exploration phase. The last phase, the expansion phase, allows the student to apply the new terms to additional examples.

Many exploration and expansion phase activities of learning cycle investigations are conducted by students working in small groups. Students within these groups are required to communicate with one another, cooperatively conduct experiments, and gather data. However, how students use knowledge from an investigation to negotiate meaning in a collaborative cooperative learning group and how they use possible alternate concepts to construct, reconstruct, and transform ideas as a result of their group interaction is not fully understood. The teacher-facilitated discussions during the term introduction phase is also an important component of a learning cycle investigation. Yet, little is known about the teacher's mediatory role within any of the learning cycle phases. The questions then arise: How do the collaboratively produced conceptual understandings and discussions that evolve within the learning cycle's cooperative learning groups influence the individual student's conceptual development? How does the teacher influence the classroom discussions' mediation of the students' concept development? Clearly the constructive processes involved in how a child learns throughout the learning cycle activities and the impact of the social interaction which takes place within these activities on the individual's learning process are significant research factors.

Statement of the Problem

This study examined how sixth grade students constructed science concepts during a laboratory-based learning cycle science unit. It investigated individual student's concepts and the development of these concepts during the three phases of the learning cycle. The study also explored the mediation of the students' class and small cooperative learning group discussion on that development.

The research questions guiding this study were:

1. How do individual student's concepts develop over each of the three phases of the learning cycle?

2. How is the development of individual student's concepts mediated by classroom discussions and the students' small cooperative learning group?

3. How stable are the individual student's concepts over time?

CHAPTER 2

REVIEW OF THE LITERATURE

In 1991 the Secretary of Education and the President of the United States announced "AMERICA 2000: An Education Strategy" as a long-range plan for the American people. One of the plan's major goals is that American students will be first in the world in science achievement by the year 2000. In order to assess student progress the plan suggested changes in the National Assessment Program. These changes included the implementation of the American Achievement Tests (Alexander, 1991). These tests are based on the World Class Standards (Alexander, 1991) which represent what young Americans need to know and be able to do to be successful in today's world. These tests are currently administered on a voluntary basis in the fourth, fifth, and twelfth grades.

This goal, that U.S. students be first in science achievement, has placed new challenges on science educators. Science educators have therefore begun to undergo what Kuhn (1962) referred to as a paradigm shift. This shift has resulted in a change from an emphasis on empirical knowledge as seen in traditional classrooms to an emphasis on the processes involved in how the student constructs knowledge. This paradigm shift has resulted in a quest for research imbedded in constructivist theory that investigates the processes involved in concept development. In order to thoroughly understand the background for this study, the following literature review presents the study's theoretical framework and a discussion of the learning cycle, cooperative learning, concept development, and concept mapping.

Theoretical Framework

Constructivism is a theory that assumes knowledge is a construction of reality (Tobin, 1989). "Constructivist theories suggest that meaningful learning requires a personal restructuring of one's conceptual framework in a dynamic process punctuated by periods of conceptual equilibration, experience, disequilibration, assimilation, accommodation, and reequilibration" (Shymansky et al., 1997, p. 571). The fundamental component of the constructivist theory is that children learn by actively constructing their own knowledge. This is accomplished by comparing new information with their prior understanding, and using all of this data to work through discrepancies and come to a new understanding (Martin, Sexton, Wagner, & Gerlovich, 1994). Constructivists also believe that understanding, synthesis, eventual application, and the ability to use information in new situations should be the true goals for education (Yager, 1991).

Important aspects of the constructivist epistemology are based on the theories of Lev Vygotsky (Wandersee, Mintzes, & Novak, 1994). Vygotsky's ideas are central to contemporary efforts to analyze the human mind in terms that consider the contributions of the social interactions among individuals as well as society as a whole (Bredo & McDermott, 1992). Vygotsky believed there were four aspects to an individual's development: (a) phylogenetic or the evolutionary genetic development of the species; (b) sociocultural or the historical cultural legacy such as literacy or cultural norm; (c) ontogenetic or changes in thinking across a person's lifetime; (d) and microgenetic or the moment to moment learning by an individual. In this theory the roles of the social world and the individual are solidly intertwined and a child's cognitive development must be understood not only in the context of social interaction but also with the socio-historically developed tools, such as language, values, and norms that mediate intellectual activity (Rogoff, 1990). According to Vygotsky's developmental theory this socio-historical context is learned by the individual through interaction with other, more capable members of society.

A primary focus of Vygotsky's research is the zone of proximal development. Vygotsky (1978) theorized that the first level of development, the actual level, is already established within the child because of previously completed developmental cycles. Vygotsky also advocated the existence of a second level, the zone of proximal development, which he defines as the "The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978 p. 86).

It was this aspect of Vygotsky's theory, the zone of proximal development, which Wood, Bruner, and Ross (1976) used as a basis for the development of a process they termed scaffolding. Scaffolding occurs when a student who is not independently capable is aided by a more capable person to construct an extension from an existing conceptual framework (Appleton, 1997). Research (Campione, Brown, Ferrrara, & Bryant, 1984) has focuesed on this point by using several children of various ages, all who tested at a seven year mental development level. Results indicated that there was significant difference in their need for assistance from a more capable person in order to learn a sorting task and an even greater difference in their ability to transfer that knowledge to new situations. Their study supported Vygotsky's stand that I.Q. Is only one aspect of a child's ability to learn. It was Vygotsky's belief in the contribution of social interaction to the learner's cognitive development that has become a pivotal aspect of constructivist theory.

Additional components of constructivism have emerged from the theories of Jean Piaget. According to Piaget (1964), the central problem of intellectual development is to understand the formation, elaboration, organization, and functioning of the operational structures that constitute the basis of knowledge. In order to better explain these operational structures Piaget developed his developmental theories based on what he described as the Mental Functioning Model (Piaget, 1952). Piaget's Mental Functioning Model seeks to explain the aspect of intellectual development that deals with the invariant aspect of learning. The invariant side of learning is that portion of learning which takes place within the mind of the learner. Piaget's first general principle of mental functioning is adaptation. Adaptation may be considered in terms of the two complementary processes of assimilation and accommodation. For learning to begin, Piaget felt the learner must engage in activities that act as a stimulus to the brain. This stimulus is then "assimilated" as the learner utilizes the stimulus and incorporates it into his own psychological structures. If, however, the information taken in does not match the current thinking of the learner, a temporary imbalance occurs, an event Piaget referred to as disequilibrium. Piaget believed that disequilibrium, or cognitive conflict, is necessary for cognitive development to occur and equilibration is a necessary function of homeostasis for the learner. Cognitive development is a process of attaining equilibrium between external intrusions and previous thought and is therefore a transitional stage between assimilation and accommodation. Once equilibrium has been attained and accommodation has occurred, that is, the learner has modified his psychological structures to meet the stimulus, adaptation has taken place.

The second general principle of mental functioning is organization Piaget believed that the learner has the tendency to organize and integrate psychological structures into coherent systems. This organization acts as a framework onto which the incoming sensory data can fit. It is a framework that is continually changing its shape as assimilation, equilibration, and accommodation takes place. It is Piaget's notions of assimilation, disequilibrium and accommodation, rather than his developmental emphasis, that is particularly applicable to this research.

Although both Piaget and Vygotsky placed significant importance on the interrelationship of the individual and the environment, they differed in the importance they placed on the role of the social world in their theories. Piaget did not deny the importance of social interaction but, without a more significant discussion of the role of cultural transmission of knowledge, his explanations place considerable demands on the abilities of the individual child and imply a universal set of cognitive categories of thought and development (Confrey, 1991). However, if one looks closely at Piaget's writings it can be seen that he realized the importance of social interaction. Piaget's (1952) developmental theory stated that the learner's genetic make-up and his or her environment are mutually important to cognitive development: "The organism and the environment form an indissoluble entity . . . the two being inseparable from each other" (p. 16). Piaget (1977) also believed that the principal component of society was not the individual or the collection of individuals but was instead the relationship between individuals, a relationship that he believed endlessly modified the consciousness of the individual. Piaget pondered whether a child's logic was a social thing and in what sense it was a social thing. This was a point that he referred to when he said, "I have been bothered by . . . I have sought to put it aside, it has always returned" (Piaget, 1977, p. 204). Therefore, Piaget realized social interaction was an aspect of development; however he did not direct his research to the influences of social factors. Piaget instead focused on the involvement of the child as an individual and how his experiences with objects affected his perception. In contrast, Vygotsky placed the role of social interactions at the forefront of his theories.

When one considers the theories of Piaget and Vygotsky, the emphasis on the constructivist view of learning can easily be seen. Still, the practitioner must consider how to translate these theories into classroom practice. The type of methodology to use in order to expedite the learner's conceptual reorganization is of the utmost importance. Research has shown that techniques such as cooperative learning can be effective tool in this endeavor. However, the utilization of these techniques within the laboratory-based learning cycle framework is yet to be thoroughly investigated.

The Learning Cycle

The learning cycle is a teaching methodology based on Piaget's model of intellectual development (Karplus & Thier, 1967; Renner & Marek, 1988). The three phases of the learning cycle, exploration, term introduction, and expansion, were developed to correspond with the assimilation, accommodation, and organization principles of Piaget's mental functioning model (Lawson, Abraham, & Renner, 1989). During the student-centered exploration phase the learner is provided with laboratory-based activities to stimulate the brain and encourage assimilation and disequilibrium as described by Piaget. During the term introduction phase of the learning cycle the learner gathers, discusses, and organizes the data gathered in the exploration phase and is introduced to applicable terminology. The term introduction phase allows for Piaget's principles of accommodation of the new concept by the learner and the learner begins to organize the concept into his psychological structures. In the last phase of the learning cycle, the expansion phase, the learner is encouraged to apply the newly developed concept in different situations and thus reinforce and expand what Piaget described as the learner's organizational framework. The learning cycle provides experience, social interaction, and disequilibrium for the learner, three of the four components Piaget felt were necessary for the promotion of intellectual development.

Although the learning cycle was based on Piagetian theory, the learning cycle's teacher-led term introduction phase and the cooperative grouping utilized within the methodology both contain aspects that relate to Vygotsky's socio-historical view of learning. It is important to consider that researchers have reported that the type of teaching methodology used affects the opportunity for Vygotskyian based verbal scaffolding by teacher with student and student with student to occur (Appleton, 1997). Consequently, research in this area must use an applicable teaching methodology. The learning cycle provides a framework for both of these types of scaffolding to occur.

The effectiveness of the learning cycle methodology in various aspects of learning has been well documented. In a study of procedural acquisition done by Eaton (1974), 65 upper elementary students were used as an experimental group taught by learning cycle methodology and compared to a control group of 55 students taught by conventional methods. It was reported that learning cycle based instruction resulted in greater achievement in the elementary school students' abilities to utilize science processes such as observation, classification, measuring, experimentation, interpretation and prediction than those students taught with non-learning cycle methods. Additional studies by Brown, Weber, and Renner (1975) and Lawson and Snitgen (1982) have reported similar findings.

Another study by Saunders and Shepardson (1987) was conducted with 115 sixth grade students. The study found that the students taught with the learning cycle approach showed a greater percentage gain from the concrete to the formal stage of reasoning than students taught using a conventional textbook-based instructional methodology when measured by Lawson's Classroom Test of Scientific Reasoning. It was also reported in the same study that those students taught using learning cycle methodology showed greater science achievement when measured by teacher made tests covering the studied units.

Furthermore, two different reviews of the research done on the learning cycle since it's origination by Tobin, Tippins, and Gallard, (1994) and Lawson, Abraham and Renner (1989) reported that studies had found that the learning cycle was a process that facilitates conceptual change. These reviews included a study done by Schneider and Renner (1980) which found that 9th grade concrete students taught with learning cycle methodology showed significantly greater gains in concept knowledge than those students taught by formal or lectured-based instruction when measured by a written test. A meta-analysis of research testing the success of the learning cycle and its modifications in affecting conceptual change also provided support for the learning cycle approach (Fuzzetti, Snyder, Glass & Gamas, 1993).

Many of the exploration and expansion phase activities in the learning cycle are conducted by students working in small groups. Consequently, students are required to communicate with one another and cooperate to conduct experiments and gather data. Unfortunately, very little research has been done on the impact the small groups may have on the individual learner within the learning cycle framework. Related research done by Lawrenz and Munch (1984, 1985) found homogeneous ability grouping to be the best in terms of student gains in content achievement when compared to heterogeneous ability groups or student chosen groups. Their results seem to imply that students using learning cycle methodology learn best when they interact with others at or near their level of thinking. However, there are significant complexities of learning cycle group activities including collaboration dynamics and the confidence level of the more capable peers within the learning cycle framework which deem further exploration.

Many of the preceding studies have centered on the effectiveness of the use of learning cycle methodology on learner achievement when compared to traditional or textbook methodologies or the effectiveness of the use of the learning cycle when measured by concept content or process achievement. In contrast, none of the previous research has examined the learner's conceptual organization within the framework of the learning cycle learning groups. These cooperative laboratory learning groups are an essential aspect of the learning cycle; therefore, how the groups' interactions may affect the individuals' conceptual organization are of significant concern. However, none of the studies in science have investigated the collaborative processes within cooperative laboratory groups and examined their effect on the individual's conceptual organization within the framework of the learning cycle.

Cooperative Learning

The cooperative learning movement originated as a method of increasing academic achievement and social skills among diverse junior high school students (Lazarowitz, Hertz-Lazarowitz, & Baird, 1994; Slavin, 1980). Since it's origination, numerous studies have been conducted on various aspects of cooperative learning. Johnson and Johnson (1985) reviewed over a thousand cooperative learning studies and reported that cooperative learning experiences promote more learning than competitive or individualistic learning. Several studies that have been conducted in the science area (Brody, 1991; Jones & Steinbrink, 1989; Scharmann, 1992) have focused on the teacher's use and beliefs toward cooperative learning instead of researching the collaborative processes within the learning groups themselves.

Much of the cooperative learning group research that has been conducted in the science field has focused on student roles within the cooperative learning group. The impact of these student roles within cooperative learning groups has been reported by several researchers. Richmond and Striley (1996) researched the small-group processes of student-designed laboratory investigations within a tenth grade interdisciplinary science classroom. Their research indicated that different types of leadership evolved within cooperative learning groups. They also reported a correlation between the types of leadership within the groups and the small groups' approach to problem solving. Additional research on student roles has been reported by Lumpe and Staver (1995). Their study researched the effectiveness of assigned traditional roles and assigned cognitive roles as compared to the natural emergence of student roles within a high school biology class. They reported that while cognitive roles where more productive than traditional roles, allowing natural roles to emerge may be the most effective way to promote learning. In addition, Bianchini (1997) reported that students' perceived status by other members of the group had an impact on the students access to group materials and discourse within the small group.

Another area of cooperative learning science research has centered on science achievement when utilizing cooperative learning groups as compared to individual learning. This group of research has resulted in mixed results. Some research has reported higher achievement when utilizing cooperative learning groups (Humphreys, Johnson, & Johnson, 1982; Lazarowitz, Hertz-Lazarowitz, & Baird, 1994; Okebukola, 1986; Okebukola & Ogunnig, 1984; Watsun, 1992; Scott & Heller, 1991). In contrast, other studies have not found significant differences between the two approaches (Sherman, 1989; Tingle & Good, 1990).

Other cooperative learning research in the area of science has investigated cooperative incentives (Watson, 1992), gender issues (Heller, 1992), and student attitudes (Okebukola, 1986; Renner et al., 1985). However, Tobin, Tippins and Gallard (1994) reported that little has been done to investigate the collaborative processes within the learning groups themselves. In addition, Tobin, Tippins and Gallard point out that some classes and tasks might lend themselves to cooperative learning while others do not. Yet science classrooms have, out of laboratory equipment constraints, usually required students to work in groups of two to four. Consequently, further research on cooperative learning processes specifically within the framework of the laboratory-based science classroom is needed.

This is especially true of the elementary levels. Lazarowitz and Tamira (1994) did an analysis of the history of research relating to the use of the laboratory in science teaching and found that there is little reference to science laboratories in the elementary school. This lack of research could be because science is rarely taught in the elementary classroom and when it is taught the approach is primarily textbook based (Roychoudhury, 1994). Tobin and Gallagher (1987) reported that most teachers, at both the elementary and secondary levels, see labs as verification or cookbook activities. Therefore, these teachers do not view the role of the laboratory activities as a way to allow students to solve problems and thereby construct their own knowledge of science. These teacher beliefs restrict the usage and application of the laboratory within the science education community and may be significant factors in the lack of elementary science educational research in the collaborative cooperative learning context.

Reading Level and Science Achievement

Research has shown that reading vocabulary and reading comprehension make a significant difference in science achievement. Saturnelli and Repa (1995) studied the relationship between the reading scores of 1,381 fourth grade students and their scores on multiple-choice and hands-on/manipulative assessment tasks. Their results revealed that reading scores had a significant effect on both tasks although all students performed better on the hands-on test. Yore (1993) has also done research on the impact reading ability has on multiple-choice tests. His results indicated that middle school students with high-ability reading levels had significantly higher scores than did low-ability readers. Yore and Craig (1992) also reported that there was a significant difference between high-ability readers and low-ability readers when tested on declarative, procedural and conditional knowledge at the middle school level. Yore (1987) found that a teaching methodology that initiates learning with concrete experiences, supplemented with textual materials and mediated with direct instruction on critical science reading skills, is an effective teaching strategy in discounting initial differences in general reading vocabulary and reading comprehension. While Yore was not referring to the learning cycle, the description of the initiation of learning with concrete experiences aptly fits the basic teaching methodology. Unfortunately, no direction on critical science reading skills is currently included in the learning cycle structure.

However, Renner et al. (1973) did research the transfer of basic learning cycle skills to those necessary to the learning of reading in first grade students. In this study the experimental group studied a learning cycle unit on material objects while the control group was given a commercial reading readiness program. Both groups were then evaluated with a reading readiness test. The researchers reported that the experimental group showed greater gains than the control group in these sub-tests: word meaning, listening, matching, alphabet, and numbers. The control group showed greater gains in copying.

No specific research was found relating reading level, learning cycle methodology, and student achievement.

Concept Development

Defining what a concept is and how to measure the development of a concept are both factors in understanding how a learner assimilates and retains knowledge. The definition of a concept that will be used in this study is a repeatable pattern of two or more distinguishable objects, events, or situations that have been grouped or classified together and set apart from other objects, events or situations on the basis of some common feature, form, or properties (Lawson, Abraham, & Renner, 1989). In contrast, the term alternative concept refers to experience-based explanations constructed and adapted by a learner to make a range of natural phenomena and objects intelligible. Earlier researchers referred to these concepts as misconceptions; however, more recent researchers feel that the term misconception erroneously implies that such ideas serve no cognitive purpose for the learner. Wandersee, Mintzes, and Novak (1994) reported that the term alternate conception, rather than misconceptions, appears to be the term used by the majority of researchers in the field. They also reported that alternative conceptions are now considered as natural intermediates of the learning process that is a natural part of concept development. This shift in philosophy is more compatible with constructivist ideas of concept development (Cleminson, 1990). Therefore, the term alternate conception is a more accurate term because it implies the existence of the conceptual reorganization required of the learner to form valid conceptions. Researchers also agree that in order to learn more about the phenomena of concept development investigators should use research tools that provide a maximum of expression for their subjects. They, therefore, believe that interviewing and concept maps appear to be two of the current research tools of choice.

Concept Mapping

Shymansky et al. (1997) reported that conceptual growth can be recognized by the integration of new valid ideas or by the deletion of invalid concepts, propositions, or linkages. One research tool which has been shown to be sensitive to these evolutionary changes in students' conceptual organization and complexity is concept mapping (Markham, Mintzes, & Jones, 1994; Wallace & Mintzes 1990). Concept mapping as a technique was developed from work done by Novak (1972) and was originally used for exploring meaningful learning acquired through audio-tutorial instruction in elementary school science. Concept maps represent concepts, terms, features and the interrelationships between these factors that comprise a student's knowledge (Dykstra, 1992). The concept map cartography has been described by Wandersee (1990) as a diagram composed of circles or nodes used to enclose terms which refer to concepts and solid lines with linking words to indicated relationships between concepts. The combination of two nodes and a labeled line is referred to as a proposition. This fundamental unit is used to assess the validity of the relationship drawn between two nodes. The original technique described by Novak and Gowin (1984) was a hierarchical framework with superordinate concepts and linking words.

An alternate concept mapping technique was developed by Shavelson and defined by Ruiz-Primo and Shavelson (1996) as a network concept map. These concept maps are not necessarily hierarchical. Network maps are composed of concept nodes linked directionally by labeled lines to produce propositions. These lines represent the relationship between nodes. The network may be divided into subsets and indicate links between these subsets. The meaning of a concept is therefore defined by its relationship to other concepts. For example the concept precipitation is partially defined by its' connecting concepts which may include rain, sleet, or snow.

The concept mapping tasks used in past studies have varied with the researcher. Tasks have included: constructing a concept map independently (Roth & Roychoudhury, 1993; Wallace & Mintzes, 1990), filling in a skeleton map provided by an expert source (Anderson & Huang, 1989), writing an essay (Lomask et al., 1992), and responding to an interview (Heinze-Fry & Novak, 1990). Student responses varied in format including written, verbal interviews, drawn, or computerized responses.

Concept maps continue to gain attention among educators; however, researchers Ruiz-Primo and Shavelson (1996) have recommended that additional research is needed in this area to provide additional reliability and validity information. While their analysis reported several results showing consistent correlations between mapping and other student achievement measurements, other researchers (Novak, Gowin and Johansen, 1983), have reported a correlation close to zero between concept map assessment and multiple-choice test. This zero correlation may indicate that these assessments may measure different types of learning. In particularly, research has shown that concept maps were sensitive to changes in knowledge which were not discerned by traditional multiple-choice/free-response evaluation (Wallace & Mintzes, 1990). Additional evidence of the validity of concept mapping as a research and evaluation tool in science education (Marham, Mintzes, & Jones, 1994) suggests that concept mapping indicates significant differences in the structural complexity and organizational pattern of students and was found to be a sound tool for assessing conceptual change in experimental and classroom settings. Concept mapping has also been advocated as an effective assessment of the evaluation of student understanding within the learning cycle framework (Fleener & Marek, 1992). Therefore, successive concept maps constructed within the learning cycle can be used to represent the changes a student may make as learning occurs and therefore act as a method of tracing the students' conceptual learning.

Summary

The recent shift to a constructive paradigm in the educational field has resulted in a significant number of educators reconsidering the basic premises and implications of theorists Piaget and Vygotsky. This renewed interest in these two theories of learning, and how they intertwine with one another, has resulted in a more integrated approach to science educational research. Past research based on Vygotskian theory has studied various aspects of the students' environment, including the social aspects of cooperative learning. In contrast, Piagetian-based research has focused on the students' mental development, process acquisition, and those teaching methodologies that may expedite the development of the students' mental processes. However, the current project is unique in that it seeks to discover information on how student's conceptual organization develops and how that development is mediated within the Piagetian-based learning cycle framework.

CHAPTER 3

METHODOLOGY

Participants and Setting

The study was conducted in two 6th-grade science classrooms at an urban middle school. The science teacher involved in this study, Ms. R., used a hands-on, experience-based instructional approach in the science classroom and implemented learning cycle methodology which utilizes small cooperative learning groups. Ms. R. has a bachelors degree in secondary science education and was in her ninth year of teaching. She has had experience in teaching science from the sixth through the twelfth grades and has taught the sixth through the eighth grades using the learning cycle methodology. The learning cycle methodology was the required science curriculum for the school and the assistant principal, Ms. Q., had taught elementary learning cycle science methodology at the undergraduate level. Ms. Q. had previously observed the science teachers from several schools in the district and recommended Ms. R. as an excellent learning cycle instructor. Ms. R. also had utilized concept mapping techniques in the classroom.

The 53 potential participants for the study were sixth grade students, ranging in age from 11 to 13 years, in two of Ms. R.'s sixth grade classrooms. The 48 students who returned signed consent forms were the only students included in the data analysis. The researcher also included only the consenting participants in the audio and video taping procedures. The participants consisted of 24 female and 24 male students. The participants were culturally diversified and were identified by the teacher as 2% Asian American, 2% African American, and 85.5% Caucasian, as well as 10.5% from Middle Eastern countries. The two classes included children with learning, social, and emotional disabilities. Due to inclusion regulations, these students were an existing factor in the classroom and contributed to classroom dynamics. Therefore, all students, including the disabled students, were asked to participate.

Due to the structure of the learning cycle methodology, reading was an integrated component of the unit. Instructions and data collection during the exploration phase and the expansion phase, as well as the lab reports during the term introduction phase, are often in written form. In order to assess the impact of reading ability on concept development in the learning cycle, reading levels of all students who return signed consent forms were obtained for use in analysis. The students were placed into three reading groups according to their reading scores. Those students who tested below grade level were placed in the low group, those who tested at grade level and up to the ninth grade level were placed in the medium group, and those who tested above the ninth grade level were placed in the high group.

In order to ensure the most harmonious learning situation with the least amount of classroom disruption, the students were retained in the co-operative learning groups that had been previously established by the teacher. However, due to the science classrooms' constructive nature and their utilization of multiple co-operative groups, it was not feasible to collect and analyze the activities of all of the students. Therefore, one existing cooperative learning group composed of four students was randomly selected. The group consisted of two female and two male Caucasian students, none of whom was disabled. The members of this group were used as focal subjects in order to obtain in-depth information on the talk and activities that occurred during group activities.

Instruments

Multiple-Choice Tests

A teacher written multiple-choice test was given as part of the pre-test, expansion test, and retention test. The expansion test, given at the completion of the unit, was composed of a different version of the written multiple-choice pre-test. The retention test, administered six weeks after the completion of the unit, was the pre-test version of the written multiple-choice test. The classroom teacher provided 60 questions covering the concept. Questions were randomly assigned to the two versions of the test. The tests were assessed for content by a Professor of Environmental Sciences at the University of Oklahoma who served as a scientific expert. These two tests were administered in a pilot study to two additional classes of Ms. R. prior to the start of the study to test for reliability. The pilot tests resulted in two versions of the test, with 20 questions each, that were used in the study (see Appendix A). These two tests had a correlation coefficient of .86. The Cronbach's alpha determined the internal reliability of test A to be .808 and test B to be .815. Reliability of the research subjects' tests were also calculated using a Cronbach's alpha to determine internal consistency. Tests resulted in a pre-test (test B) reliability of .726, an expansion-test (test A) reliability of .708, and a retention test (test B) reliability of .836. It is noted that these reliabilities were specific to these samples at this particular time. However, the lower reliability found in the research subjects' scores indicates a degree of measurement error. The presence of measurement error will be considered when making statistical inferences.

Concept Mapping and Written Explanation

A concept map is a graphic hierarchical representation consisting of labeled circles representing concepts and labeled lines designating the linkages or relation between a pair of circles. Maps were collected by the classroom teacher and given to the researcher for coding and analysis. Students were also required to give a written explanation accompanying each concept map explaining the meaning of the concept map. The maps and written explanations were broken down into idea units for analysis. For the purpose of this study an idea unit was defined as subject-linking word-object unit. This idea unit parallels the proposition units used in Novak and Gowin's (1984) concept mapping scoring system.

Quantitative use of the maps and written explanations utilized the individual concept maps and explanations produced by each individual five times during the study (a) as a pre-test, (b) after the exploration phase, (c) after the term introduction phase, (d) after the unit was completed and (e) as a retention test. Concept maps and explanations were scored using a comparison of their components with a criterion map. The criterion map was produced by the classroom teacher for ecological validity and was assessed by a science expert for content (see Appendix B). The teacher criterion map was used to develop a scoring system template. This template was devised by the researcher and a secondary coding analyst. The secondary coding analyst is a science education researcher familiar with middle school science research and concept mapping techniques. She was first familiarized with the research questions and the learning cycle unit used in the study. The teacher criterion map idea units were then individually coded by each coder. The results were compared, discussed, and the scoring template was agreed upon by both coders. This template resulted in the development of a tally sheet listing the 16 idea units found in the map. The idea unit components found in the students' concept maps and written explanations were combined and then compared to the tally sheet and scored accordingly. The possible scores ranged from 0 to 16. Each coder independently scored five randomly chosen maps. These map scores were then compared, differences were discussed, and coding was agreed upon by both coders. Each coder then independently scored 10 randomly chosen maps. These map scores were then compared and were found to have a > 95% inter-rater reliability. Each coder then scored 50% of the remaining maps. In order to double check the inter-rater reliability over time, 10% of these maps were then cross coded by the other coder, compared and found to have a >95% inter-rater reliability.

Audio and Video Tapes

Video and audio tapes of the focal group were made for further qualitative analysis of student, group and teacher interaction. The initial transcription of the audio tapes was done by a professional transcriptionist. The researcher first reviewed the transcripts and audio tapes to check for accuracy. The researcher then reviewed the video tapes and combined them with the audio transcripts into one master transcript of classroom activities. The coders used in coding the concept mapping scores were also used in the coding of the transcripts. These transcripts were coded using idea units as described in the mapping analysis. Each coder separately coded five pages of the transcripts. These codes were then reviewed, discussed, and agreed upon. Next, 10 randomly chosen pages of transcripts were coded by both coders. When these 10 pages were compared the percentage of agreement established the inter- rater reliability. Percentage agreement was established at >90%. Each coder then coded 50% of the remaining pages of the transcripts. In order to double check the inter-rater reliability over time, 10% of these maps were then cross coded by the other coder, compared and found to have a >90% inter-rater reliability. The transcript coding resulted in a master spreadsheet which included 51 idea units including the 16 idea units identified in the mapping coding. The idea units were then traced throughout the learning cycle unit including transcripts of classroom discussions, small group discussion, as well as student map and laboratory sheets. The idea units were identified as either teacher or student originated. This master spreadsheet identification and tracking of idea units was then collapsed in the tables found in the results section.

Interviews

The four focal students were interviewed at the completion of the unit. Interview questions are found in Appendix C. These interviews were audio and video taped and later transcribed to aid in the qualitative analysis of the students' interpretation of the post-test concept maps and how the students believed these concepts developed. These tapes were also coded by idea units and origin of ideas by both coders on four randomly chosen pages of transcripts for inter-rater reliability. These codes were then compared by the researcher and the percentage of agreement was established at >95%.

Procedure

Data collection took place during the second semester of the 1996-1997 school year. During the month prior to the actual data collection, the researcher visited and observed the classes on several occasions. The researcher was a doctoral candidate with experience in teaching science from the fifth through the twelfth grades and has taught the tenth through the tewlfth grades using the learning cycle methodology. She also has taught elementary learning cycle science methods class at the university level. The classroom teacher introduced the researcher as a person who is interested in finding out about how 6th grade students learn science, and told the students that the researcher would be observing and taping some of their classroom activities and talking to some of them about their activities. In the observational visits, the researcher observed the class activities and took field notes about the science instruction implemented in the classroom, particularly the concept mapping activities, in order to have a more complete understanding of the existing classroom procedures and how the students used these activities. Notes were also taken on classroom organization, time use, and learning cycle implementation. These observations and notes not only provided a context for the study but also allowed students to become accustomed to the researcher being in the classroom and her use of a lap top computer as a means of data collection. A tape recorder and a video camera were also placed in various places around the room on occasional visits to allow the students to become familiar with the equipment that would be used to gather data from the focal group.

During the month prior to the actual study, Ms. R. distributed and explained the permission slips (see Appendix D) to the students.

The students and their parents were asked to indicate on the forms if they would like to participate or not, sign the form, and return the slips. It was explained in the permission slips that each student and his or her parents could chose not to participate without any problems or without having any effect on their grade.

The study investigated one learning cycle unit on the water cycle that was taught by the regular science teacher and was part of the existing curriculum. One week before the unit began, all students were asked by the regular classroom teacher to complete the pre-tests on the water cycle unit. The pre-tests included the multiple-choice test, student constructed concept map, and written explanation of the concept map. The teacher then facilitated the class through each of the three learning cycle phases in the typical classroom manner.

At the start of the learning cycle unit, the teacher led a discussion about previous related investigations on evaporation and condensation. The teacher referred the students to their terminology notebooks for the definitions of evaporation and condensation that had been constructed during previous investigations. During the exploration phase the teacher introduced the unit's initial experiment which consisted of the observation of a beaker filled with red dyed ice water. Students then discussed their observations in their small groups and completed Part A of the exploration lab sheet (see Appendix E). Students then observed an ecosystem model set up in a classroom aquarium. The aquarium was filled with 7cm of water and covered with plastic wrap. A heat lamp was set up to shine at one end of the aquarium. The ecosystem was then left overnight. The next day the students observed the ecosystem and discussed their observations as they completed Part B of the exploration lab sheet. The teacher supervised the students as they made their observations, interacted with one another, collected, and recorded their data. After the exploration phase each student again: (a) completed a concept map without the help of peers or the teacher and (b) wrote an explanation of that concept map.

During the term introduction phase the teacher facilitated the class in a discussion as the concepts involved in the water cycle were developed and the scientific terms for the concepts were introduced. The term introduction phase was structured to allow the students to discuss and interact with one another and the teacher as they completed the idea page of their lab sheets. After the term introduction learning cycle phases each student (a) completed a third concept map without the help of peers or the teacher and (b) wrote an explanation of that concept map.

During the expansion phase the teacher introduced and facilitated the unit's expansion activities. These activities consisted of the students collecting evidence of interactions between water and organisms around the school grounds. Evidence found by students included a bloated dead bird, an evaporating puddle, and various plant life. These observations were recorded in Part A of the expansion of the idea lab sheet. Part B of the expansion phase consisted of the small group discussing and completing lab sheet questions. The teacher then facilitated a class discussion of Part A and Part B of the expansion lab sheets. Part C of the expansion was an individual assignment for students to use their knowledge of the water cycle to invent and draw a self-contained model that would water 12 potted plants over a two-week vacation period. Students were allowed to work on the assignment over the weekend and turn it in on the following Monday.

At the end of the unit the students (a) completed a final concept map without the help of peers or the teacher and (b) wrote an explanation of that concept map. Students also completed the multiple-choice expansion test. An interview with the four focal students was also conducted at the conclusion of the unit.

Six weeks after the completion of the unit student retention of the concept was assessed. The retention assessment included the written multiple-choice test, student constructed concept map, and accompanying student written explanation of the concept map. The multiple-choice test was the same version of the test given as a pre-test.

During the entire study the researcher observed and took field notes on a lap-top computer. The researcher also collected and identified the maps and written explanations with a confidentiality code as they were collected from the students. The researcher also audio and video taped the focal group during the entire study.

Chapter 4

RESULTS

Quantitative Analysis

Analysis of the quantitative data was performed in four stages to determine two of the three research questions: how the individual student's concepts developed over each of the three phases of the learning cycle, and how stable the individual student's concepts were over time. A summary flow chart of these four stages and their results is shown below.

Summary Flow Chart of Quantitative Analysis

Stage One

Concept Maps Tests | Multiple-Choice

Descriptives | Descriptives

(To look for relationships between measures)

Correlation Matrix
Table III
(The correlation between the maps and the tests indicate that the two measures are related)

Stage Two
(In order to determine if a categorical variable of reading group should be used in analysis)

ANOVA: Dependent Variable
Concept Map
Test
Table IV
(Found a significant main effect of reading group)

(To ascertain where differences existed)

Games Howell
Table V
(Showed significant differences by reading level on pre-test in the low and high reading groups)

ANOVA: Dependent Variable
Multiple-Choice
Table VI
(Showed significant differences)

(To ascertain where differences existed)

Scheffe
Table VII
(Showed significant differences by reading level on pre-test with the high group)

(Since significant differences were found, subsequent analysis used a group variable for entering reading level)

Stage Three

In order to answer question 1: How do individual students' concepts develop over each of the three phases of the learning cycle the following MANCOVA on the concept maps was performed.

Concept Map
MANCOVA
Table VIII
Covariate: Map 1
Between Subjects Factor:
Reading Level
(Showed significant differences over time)

Within-Subjects Contrast
Table IX
(Showed significant differences Map 3 to Map 4 and Map 4 to Map 5 Differences found in Map 4 to Map 5 are utilized in stage four)

Between-Subjects Effects
Table X
(Showed that by using Map 1 as a covariate, the map scores of the students in the three reading groups were made comparable)

(The MANCOVA performed on the concept maps indicated that the students' concept knowledge changed over time. Students' concept knowledge increased from term introduction, mean = 6.375, to the expansion-test, mean = 8.187. Students' concept knowledge decreased from expansion-test, mean = 8.187 to retention test, mean = 5.833.)

Stage Four

In order to answer Question 3: How stable are the individual students' concepts over time? A repeated measure MANCOVA was performed using both concept map and multiple choice test results.

MANCOVA
Combined dependent variables:
Maps and Multiple Choice Tests
Table XI

(The MANCOVA performed on the combined expansion and retention tests showed a significant difference between the expansion scores and the retention scores. The test indicated that students' conceptual understanding decreased from the time of the expansion-test until the time of the retention test (6 weeks). It was also shown that by using a combination of the pre-test map scores and the pre-test multiple choice scores as a covariate, the analysis has adjusted for the between subjects effect of reading level.)

Since there was a significant difference shown in the MANCOVA, an ANCOVA on the multiple-choice tests was performed to see how much the multiple choice tests contributed to the difference between expansion and retention scores.

ANCOVA
Covariate: Pre-test
multiple choice test
Table XII

(Showed a trend toward significance ($\underline{p}$=.051) in the multiple-choice expansion and retention tests)

Between subjects analysis
Table XIII
(Showed that by using the multiple-choice pre-test as a covariate, the test scores of the students in the three reading groups were made comparable)

The ANCOVA performed on the multiple-choice tests indicated that the multiple choice tests contributed to the variability found in the combined dependent variables MANCOVA.

Therefore, the two measures of conceptual knowledge may explain some overlapping variability in student concept knowledge and both the concept maps and the multiple-choice tests contribute to the significant differences found in the expansion and retention assessments.

In the first stage descriptive statistics by reading group were obtained on the concept maps and the multiple choice tests. Correlation coefficients were then calculated to determine what correlations, if any, existed between the maps and the tests that would indicate that the two measures were related. In the second stage one-way ANOVAs comparing different reading groups were performed on pre-test map scores and multiple-choice test scores to determine if the pretest scores by reading group should be used as a covariant in subsequent analysis. The third stage of data analysis consisted of a MANCOVA on the concept map scores to determine if students' concepts changed over time. The fourth stage of analysis included a MANCOVA performed using combined maps and tests to determine the stability of the individual students' concepts over time.

Preliminary Analysis

Descriptive statistics were first performed on the concept maps and the multiple-choice tests in order to examine the impact of students' levels of reading and entering knowledge. Appendix F gives the combined concept map and explanation score for each subject included in the study. The means and standard deviations for each set of maps by reading group is reported in Table I.

TABLE I

Concept Map Scores by Reading Group*

	Pretest	Explore	Term Intro	Expansion	Retention
RL=Lo, N=13					
Mean	.8	5.2	4.5	7.2	4.8
SD	.8	2.3	2.7	3.2	3.6
RL=Md,N=17					
Mean	1.2	5.0	6.8	8.2	6.1
SD	1.4	2.4	1.8	3.0	2.4
RL=Hi, N=18					
M	2.3	6.3	7.3	8.8	6.3
SD	2.2	2.6	2.0	2.6	3.6

* Highest total score possible = 16

In addition to the concept mapping scores, the multiple-choice test scores were analyzed. Multiple-choice test scores for each subject included in the study are also reported in Appendix F. The means and standard deviations for each set of multiple-choice tests by reading group is reported in Table II.

TABLE II

Multiple-Choice Test Descriptives by Reading Group*

	Pretest	Expansion Test	Retention
RL=Lo, N=13			
Mean	12.2	15.8	12.3
SD	3.5	3.0	4.0
RL=Med, N=17			
Mean	12.4	15.7	14.8
SD	3.4	2.5	2.6
RL=Hi, N=18			
Mean	15.3	18.1	16.1
SD	2.5	1.6	3.8

*Highest total score possible = 20

To determine the relationship of all the measures used a correlation of the five concept mapping scores and the three multiple choice test scores was calculated. The matrix for the measures used is shown in the Table III. The significantly high correlations between measures are not unexpected due to the similarity of the tests.

TABLE III

Correlation Matrix for Measures

	PRE CM	EX CM	TI CM	EXP CM	RET CM	PRE MC	EXP MC	RET MC
PRE CM	1	.40*	.41*	.45*	.34*	.31*	.34*	.29*
EX CM		1.	.48*	.59**	.41*	.23	.44*	.07
TI CM			1.	.60**	.63**	.45*	.42*	.29
EXP CM				1.	.68**	.34*	.28	.21
RET CM					1.	.29	.34*	.23
PRE MC						1.	.59**	.54**
EXP MC							1.	.44*
RET MC								1

*p<.05
**p<.001

Previous research (Saturnelli & Repa, 1995; Yore, 1987, 1993; Yore & Craig, 1992) has shown an effect of reading level on science achievement. Therefore, the second stage of data analysis utilized one-way ANOVAs to compare different reading groups on the pre-test scores in order to determine if a categorical variable of entering knowledge by reading group should be utilized in the remainder of the study's analyses. The results of these analyses are reported separately for the mapping pre-test scores and the multiple choice pre-test scores.

The ANOVA on the pre-test mapping scores and their subsequent analysis are reported first. Results of the ANOVA which compared reading groups on the pre-test map scores are reported in the table below.

Table IV

ANOVA Summary Table for Pre-test Map Scores Comparing Different Reading Groups

SOURCE	df	SS	MS	F
Between reading groups	2	19.02	9.51	3.37 *
Within groups	45	126.98	2.82	
Total	47	146.00		

*$p < .05$

As shown in the table results indicated a significant main effect between reading groups. Initial inspection of the concept map data indicated the possibility of non-homogeneity of cell variances; therefore, a test of this factor was made using Levene's technique, as suggested by Glass (1966). The degree of heterogeneity was significant ($F=4.26$, $df=2/45$, $p<.05$). Consequently, the Games-Howell multiple comparisons post-hoc test was used to determine where differences in the concept map mean scores existed. The results of the Games-Howell Test are summarized in Table V.

Table V

Games-Howell Summary Table of Comparison of Group Differences of Pre-test Map Scores by Reading Group

	Low Reading Group (mean=.769)	Medium Reading Group (mean=1.23)	High Reading Group (mean=2.27)
Low Reading Group		Mean Dif = -.466 Std. Error = .619 p = .514	Mean Dif =-1.50* Std. Error = .611 p = .04
Medium Reading Group			Mean Dif =-1.04 Std. Error =.568 p =.243

* $p < .05$

An examination of the means in Table V indicates that the mean for the low reading group is lower than the mean for the medium reading group and that the latter is lower than that of the high reading group. The difference between the low reading group and the high reading group is large enough to be significant at the .05 level of confidence. No other differences are significant.

A second one-way analysis of variance was performed on the pre-test multiple-choice scores in order to determine if a categorical variable of entering knowledge by reading group should also be utilized in the multiple-choice scores test analysis. Results of the ANOVA are reported in Table VI.

Table VI

ANOVA Summary Table for Pre-test Multiple Choice Scores Comparing Different Reading Groups

SOURCE	df	SS	MS	F
Between reading groups	2	106.09	53.04	5.357 *
Within groups	45	445.57	9.90	
Total	47	551.66		

*$p < .05$

The ANOVA indicated a significant difference between the reading groups on the pretest. As with the concept map data, the initial inspection of the multiple-choice data, as shown in Table II, indicated the possibility of non-homogeneity of cell variances, a test of this factor was made using Levene technique. However, the degree of heterogeneity was not significant (F=.603, df=2/45, p >.05). Therefore, the Scheffe' multiple comparisons post-hoc test was used to determine the means between which significant differences existed. The results of the Scheffe' test is reported in Table VII.

Table VII

Scheffe Test Summary Table of Comparison of Group Differences of Pre-test Map Scores by Reading Group

	Low Reading Group (mean=12.15)	Medium Reading Group (mean=12.35)	High Reading Group (mean=15.33)
Low Reading Group		Mean Dif = -.1991 Std. Error = .1.159 p = .985	Mean Dif =-3.18* Std. Error = 1.145 p = .029
Medium Reading Group			Mean Dif =-2.98 * Std. Error =1.06 p =.027

* $p< .05$

An examination of the means in Table VII indicates that the mean for the low reading group is different than the mean for the high reading group and that the medium reading group is different than the high reading group. These differences are significant at the .05 level of confidence.

These preliminary tests (shown in Table IV through Table VII) performed in the second stage of data analysis indicated that reading level did have an effect on students' pre-test scores in both the concept mapping and the multiple-choice assessments. To control for these initial differences in performance on the concept mapping scores and the multiple-choice tests between reading groups a covariant design was implemented for the following analyses. That is, the concept mapping pretest and the multiple-choice pretest were used as the covariant in subsequent analysis.

<u>Concept Development Over Time</u>

In the third stage of data analysis a repeated measures MANCOVA was performed on the concept maps in order to answer how individual students' concepts develop over each of the three phases of the learning cycle. Results of this analysis is reported in Table VIII.

Table VIII

Summary Table of Concept Maps MANCOVA by the Wilkes' Lambda Criterion.

SOURCE OF VARIATION	*df*	*F*
Time	3/42	11.902*
Time X Pre-test Map	3/42	.646
Time X Reading Group	6/84	1.549

*p<.001

As a result of the significance of time, a test of within-subjects contrasts of the time variations was performed to ascertain the specific significant time periods. During Time I, from the exploration maps to the term introduction maps, the total mean increased from 5.56 to 6.37. During Time 2, from the term introduction maps to the expansion maps, the total mean significantly increased from 6.37 to 8.18. During Time 3, from the expansion maps to the retention maps the total mean significantly decreased from 8.18 to 5.83. (The difference during Time 3 will be used in stage four analysis). The results are reported in Table IX.

Table IX

Summary Table of Tests of Within-Subjects Contrasts of Concept Map Variation of Time

Time Variable	*df*	*SS/MS*	*F*
Time 1 exploration - term introduction	1	4.252	.842
Time 2 term introduction - expansion	1	62.699	27.967**
Time 3 expansion - retention	1	25.962	8.588*

*$p<.05$
**$p<.001$

An analysis of between-subjects effects of the pre-test map and the reading groups was performed. The analysis indicated that the pre-test map was significant. These results indicate that regardless of reading group there is a significant difference over time in student's concept knowledge as measured by concept maps when the pre-test map is used as a covariant. Results are reported in Table X.

Table X

Summary Table of Tests of Between-Subjects Effects of Concept Maps

Source	*df*	*SS/MS*	*F*
Pre-test Map	1	164.143/164.143	10.045*
Reading	2	14.905/14.905	.912
Error-between	44	719.016/16.341	

*$p<.05$

Individual Students' Concept Stability

In stage four a repeated measures MANCOVA was performed in order to analyze any differences on the expansion scores and the retention test scores with the concept map results and the multiple-choice test results combined. Prior analysis shown in Table IX showed a significant difference with the concept map results alone. Results of the combined scores are reported in Table XI.

Table XI

Summary Table of Multivariate Analysis of Covariance of Pre-test Maps Combined with Pre-test Multiple-Choice Tests on Expansion and Retention Tests

Source of Variance	Criterion Test	*df*	*F*
Covariate	Pillais	4/86	6.98**
	Wilkes' Lambda	4/84	7.64**
Reading	Pillais	4/86	1.07
	Wilkes' Lambda	4/84	1.05
Reading X Time	Pillais	4/90	1.02
	Wilkes' Lambda	4/88	1.02
Time	Pillais	2/44	29.98**
	Wilkes' Lambda	2/44	29.98**

**$p<.001$

The MANCOVA showed a significant difference between the expansion scores and the retention scores. The test indicated that students' conceptual understanding decreased from the time of the expansion-test until the time of the retention test (six weeks). It is also shown in the table that there was a significant difference between the linear combinations of the pre-test maps and pre-test multiple-choice tests. To ascertain if this difference was a result of the significant difference found in the maps, in the multiple choice tests or in a combination of the two measures, a repeated measures ANCOVA was performed on the multiple-choice tests. Results of the analysis are shown in Table XII.

Table XII

Summary Table of Multiple-Choice ANCOVA by the Wilkes' Lamabda Criterion

Source of Variation	*df*	*F*
Time	1/44	4.033, $p = .051$
Time X Pretest	1/44	1.168, $p = .286$
Time X Reading	2/44	2.02, $p = .145$

As shown in the table there is a trend towards a significance of time. The lack of a higher significance may be due to the degree of measurement error found in the initial Cronbach's alpha testing of the research subjects' test results. However, the lack of significance of the interactions of time X pre-test and time X reading validates that time alone is the variable which best explains the differences in achievement.

An analysis of between-subjects effects of the pre-test multiple-choice test and the reading groups was performed. Between subjects analysis indicated that the pre-test multiple-choice test was significant. However, when the pre-test multiple-choice test was covaried out the analysis indicated that the reading group was not significant. Results are reported in Table XIII.

Table XIII

Summary Table of Tests of Between-Subjects Effects of Multiple-Choice Tests

Source	*df*	SS/MS	*F*
Test	1	188.041/188.041	23.482*
Reading	2	36.262/18.131	2.264
Error	44	352.344/8.008	

*p<.001

The ANCOVA performed on the multiple-choice tests indicated that the multiple-choice tests contributed to the variability found in the combined dependent variables MANCOVA. From the time of the expansion tests to the time of the retention tests the mean dropped from 16.6 to 14.6. Therefore, the two measures of conceptual knowledge, the concept maps and the multiple-choice tests, both contribute to the significant differences found in the expansion and retention assessments.

Qualitative Analysis

Qualitative data were analyzed in two stages to determine the degree individual student's concepts were mediated by classroom discussions and the students' small cooperative learning group. In the first stage of the qualitative analysis the four focal student maps constructed at the completion of each of the three phases of the learning cycle and the retention map constructed six weeks after the completion of the unit were utilized. Focal students will be referred to with the pseudonyms: Van, Lora, Becky, and Kevin. These maps were then correlated with the audio and video tapes of the investigation. A qualitative summary of each phase of the learning cycle and the idea units presented during that phase are included in Appendix G. The following tables are organized with four major areas of idea units: water cycle, precipitation, evaporation and condensation. Listed under each of these four areas are related idea units. Each group of focal students' maps where itemized by the idea units that the students had included in the maps. The charts indicate which students included the idea unit in their map and then trace the origin of the idea unit within the investigation.

The following key was used to construct the summary charts:

NR: Indicates the student did not include the idea unit in their map.

PR: Indicates the idea unit was included in that student's pre-test map.

EX: Indicates the idea unit was included in that student's exploration map.

TI: Indicates the idea unit was included in that student's term introduction map.

EP: Indicates the idea unit was included in that student's term expansion map.

RV: Indicates the idea unit was included in the Bill Nigh review video shown as a review at the end of the investigation.

The numerals 1 through 5 indicate the order of the references to that idea unit during that phase. Each numeral is then followed by a "S" or a "T" which indicates that the reference was made by a student or the teacher. The term "self" indicated that student made the reference during class.

If the idea unit was not referenced during that phase of the learning cycle or in a prior map constructed by that student, PH1 indicates that it was referred to during the discussions that took place in the exploration phase and PH2 indicates that it was referred to during the discussions during the term introduction phase. A "?" indicates that no prior reference had been made to the idea unit during the investigation. The italicized idea units and "*AC*" designate that the unit is an alternate concept.

In order to examine the quantitative findings with the qualitative analysis the following results are presented by phase. Tables XIV through table XVII summarize the results of the phase analysis.

Table XIV

Qualitative Summary Chart of Exploration Phase Maps

EXPLORATION IDEA UNIT	Becky	Van	Kevin	Lora
WATER CYCLE				
Includes Precipitation	NR	NR	NR	1S
Includes Evaporation	NR	NR	NR	1T,2S
Includes Condensation	NR	NR	NR	1T,2S,3S
Is a continuous cycle	1S	PR	NR	NR
River, etc. to ocean	NR	NR	PR	NR
PRECIPITATION				
Is rain	NR	1S	NR	1S
Is snow	NR	?	NR	?
Is sleet	NR	?	NR	?
Is hail	NR	?	NR	?
Leads to evaporation	NR	1S	NR	NR
Rain to river, etc.	PR	NR	PR	NR
Involves hot/cold temp	NR	AC	NR	NR
EVAPORATION				
Is steam	NR	NR	NR	1T
From ocean/source	PR	NR	PR	NR
Leads to condensation	1S	NR	1S	NR
Leads to clouds	NR	NR	?	NR
CONDENSATION				
Caused by temp. change	NR	NR	NR	1T,2S,3S,4T,5S
Moves with wind	NR	NR	?	NR
Leads to precipitation	NR	NR	Leads to rain	NR
Leads to rain	1S	NR	NR	NR
Is H2O vapor in the air	NR	NR	NR	1T,2S,3T

Table XV

Qualitative Summary Chart of Term Introduction Maps

TERM INTRO. IDEA UNIT	Becky	Van	Kevin	Lora
WATER CYCLE				
Includes precipitation	NR	1S,2T,3S	Self,2T,3S	EX, 1S,2T,3S
Includes evaporation	NR	NR	Self,	EX,1S,2T,3S
Includes condensation	NR	NR	Self,2T,3S	EX,1S,2T,3S
Is a continuous cycle	EX 1S,2T,3S	NR	1S,2T,3S	NR
Includes rain	PR	NR	NR	NR
River, etc. to ocean	NR	NR	PR,EX, 1T	NR
Includes moisture	NR	Cond-PH1-S	NR	NR
Includes steam	NR	Evap-PH1-T	NR	NR
PRECIPITATION				
Is rain	NR	EX,1S	NR	EX,1S
Is snow	NR	EX	NR	EX
Is sleet	NR	EX	NR	NR
Is hail	NR	EX	NR	EX
Leads to evaporation	1S,2T	NR	NR	1S
Rain to river, etc.	NR	PR,1T	PR,EX,1T	NR
EVAPORATION				
Is steam	NR	PH1-T	NR	EX
From ocean/source	NR	PR	PR, EX	NR
Rises to the sky	NR	NR	NR	?
Leads to condensation	EX,1S	1S	EX,1S	1S
CONDENSATION				
Moves with wind	NR	NR	EX	NR
Leads to Precipitation	1S	NR	EX,1S	NR
Is moisture	NR	PH1-S	NR	PH1-S
Is steam making clouds	NR	NR	NR	?

Table XVI

Qualitative Summary Chart of Expansion Maps

EXPANSION IDEA UNIT	Becky	Van	Kevin	Lora
WATER CYCLE				
Includes precipitation	1S,RV	TI,1S,RV	TI,1S,RV	EX,TI,1S,RV
Includes evaporation	NR	1S,RV	NR	EX,TI,1S,RV
Includes condensation	NR	1S,RV	NR	EX,TI,1S,RV
Is continuous	EX,TI,1T,RV	NR	TI,1T,RV	NR
PRECIPITATION				
Is rain	NR	EX,TI,1S,RV	1S,RV	EX,TI,1S,RV
Is snow	NR	EX,TI,1S,RV	1S,RV	EX,TI,1S,RV
Is sleet	NR	EX,TI,1S,RV	1S,RV	EX,1S,RV
Is hail	NR	EX,TI,RV	RV	NR
Leads to evaporation	TI,RV	NR	NR	TI,RV
Rain to river, ect.	NR	NR	PR,EX,TI,RV	NR
Clouds get heavy	NR	NR	NR	1T,RV
EVAPORATION				
Is steam	NR	TI	NR	TI
Is mist	NR	?	NR	NR
From ocean/source	NR	NR	PR,EX,TI,RV	NR
Leads to clouds	NR	NR	NR	PH2-S
Leads to condensation	TI,RV	NR	TI,RV	TI,RV
CONDENSATION				
Caused by temp change	NR	NR	NR	1-4S,RV
Is sweat on glass	NR	PH1,4Ss,T,RV	NR	NR
Steam leaving mouth	NR	1S,2S	NR	NR
Leads to precipitation	TI,RV	NR	EX,TI	NR
Is clouds	PH2-S,RV	NR	NR	PH2-S,RV

An overview of Table XIV of the exploration maps reveals that of the 21 idea units included in the focal group's maps only one could be traced back to teacher-mediation alone. Four additional idea units were traced to a combination of teacher and student mediation. However, Lora was the only student to include any teacher mediated idea units in her exploration map. The other three students' traceable idea units came from their pre-existing knowledge, as illustrated on their pre-test maps, or from other students.

The Table XV summary chart of the term introduction phase reveals that of the 22 idea units included in the group's maps only two, included by Van, could be traced back to teacher mediation alone. Four idea units illustrated by Becky and Van were traced to student mediation alone. An additional four idea units were traced to a combination of teacher and student mediation with the first mention of the idea coming from a student. The majority of the 22 ideas had been included by at least one of the students in the previous exploration phase map.

The Table XVI summary chart of the expansion maps indicated that of the 21 idea units included in the group's maps all but four had been included in the review video. Fourteen of the idea units had been included in maps by at least part of the group. Six of these 14 ideas were included for the first time by at least one student. All six of these ideas were traced to student mediation during this phase. Only one of the 21 idea units was traced to teacher mediation alone.

Table XVII is a summary chart of the focal groups' retention map idea units. The table also includes previous map inclusions of the idea units by student.

Table XVII

Qualitative Summary Chart of Retention Maps and Previous Map Origin

RETENTION IDEA UNIT	Becky	Van	Kevin	Lora
WATER CYCLE				
Includes precipitation	NR	NR	NR	EX,TI,EP
Includes evaporation	NR	NR	NR	EX,TI,EP
Includes condensation	NR	NR	NR	EX,TI,EP
Is continuous	EX,TI,EP	PR,EX	NR	NR
PRECIPITATION				
Is rain	No map	EX,TI,EP	EP	EX,TI,EP
Is snow	NR	EX,TI,EP	EP	EX,TI,EP
Is sleet	NR	EX,TI,EP	EP	NR
Is hail	NR	EX,TI,EP	EP	EX,TI
Leads to evaporation	TI,EP	NR	NR	NR
Rain to river, ect.	NR	PR,TI	NR	NR
Leads to condensation	NR	NR	NR	*AC*
EVAPORATION				
Is steam	NR	TI,EP	NR	NR
Is liquid turning to gas	NR	NR	NR	No map
Comes from rivers etc.	NR	PR,TI	PR,EX,TI,EP	NR
Leads to condensation	EX,TI,EP	NR	EX,TI,EP	NR
Is gas	NR	No map	NR	NR
Is dew	NR	*AC*	NR	NR
CONDENSATION				
Leads to precipitation	TI,EP	NR	EX,TI,EP	NR
Is clouds	NR	NR	No map	NR
Leads to evaporation	NR	NR	NR	*AC*

In the second stage a qualitative analysis was made of the four focal students' interviews which were conducted at the completion of the unit. The interview questions can be found in Appendix C. Table XVIII is a summary of the differences the students identified between their pre-test map and their expansion map completed just before the interview. The chart also identifies where the student believed the idea originated during the investigation.

Table XVIII

Interview Summary Chart:

Student	New Item	Origin
Becky	The term evaporation	Ecosystem lab, PH1
	The term condensation	Ecosystem lab, PH1
	The term precipitation	Don't remember
Van	The term evaporation	From all labs
	The term condensation	Red ice water lab, PH1
	The term precipitation	Red ice water lab, PH1
	Rain, sleet, snow, hail = Prec	Don't remember
Kevin	The term evaporation	From group discussions
	The term condensation	From group discussions
	The term precipitation	From group discussions
Lora	The term evaporation	Ecosystem lab, PH1
	The term condensation	Ecosystem lab, PH1

In order to more easily track each of the four focal students summary charts are displayed for each student. These charts are shown in Tables XIX through Table XXII.

Table XIX

Summary Chart of Map Contents for Becky

WATER CYCLE	Pre-test	Expl	Term Intro Map	Expansion Map	Retention Map
Includes Precipitation				1S, RV	
Is a continuous cycle		1S	EX,1S,2T,3S	EX,TI,1T,RV	EX, TI, EP
Includes Rain	yes		PR		
Source flows to ocean	yes				
PRECIPITATION					
Is rain					No Map
Leads to evaporation			1S,2T	TI,RV	TI, EP
Rain to river, etc.	yes	PR			
EVAPORATION					
From ocean/source	yes	PR			
Leads to condensation		1S	EX,1S	TI,RV	EX, TI, EP
Leads to rain	yes				
CONDENSATION					
Leads to rain		1S			
Leads to precipitation			1S	TI,RV	TI, EP
Is clouds				PH2-S,RV	

Table XX

Summary Chart of Map Contents for Van

WATER CYCLE	Pre	Expl	Term Intro Map	Expansion Map	Retention Map
Includes Precipitation			1S,2T,3S	TI, 1S, RV	
Includes evaporation				1S,RV	
Includes condensation				1S,RV	
Is a continuous cycle	yes	PR			PR,EX
Includes moisture			Cond-PH1-S		
Includes steam			Evap-PH1-T		
Includes rain	yes				
PRECIPITATION					
Is rain		1S	EX,1S	EX,TI,1S,RV	EX,TI,EP
Is snow		?	EX	EX,TI,1S,RV	EX,TI,EP
Is sleet		?	EX	EX,TI,1S,RV	EX,TI,EP
Is hail		?	EX	EX,TI,RV	EX,TI,EP
Leads to evaporation		1S	EX		
Involves hot/cold temp		AC	EX		
Rain to river, etc.	yes		PR,1T		PR,TI
EVAPORATION					
Is steam			PH1-T	TI	TI,EP
Is mist				?	
From ocean/source	yes		PR		PR,TI
Leads to condensation			1S		
Is gas					No map
Is dew					AC
Is caused by heat	yes				
CONDENSATION					
Is sweat on glass				PH1,4Ss,T,RV	
Steam leaving mouth				1S,2S	
Is moisture			PH1-S		

Table XXI

Summary Chart of Map Contents for Kevin

WATER CYCLE	Pre-test	Expl. Map	Term Intro Map	Expansion Map	Retention Map
Includes Precipitation			Self, 2T,3S	TI,1S,RV	
Includes evaporation			Self, 2T,3S		
Includes condensation			Self, 2T,3S		
Is a continuous cycle			1S,2T,3S	TI,1T,RV	
River,etc. to ocean	yes	PR	PR,EX,1T		
PRECIPITATION					
Is rain				1S, RV	EP
Is snow				1S,RV	EP
Is sleet				1S,RV	EP
Is hail				RV	EP
Rain to river, etc.	yes	PR	PR,EX,1T	PR,EX,TI,RV	
EVAPORATION					
From ocean/source	yes	PR	PR,EX	PR,EX,TI,RV	PR,EX,TI,EP
Leads to condensation		1S	EX,1S	TI,RV	EX,TI,EP
Leads to clouds		?			
Leads to rain	yes				
CONDENSATION					
Moves with wind		?	EX		
Leads to precipitation	yes	PR	EX,1S	EX,TI	EX,TI,EP
Is clouds					No prev. map

Table XXII

Summary Chart of Map Contents for Lora

WATER CYCLE	Pre	Explore Map	Term Intro Map	Expansion Map	Retention Map
Includes Precipitation		1S	EX,1S,2T,3S	EX,TI,1S,RV	EX,TI,EP
Includes evaporation		1T,2S	EX,1S,2T,3S	EX,TI,1S,RV	EX,TI,EP
Includes condensation		1T,2S,3S	EX,1S,2T,3S	EX,TI,1S,RV	EX,TI,EP
Source flows to ocean	yes				
Is cleansing	yes				
PRECIPITATION					
Is rain		1S	EX,1S	EX, TI,	EX,TI,EP
Is snow		?	EX	EX, TI,	EX,TI,EP
Is sleet		?		EX,1S,RV	
Is hail		?	EX		EX,TI
Leads to evaporation			1S,2T	TI,RV	
Clouds get heavy				1T,RV	
Leads to condensation					MC
Rain flows to river etc	yes				
EVAPORATION					
Is steam		1T	EX	TI	
Rises to the sky			?		
Leads to clouds				PH2-S	
Leads to condensation			1S	TI,RV	
Liquid turning to gas					No map
Leads to rain	yes				
Comes from ocean	yes				
CONDENSATION					
Caused by temp. change		1T,2,3S,4T		1,2,3,	
Is Moisture			PH1-S		
Is steam making clouds			?		
Is clouds				PH2-S,RV	
Leads to evaporation					MC

Summary

Preliminary quantitative analyses found significant differences by reading level on pre-test scores therefore, a covariant design was implemented in subsequent analyses. The quantitative analysis of the concept mapping scores indicated that the students' concept knowledge increased from the time of the term introduction map to the time the expansion-test was given. However, qualitative analysis showed a great diversity among the students' patterns of conceptual development throughout the stages of the learning cycle. Quantitative analysis of concept mapping scores and multiple choice scores also found significant decreases in the expansion and retention scores. In addition, qualitative analyses of student-teacher and student discussions within the classroom and individual concept development also indicate definite interaction patterns.

Chapter 5

DISCUSSION

This research attempted to trace the development and retention of science concepts within a learning cycle classroom that uses cooperative learning laboratory groups. Volunteers from two sections of sixth grade science classes participated in the study. Due to the limited number of participants, the study was exploratory in nature. Time restrictions confined the data collection to one learning cycle unit, taught by one teacher, during the spring semester of 1997. Consequently, it is acknowledged that the findings may not be generalizable to larger populations or other concepts. However, the research did yield data patterns that suggest trends in concept development and the role of teacher and peer mediation in students' concept development and retention within the learning cycle.

The learning cycle is known as a "hands-on, minds-on" based instructional methodology (Scharmann, 1992). However, learning cycle units incorporate many written laboratory sheets, expansion materials, and testing assessments. The cursory review of the descriptives of the pre-test map and multiple-choice scores (See

Tables I and II) suggested that reading abilities might have a significant effect on scores. In addition, prior research (Yore, 1987) had shown that reading vocabulary and reading comprehension make a significant difference in science achievement. Therefore, one-way ANOVAs were performed on both the concept map and multiple-choice pre-tests. These analyses indicated that there were significant differences between reading groups (See Tables IV through VII). As a result, subsequent analysis used a group variable for entering reading level.

The first question that guided this study was: How do individual students' concepts develop over each of the three phases of the learning cycle? The MANCOVA performed on the concept maps revealed the students' concept knowledge increased significantly during the learning cycle. However, this increase was only significant from the time the students constructed the map at the conclusion of the term introduction phase to the time that they constructed the map at the conclusion of the expansion phase.

In order to better understand why a significant increase occurred at this point in the learning cycle the concept mapping data were reviewed. When the concept mapping idea units were compared it was found that the idea units that are only found in the expansion phase maps had all been discussed in the previous phases. For example the idea units that were most often added at the conclusion of the expansion phase included idea units fundamental to the water cycle concept. These idea units included: evaporation leads to condensation (added by 11 students), condensation leads to precipitation (added by 13 students), and precipitation leads to evaporation (added by 9 students). The questions then arise: Were these idea units part of earlier phases? And if so, why were these ideas not integrated into earlier concept maps?

By reviewing the transcripts it was found that the class discussions during Part B of the exploration phase included all three of these ideas. The discussion centered around the students' observations of the enclosed aquarium. The aquarium had been filled with 7cm of water and covered with plastic wrap. A heat lamp was then placed at one end of the aquarium and left overnight. The student observations included: the water level had decreased to 6.8cm, water droplets had formed on the inside of the plastic wrap, no droplets were found at the end closest to the heat lamp.

The following excerpt was taken from the class discussion;

therefore, all students heard the following dialog:

Ms. R: you noticed there was moisture on the side away from the light. . . Who has an idea why?

Laurie: There is no moisture on the side closest to the light because It was too hot and the light made it too hot to condense.

Ms. R: Very good! . . .From where did the moisture that condensed on the side on the come?

Kevin: Evaporation.

Ms. R: Evaporation from where?

Kevin: Inside the container.

Ms. R: Danielle, what is happening to the water as it evaporates and then it starts to hit a cool surface?

Danielle: It condenses.

Ms. R: We have a lot of condensation . . . On top inside the plastic wrap. . .If you touch the plastic wrapper a lot of the water droplets turn together and drift into the tank. . What would we call that if the water droplets fall?

June: Rain

Ms. R: Could we call that precipitation? That's one of our vocabulary words for today.

It can be seen from this excerpt the all three idea units were included in the exploration discussion: the water in the tank had evaporated, condensation on the top came from evaporation, precipitation resulted from condensation, and that the precipitation fell back into the water at the bottom of the tank. However, although the idea units are included in the discussion, it was never explicitly stated that one leads to the other.

The same three idea units were also included in the term introduction "idea page" discussion. This discussion took place the day after the students had completed the idea page in their small groups. The following excerpt was taken from the class discussion to ensure that all students had heard the dialogue exchange.

Ms. R: you have a puddle and what in the environment is providing heat?

All: Sun.

Ms. R: The sun, what does the heat cause to happen?

All: Evaporate.

Ms. R: And once the water is evaporated and it's in the air, it cools off and it does what, Michael?

Michael: It condenses and makes a cloud.

Ms R: And what does it do when it condenses? A lot of water droplets . . . They get heavy and gravity pulls them down, what do we call that?

Jane: "Rain, precipitation."

It can be seen from this excerpt that all three ideas were reinforced by the classroom discussion: water evaporates, the evaporated water condenses, and condensation causes precipitation. It can also be seen that the teacher used scaffolding to build on these three basic ideas to include the idea that temperature changes cause evaporation and condensation. Later in the same discussion the class further considered how evaporation, condensation and precipitation related to one another.

Ms. R: "Look at the ecosystem over here (teacher was referring to the ecosystem that the students had observed in the exploration phase) how does it relate to what happens to water in a pond."

Becky: "It relates because the water evaporated and condenses and then it rains."

Ms. R: "What do we call that? Evaporation and condensation and precipitation?"

John: "The water cycle."

Ms R: "What conclusions can you make about what happens to the repeated process of water in nature?"

Amanda: "The water cycle never ends."

David: "The water is recycled."

Joelle: "Water is used over and over."

David: "It is an everlasting cycle."

It can again be seen from this third excerpt that all three ideas were reinforced by the classroom discussion: evaporation, condensation and precipitation are all part of a continuous process. The three ideas were again covered at the conclusion of the expansion phase. The following excerpt was from the video that the teacher used as a review for the unit.

"Water is always moving all around the earth in something called the water cycle. So let's start right here, where water is a liquid it's in the ocean or a lake. Anyway, something that's making a change, runs a liquid into a vapor. Heat comes from the sun . When water goes back into the air we say it evaporates. Evaporate. So look right here when it is evaporated it's invisible. Isn't that cool? So when it gets up here, it cools off, and turns into a liquid, we call that condensation. It condenses. . . What makes this vapor return to the earth as water? The rain, that's right. Let the water turn into a liquid, or rain. That's called precipitation. Now precipitation is when water falls like rain, sleet, or snow or hail. It falls down and collects in like a lake or stream. It swirls to the sea to start the cycle all over again."

From these four excerpts taken from the teacher and student classroom discussions and video review tape it can be established the three idea units: evaporation leads to condensation, condensation leads to precipitation, and that precipitation leads to evaporation, where included in each of the three learning cycle phases. In addition, it is also noted that since the classroom discussion excerpts where taken from discussions of the small group lab sheets it is presumed that these ideas were also discussed in some manner by each of the small groups. Therefore, each of the students had been exposed to multiple conversations within their groups and within the classroom during each learning cycle phase. However, the significant inclusion of the three units did not take place until after the expansion phase concept map on the seventh day of the water cycle unit. This would infer that the students did not accommodate, integrate, and organize the new concepts into their conceptual framework until after the expansion.

These findings are in conflict with previous findings (Renner, Abraham, & Birnie, 1988). This previous study involved secondary school physics classes. The research was designed to test the necessity of the experience of all three phases of a learning cycle unit. Students in the experimental and control groups where given Concept Achievement Tests before and at the completion of each phase. The researchers reported "the expansion-of-the-idea phase of the learning cycle seems unnecessary". The question then arises: How can these two studies appear to be so diametrically opposed?

The first obvious variation between the two studies is the difference in the age groups of the two studies. The present study utilized sixth grade students while the previous study used twelfth grade physic students. These two groups vary immensely in their ability to think at a formal level. According to Piaget, formal operational thought only begins to be apparent at about age 12 and is consolidated during adolescence. Ginsburg and Opper (1969) interpreted Piaget's theory to mean that "the adolescent can imagine the many possibilities inherent in a situation. Unlike the concrete-operational child, whose thought is tied to the concrete, the adolescent can transcend the immediate here and now"(p. 181). As a result, a twelfth grade student, especially the typical physics student, is *significantly* more advanced than a sixth grader in his abilities to think independently and predict outcomes. The expansion phase is intended to extend the students' new ideas to other related ideas and aid in the organization and integration of the new ideas with previous knowledge. Therefore, this accommodation and integration may not occur until the more concrete student has the opportunity to reinforce, extend, review, and apply the new concepts to other situations. The expansion phase may be a fundamental component which is necessary for integration to occur in the more concrete learner.

The second difference between the two studies is the method of assessment. The Renner, Abraham, and Bernie (1988) study utilized a Concept Attainment Test, which was a written multiple-choice test, while the present research used concept mapping techniques. Research in the comparison of the two types of assessment have had mixed results. However, Novak, Gowen & Johansen (1983) have reported a correlation close to zero between mapping and multiple-choice tests. The researchers therefore speculated that these two types of assessments measure different types of learning. Other researchers have found that concept maps were more sensitive to changes in knowledge than multiple-choice tests (Wallace & Mintzes, 1990). It is also possible that multiple-choice test questions and multiple answer choices could cue the students' memories of the concepts covered in previous phases. The students' response may be interpreted as the attainment of a concept when the student may not have truly integrated and organized the new concept into his existing organizational framework. In comparison, the concept mapping technique utilized in this study only provided the student with a blank sheet of paper and the only cue given was the teacher's instructions to "draw a concept map over the water cycle". Therefore, the concept maps were more representative of the students' own structural complexity and organizational patterns.

While quantitative findings indicated the necessity of the expansion phase for a significant number of students, it is also important to recognize the diversity among the students' patterns of conceptual development. For example, two of the same idea units that were listed before as the most often added at the conclusion of the expansion phase were also added at the conclusion of the exploration phase by many of the students. These idea units were: evaporation leads to condensation (added by 20 students), and condensation leads to precipitation (added by 19 students). Fifteen of these students added both of these idea units during the expansion phase.

This diversity of concept acquisition does not support the linear model of the learning cycle that equates students' mental functioning to the cycle phase by phase. That is, exploration is equated to assimilation and disequilibration, term introduction equated to accommodation, and expansion is equated to organization (Marek & Cavallo, 1997). While this model may represent the theoretical basis for the structure of the learning cycle, it should not be taken as a literal correlation of students' mental functioning processes. This research revealed a number of students did not progress through these stages as defined. That is, specific concepts were integrated into students' conceptual frameworks during different phases of the learning cycle, and an individual student may integrate concepts at different times regardless of their time of introduction during the cycle. Therefore, the rate of assimilation, disequilibration, accommodation, and organization is a very dynamic and individual internal process. This view of concept development is supported by Shymansky's et. al. (1997) description of conceptual attainment as "a personal restructuring of one's conceptual framework in a dynamic process" that is therefore, a "punctuated, saw-toothed, conceptual growth process"(p. 571).

The second question that guided this study was: How is the development of the individual students' concept mediated by classroom discussions and the students' small cooperative learning group? The qualitative information obtained from the focal group was utilized in this section of the data analysis.

When the summary charts of the exploration, term, introduction, expansion, and retention maps (found in tables XIV-XVII) where reviewed it was found that only Van and Lora included ideas that where teacher mediated alone. The other two focal group students, Becky and Kevin, only incorporated idea units that were partially or wholly student mediated.

Student interactions were analyzed for idea unit origin and student mediation in order to better understand the impact of the mediation process within the small group. Since Van had been assigned as Lab Captain he read the lab sheet questions and asked for group responses. It was noted that he always called on either Becky or Kevin whenever he asked for a response from a group member by name. It was also noted that all of the identifiable idea units that originated within the focal small group originated with either Kevin or Becky. All of Lora and Van's identifiable comments within the small group fell into one of four different categories: (a) reading directly from the lab sheet, (b) asking questions to which Kevin and Becky responded, (c) restating of an earlier comment made by Kevin or Becky, or (d) making an off task comment (from Van).

The following excerpt, taken from the transcript of the third day of the learning cycle, is an example of a typical small group interaction.

Van: (Reading from the lab sheet) "Observe the side and top of your container carefully. Record your observations." (Looking up) "What did we observe? Becky what did you see?"

Becky: "My observation is that there is moisture on the side of the container and the top of the container."

Lora: (Repeating as she writes down the answer) "There is moisture on the side and on the top of the container?"

Kevin: "That's not exactly or entirely true. My input is the there was only moisture on the side that was furthest from the light and on the top furthest from the light."

Van: (Again reading from the lab sheet) "One side of your container was nearer the light than the other side. What differences do you observe in the amount of water you find on the sides of the container?"

Kevin: "The part closest to the light doesn't have any water on it. The part furtherest from the light has a whole bunch of moisture on it."

Van: (Restating Kevin's earlier comment) "All right, my input is that there is only moisture on the side that was furthest from the light on the top."

It is also noted that Kevin and Becky would reprimand Van at times to be quite or to stay on task. In the post interview Kevin recounted the group interactions by stating: "Basically we did the questions on our own when we read the question, or one of us would answer while the teacher was talking and one of us would be goofing off during class time - which would be Van who was goofing off."

Research on student equity in traditional science classrooms was recently conducted by Bianchini (1997). She reported that students hold tightly to their conceptions of peer intelligence and often develop a clear status or "pecking order" within their small groups. The study also reported that students that were perceived as being less intelligent as others in the group where excluded from participation during group work and seen as unable to provide intellectual insight, rarely asked to voice their opinions, or allowed to do little substantive work. Ironically, it was also reported that these students are not as incompetent as their fellow group members believed. It was also noted that the students' status within the group significantly correlates with the rate of on-task talk.

The present research substantiates these findings. It is easily seen from transcripts that different patterns of interaction took place between the students within the small group. As an example of a low-status student, Van clearly had taken on the role of the less intelligent and less responsible student in the following ways: (a) he represented himself as "stupid" to the small group and the teacher, (b) he presented himself as a student with a poor work ethic by revealing that he was often late to class, (c) at one point in the small group discussion he confided to the small group that he had "ditched" classes earlier in the day, and (d) was obvious when he copied from others.

In contrast Kevin and Becky where treated with a higher regard by the other two students in the group. This was evident in several ways: (a) Van repeatedly called on them by name for answers, (b) Van and Lora copied answers from both of them, and (c) all the student mediated idea units that were included by small group members originated with either Kevin or Becky.

It is interesting to note that when the qualitative summary chart of retention maps and previous map origin (Table XVII) was compared to the interview summary chart (Table XVIII) and the individual summary charts (Tables XIX through XXII) it was discovered that Becky, Van, and Lora all attributed the identified knowledge that they had gained in the learning cycle to the laboratory experiences in phase 1 of the learning cycle. Only Kevin, who actually originated the majority of idea units within the small group, identified the origination of the ideas as coming from the group discussions.

In order to better understand how teacher-student interaction within the classroom discussions might impact on the students' tendency toward the inclusion of the teacher-mediated idea units the small group transcripts were again reviewed. It was discovered that the four students fell into two distinctive classes of teacher-student interactions. The first classification of interactions, termed non-engaged, involved superficial interactions between the students and the teacher. The second classification of student-teacher interactions, termed learner-engaged, involved teacher scaffold questions and positive feedback.

It was discovered that Van and Lora, the two students who included the teacher-mediated ideas in their maps, were both classified as non-engaged. Transcripts revealed that Van and Lora never raised their hands to answer a question in class discussion. It was also noted that the teacher made very little direct contact with these two students and what contact that was made was a limited low-quality interaction. Teacher-student contact with these two students was found to be limited to one of three categories: (a) a direct question from the teacher, (b) the teacher trying to direct or redirect the student back to task (Van) or (c) as a discipline interaction (again Van).

An example of category "a" the direct question, was a teacher student interaction found in phase one. At this point the small group was discussing their observations of condensation on a beaker and the teacher walked up behind the group to observe.

> Ms. R. (talking to Lora in small group setting) "Are you discussing?"
>
> To which Lora responded: "Yes, we discussed these three." (referring to three lab questions)

An example of category "b" directing the student, was found in phase two.

> Ms. R. (Talking to Van) "Now, Van, you're in charge of reading the questions out loud and getting everybody's input (Van was the assigned Lab Captain of the group) before you answer your question." Van then began reading the questions to the group.

Another example of category "b" redirection of the student, was found in the transcripts of phase one. The teacher had again walked up behind the small group to observe.

Ms. R: (talking to small group setting) "Okay, from where did this water on the side come? Does anybody else have an idea here? Share. . .Share." (Van appears to be distracted with another group). "Van, read it loud and clear."

To which Van responded: "From a gas that's a little bit of the water cycle, is all I could think of" (Other members of the small group laugh). "Hey don't laugh. I'm stupid because I want to be." At which point the teacher walked on to the next group.

Category "c", a discipline interaction, was recorded on day four of the study when Van had been counted absent earlier in the day when Ms. R. had covered another teacher's class.

Ms. R.: "Van. You weren't in class this morning."

Van: "Yeah, I was. Yeah, I was. I came in late. I thought you saw me. Am I still counted as absent?"

Ms. R: "Did you check into the office?"

Van: "The bell rang when I was in the hall."

Ms. R: "You didn't get to class on time? Is that what you are saying?"

Van nods yes.

In contrast to Van and Lora, Becky and Kevin did not include any idea units that had been mediated by the teacher alone. They only incorporated idea units into their concept maps that had been partially or completely student mediated. A vast difference was found in the teacher-student interactions with these two students compared to the teacher-student interactions described earlier with Van and Lora. Both Becky and Kevin were classified as learner-engaged. It was also noted that Becky and Kevin raised their hands and volunteered answers often during classroom discussions. Kevin was usually correct in his scientific explanations and demonstrated logical thought patterns even when demonstrating an alternate concept. Becky, though often incorrect in her answers, was still treated in a positive manner. The teacher responded to her answers using either positive verbal cues or positive body language. As a result, she was willing to repeatedly take the risk of giving an incorrect answer in classroom discussions.

An example of teacher scaffolding between these two students was found in the transcripts of the classroom discussion of the beaker of water.

Ms. R.: "Where does the water on the outside of the beaker come from?" (Kevin raises hand)

Kevin: "Condensation"

Ms. R.: "Okay, but where does the water actually come from." (Becky raises hand) "Becky."

Becky: "Water evaporates from the inside and condensates on the outside."

Ms.R.: (Ms. R. smiles) "Did the water that we put in the beaker have time to evaporate?"

Kevin: "No, it comes from the gas in the air."

It can be seen from these excerpts that the student-teacher interactions with Van and Lora where significantly different than the student-teacher interactions with Kevin and Becky. It is also noted that Van and Lora had the highest two average scores on the concept maps when compared to the teacher criterion map. This aspect combined with the inclusion of teacher mediated idea units may imply that they were more oriented to the teachers expectations in terms of what they felt was important to include in their concept maps.

Within this research a clear pattern of student-teacher interaction and the status within the small group can be seen. Those students who had non-engaged, low quality, student-teacher interactions where also the students that were treated as lower status by the small group members. In contrast the two students who were learner-engaged and had a high quality of student-teacher interactions were the students treated with high status by the group members. Whether or not this pattern would be a trend found other cooperative learning groups or if these findings represent an anomalous finding is unknown. To the best of this researcher's knowledge the inter-relationships between teacher mediation, student mediation, and student concept development has not been previously investigated. Nonetheless, this research found that the combination of student-teacher interactions and the students status within the group appears to have greatly influenced what idea units the individuals within the small group integrated into their conceptual framework as represented by their concept maps.

The third question that guided this study was: How stable are the individual students' concepts over time? The repeated measures MANCOVA (reported in Table XI) that was performed on the combined concept maps and multiple-choice tests results indicated that students' conceptual understanding decreased from the time of the expansion until the time of the retention test six weeks later. Separate ANCOVAs that were performed (reported in Tables IX and XII) indicated that both measures contributed to this variability in student concept knowledge. Therefore, statistics revealed a significant decrease in the retention of the concepts developed during the water cycle learning cycle when measured by both the concept mapping technique or the more traditional teacher developed multiple choice test.

This decrease in the retention of concepts over time is an indication that not all of the new concepts introduced in the learning cycle unit resulted in the assimilation, disequilibration, accommodation and integration into the learner's organizational framework as intended. It is possible that students may have only memorized certain concepts in a rote fashion for a brief period of time rather than truly assimilating, accommodating the concepts and integrating them into their conceptual frameworks. The students' failure to integrate these new ideas into their conceptual framework could result in students reverting back to their previous knowledge in some areas.

This lack of conceptual integration may have also been the result of the curriculum. The type of methodology utilized in this research was a descriptive leaming cycle. In a descriptive learning cycle students gather data which generally requires only the observation and identification of descriptive patterns without any attempt to explain their observations or why the phenomena takes place. In contrast, empirical-abductive learning cycles take this basic cycle pattern and further require the student to generate possible explanations of the observed pattern. This requires the transference of concepts learned in other contexts to be transferred to new applications. The hypothetical-deductive learning cycle takes this a step further and requires the student to design and conduct experiments to test their explanation. It is possible that in a descriptive leaming cycle the student is not as actively engaged in the rationale of the experiment and therefore does not integrate all of the concepts into his conceptual framework. It is interesting to note that learning cycle research is often extrapolated to make inferences on all types of learning cycle implementation regardless of the type of cycle utilized in the study. However, it is feasible that results may be different depending on the type of learning cycle implemented.

Another possible explanation for students lack of conceptual integration may have been the result of the brevity of the unit and the lack of reinforcement of the concepts over time. The learning cycle curriculum used in this study did not continue to integrate the concepts used in this unit in later units covered.

This research is unique in that it investigated the lack of retention of the learning cycle concepts themselves. The utilization of the learning cycle method significantly restricts the number of concepts to be taught when compared to traditional science teaching approaches. Consequently, one of the major concerns of implementing the learning cycle method is whether or not it allows for a sufficient number of concepts to be included in the curriculum. The NARST Monograph (Lawson, Abraham, & Renner, 1989) of learning cycle research reported that "this reduced coverage should be more than compensated for by increased understanding and retention" (p. 84). However, past research on the effectiveness of the learning cycle has focused on the retention and transfer of thinking skills rather than content retention (Renner et al., 1973; Lawson et al., 1989). While it is not argued that thinking skills are an important aspect of intellectual growth, the necessity of the acquisition and retention of the concepts themselves should not be overlooked.

Implications of the Study

Teachers must be aware that learning cycle science concept assessments may be significantly influenced by student reading level. This finding, in addition to past reading research, has several implications. First of all, results indicate that the integration of instruction of critical science reading skills with the learning cycle could significantly increase concept attainment assessment scores. This could be especially vital at the elementary and middle school levels. Therefore, the implementation of critical science reading skills should be integrated into teacher education science method classes. Secondly, researchers should study learning cycle concept assessment tools to determine if alternative assessments, such as oral testing, would result in more equitable science concept assessment regardless of student reading level. In the interim, practitioners should also consider student reading level and utilize alternate assessments in order to have a more accurate and equitable assessment of individual student's concept attainment.

The differentiation between the learning cycles' phases and students' actual rate of concept development has definite ramifications. Further research should be conducted in learning cycle classrooms to ascertain the differences between the rate and retention of concept development within the descriptive learning cycle. In addition, the practitioner must also be aware that although a concept has been explored and the terms introduced, students may not have assimilated, disequilibrated and accommodated the concept. The teacher must therefore be sensitive to individual rates of concept development within the learning cycle framework. Fortunately, the teacher has the opportunity to implement different strategies to utilize these individual differences in students' concept development as an asset in student learning. For example, the teacher can structure the questioning techniques used within the classroom discussions to help students scaffold on their various existing conceptual framework to include new concepts. In addition, the teacher can give the students the opportunity to learn in collaboration with more capable peers by encouraging student interaction during small group discussions.

Since this research was investigative in nature, it is not possible to make definitive conclusions on teacher-student mediation and its impact on small group collaboration. However, since a clear correlation was found in the focal group this aspect of concept mediation should be further researched. The findings of this type of research would have a definite effect on learning cycle teacher training and implementation in the classroom. In addition, the focal group observations made in this research would indicate that non-cognitive assigned roles do not contribute to equitable student interactions within the group. Therefore, researchers and practitioners should also search to find a way to insure more interaction between all members within the small groups.

The investigative nature of the research also restricts the conclusions that can be drawn on learning cycle concept retention. However, future research should explore this phenomena, not only with the age group and descriptive type of learning cycle investigated in this study, but also with empirical-abductive, and hypothetical-deductive types of learning cycle and how they compare in concept retention to more traditional types of teaching methodologies. Past research has implied that results found in learning cycle studies are applicable across all three types of learning cycles however, this may not be true. It is possible that empirical-abductive or hypothetical-deductive learning cycles would be more effective methodologies in facilitating student development and retention of concepts. The learning cycle methodology is very time consuming and expensive to implement within the classroom. Therefore, the lack of concept retention found in this study is a significant concern and should be considered when implementing learning cycle curriculum. It is noted that previous research has found the learning cycle to facilitate process skills and critical thinking skills however, further research should be done to ascertain the extent the learning cycle is needed to develop these skills. It is possible that learning cycle methods could be integrated with other methods of instruction and result in a curriculum which is still effective in teaching process skills and critical thinking as well as being much more economical and more time efficient.

Significance of the Study

Results from this study have built on the knowledge gained from previous researchers exploring the construction of concept development and cooperative learning (Bianchini, 1997; Cleminson, 1990; Lazarowitz, Hertz-Lazarowitz, & Baird, 1994; Lumpe & Staver,1995; Richmond & Striley, 1996; Wandersee, Mintzes, & Novak, 1994). The study contributed to greater understanding of how sixth grade students use knowledge from a learning cycle science laboratory investigation to negotiate meaning in a collaborative cooperative learning group. The study also provided information about the ways in which students construct and retain concepts as a result of their classroom interaction in the context of science education. Unfortunately, the vast majority of existing science research involves college or high school science students. Consequently, the extrapolation of these findings to an elementary level are both questionable and laborious. Therefore, the information gained from this study is extremely beneficial in the realm of elementary science education and research.

In addition to adding to the body of previous research knowledge, findings from this research can also inform those who teach in the elementary science classroom. Knowledge of these issues will enable teachers to encourage beneficial interactions within the classroom. This information is particularly important for the education of upper elementary students since these children are in a period of metamorphosis of their cognitive development. Many upper elementary students are fundamentally concrete thinkers and are therefore in a stage of transformation of their metacognitive strategies, or the ability to think about their own thinking and reasoning processes. As a result, they are often unable to fully articulate what is happening within their evolving conceptual framework from a formal perspective. Therefore, if we are to gain a fuller understanding of their mental processes, it is important to closely observe and analyze those aspects of the thinking mechanisms that are observable. This research yielded further information concerning these evolving mental processes and the part classroom discussions and collaborative groups play within the learning cycle framework.

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Appendix A
Tests

Investigation 15
Test A

1. The depositing of moisture in the form of snow is called
   (a) the water cycle
   (b) evaporation
   (c) condensation
   (d) precipitation

2. The repeated process of evaporation, condensation, and precipitation is called
   (a) an interaction
   (b) an ecosystem
   (c) a water cycle
   (d) an open circuit

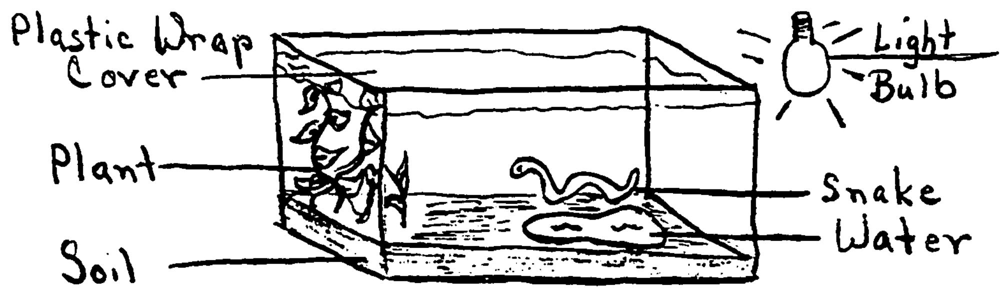
3. The change from a liquid to a gas is called
   (a) the water cycle
   (b) evaporation
   (c) condensation
   (d) precipitation

4. The change from a gas to a liquid is called
   (a) the water cycle
   (b) evaporation
   (c) condensation
   (d) precipitation

5. The water level in an aquarium going down is an example of
   (a) evaporation
   (b) condensation
   (c) precipitation
   (d) none of the above

6. Snow falling on a cold day is an example of
   (a) evaporation
   (b) condensation
   (c) precipitation
   (d) seeding

Refer to the drawing below to answer questions 7 - 11



7. If this ecosystem has been set up over night what would you expect to see on the sides and top of the container.
   (a) dirt
   (b) drops of moisture
   (c) growing spores
   (d) evaporation

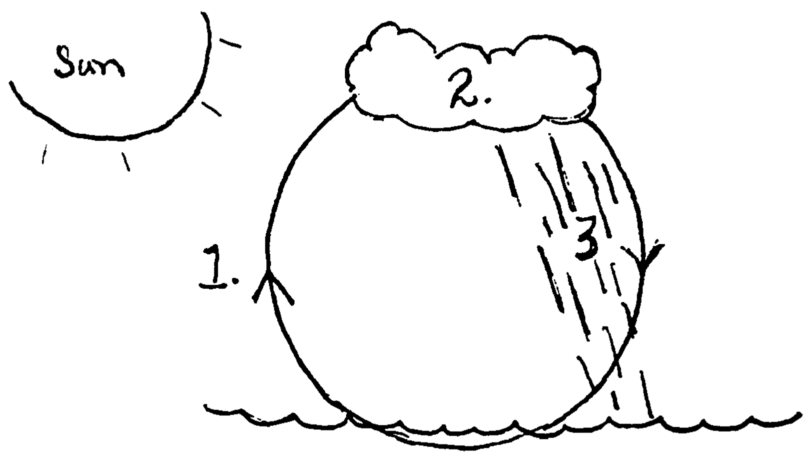
8. Where would the temperature in this ecosystem be the coolest?
   (a) along the top of the system
   (b) the lower right side close to the water
   (c) wherever the snake is located
   (d) on the lower left side close to the plants

9. This drawing represents
   (a) a closed circuit
   (b) a magnetic field
   (c) a closed ecosystem
   (d) an open ecosystem

10. You would find the majority of the condensed moisture located
   (a) on the side of the container opposite from the light
   (b) on the side of the container closest to the light
   (c) on the soil
   (d) there will be no condensed moisture in the aquarium

11. Where does the condensed moisture come from?
   (a) The outside air
   (b) the pool of water inside the container
   (c) the plants inside the container
   (d) Both b and c are correct

Refer to the drawing below to answer questions 12 - 15.



12. The drawing above represents
   (a) the water cycle
   (b) condensation
   (c) precipitation
   (d) evaporation

13. Number 1 in the drawing above represents
   (a) evaporation
   (b) condensation
   (c) precipitation
   (d) none of the above

14. Number 2 in the drawing above represents
    (a) evaporation
    (b) condensation
    (c) precipitation
    (d) seeding

15. Number 3 in the drawing above represents
    (a) evaporation
    (b) condensation
    (c) precipitation
    (d) seeding

16. In the process of evaporation liquids change to
    a. solid
    b. water
    c. a vapor
    d. liquids do not evaporate

17. How could you prove evaporation using an aquarium half filled with water?
    a. By adding ice and observing the water level raise
    b. By sealing the aquarium and observing the moisture forming on the inside of the aquarium.
    c. By letting the aquarium sit for several days and marking the water levels
    d. All of the above

18. Fog is an example of:
    a. evaporation
    b. condensation
    c. precipitation
    d. interaction

19. Explain why "sweat" forms on a cold can of pop?
    a. The can was just taken out of the cooler.
    b. It is colder outside the can than inside the can.
    c. It is colder inside the can than outside the can.
    d. The inside temperature of the can is the same as the outside temperature.

20. Rain is an example of
    a. Evaporation
    b. Condensation
    c. Precipitation
    d. Interaction

21. An example of precipitation is
    a. Drops of water on the outside of a cold McDonalds cup
    b. Rain
    c.. The puddle on a sidewalk disappearing
    d.. Clouds

22. Which of the following is a part of water cycle?
    a. Evaporation
    b. Precipitation
    c. Condensation
    d. All of the above

23. Condensation is the change of
    a. A gas to a liquid
    b. A liquid to a gas
    c. A solid to a gas
    d. A solid to a liquid

24. Fog is an example of
    a. Evaporation
    b. Precipitation
    c. Condensation
    d. All of the above

25. When “sweat” forms on a cold can of pop on a warm day, where does the moisture come from?
   a. Inside the can of pop
   b. From your hands
   c. From the surrounding air
   d. It will not form on a warm day

26. Heat and wind are both factors in causing
   a. Condensation
   b. Evaporation
   c. Magnetism
   d. None of the above

27. Cold and humidity are both factors in causing
   a. Condensation
   b. Evaporation
   c. Magnetism
   d. None of the above

28. Spilled water on the floor that disappears overnight is an example of
   a. evaporation
   b. condensation
   c. precipitation
   d. none of the above

29. The water cycle is
   a. The depositing of moisture
   b. Changing a liquid to a gas
   c. Changing a gas to a liquid
   d. The repeated process of a, b, and c.

30. Which of the following situations is NOT an example of the processes that occur in the water cycle?
   a. Fog on a mirror after a shower
   b. “Smoke” when you exhale in the winter
   c. Formation of clouds in the sky
   d. All of the above are examples of the processes in the cycle.

Investigation 15
Test B

1. What causes a liquid to evaporate?
   a. Heat
   b. Cold
   c. Humidity
   d. Pressure

2. Which of the following statements about evaporation are true?
   a. When water evaporates it no longer exists in the ecosystem.
   b. When water evaporates it becomes a solid
   c. When water evaporates it becomes a liquid
   d. When water evaporates it becomes a gas

3. Which of the following statements about the water cycle are true?
   a. It is a never ending cycle
   b. New water is constantly made during the cycle
   c. Evaporation is not a part of the water cycle
   d. Both a and b are true

4. When you go outside in the morning there may be water on the plants. What causes the water on the plants?
   a. The plants make the water during the night
   b. The water has condensed on the plants
   c. Both a and b are correct
   d. Neither a or b are correct

5. Snow is an example of
   a. Evaporation
   b. Condensation
   c. Precipitation
   d. Interaction

6. Which of the following are factors in the water cycle?
   a. Temperature
   b. Humidity
   c. Both a and b
   d. Neither a or b

7. When warm air hits a cold surface the water vapor in the air will
   a. condense
   b. precipitate
   c. evaporate
   d. disappear

8. What causes water to evaporate?
   a. heat
   b. wind
   c. cold
   d. both a and b cause evaporation
   e. water does not evaporate

9. Dew on the ground in the morning is an example of
   a. evaporation
   b. condensation
   c. precipitation
   d. none of the above

10. Which of the following has no effect on the rate of condensation?
   a. Temperature of the air
   b. Humidity of the air
   c. Both a and b have an effect on the rate of condensation
   d. Neither a or b have an effect on the rate of condensation

11. Water drops on the outside of a glass of cold iced tea is an example of
   a. evaporation
   b. condensation
   c. precipitation
   d. none of the above

12. Moisture that appears when you breath on a mirror is an example of
    a. evaporation
    b. condensation
    c. precipitation
    d. seeding

13. How does heat affect the rate of evaporation?
    a. It has no effect
    b. It speeds up the rate
    c. It slows down the rate
    d. The hotter it is, the slower the rate.

14. How does temperature affect the rate of condensation on a window?
    a. The <u>bigger</u> the temperature difference between the inside and the outside of the window the <u>faster</u> the rate of condensation.
    b. The <u>smaller</u> the temperature difference between the inside and the outside of the window the <u>faster</u> the rate of condensation.
    c. The <u>bigger</u> the temperature difference between the inside and the outside of the window the <u>slower</u> the rate of condensation.
    d. The temperature has no effect on the rate of condensation.

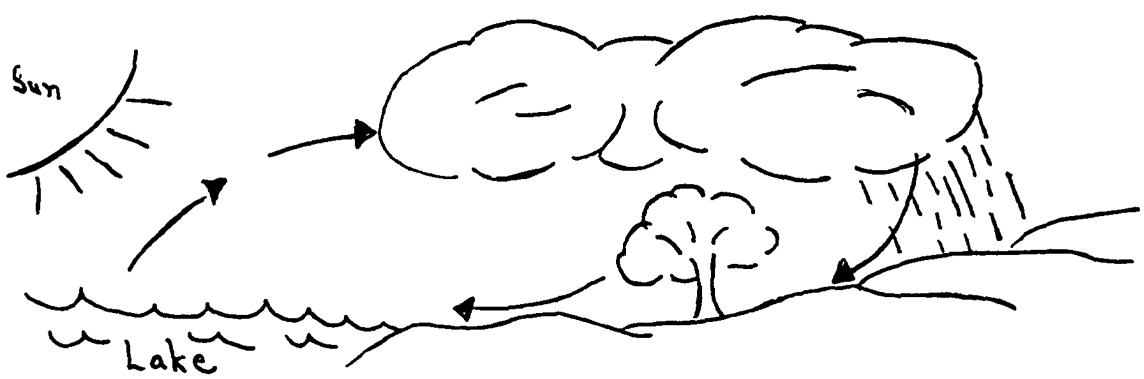
15. What causes a gas to condense?
    a. Heat
    b. Cold
    c. Sunlight
    d. Pressure

16. Clouds are an example of:
    a. evaporation
    b. condensation
    c. precipitation
    d. temperature

17. The earth creates new water
    a. Once a year
    b. Once every season
    c. Only in the spring
    d. The earth never creates new water, it recycles the existing water.

18. Sleet is an example of
    a. Evaporation
    b. Condensation
    c. Precipitation
    d. Interaction

Questions 19 -25
Study the picture below and fill in the blanks with the correct word to explain the diagram.



Fill in the blank on your answer sheet with the correct letter.

a. interaction	d. condensation	g. gas
b. evaporation	e. solid	h. rains
c. precipitation	f. liquid	I. water cycle

When it ___19______, water soaks into the ground, rivers and lakes increase and puddles form on the roads and sidewalks. This process is called ___20_____. as the weather clears, ___21_____occurs as the puddles disappear. The water has become a ___22______and is in the air. Clouds are formed from the process called ___23____. When the clouds become full, the water becomes a ___24_____ and falls to the ground as rain. Thus, the __25___ starts again.

26. An example of condensation is
    a. Drops of water on the outside of a cold McDonalds cup
    b. Rain
    c. Sleet
    d. The puddle on a sidewalk disappearing

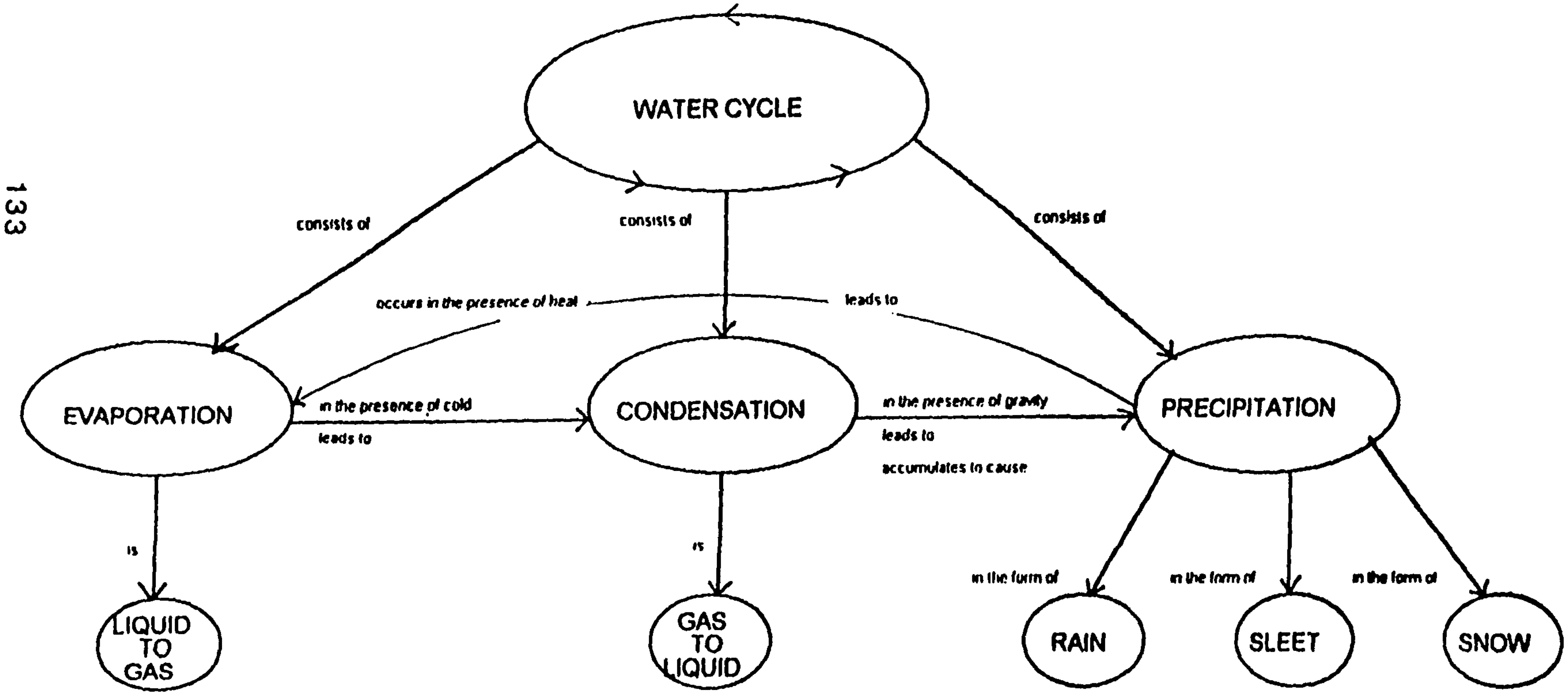
27. An example evaporation is
    a. Drops of water on the outside of a cold McDonalds cup
    b. Rain
    c. Fog
    d. The puddle on a sidewalk disappearing

28. Evaporation is the change of
    a. A gas to a liquid
    b. A liquid to a gas
    c. A solid to a gas
    d. A solid to a liquid

29. The water level in an swimming pool going down over a period of days is an example of
    a. Evaporation
    b. Precipitation
    c. Condensation
    d. All of the above

30. When you are drinking a glass of cold lemonade on a hot day what would you expect to see?
    a. Condensation on the glass <u>above</u> the level of the lemonade in the glass
    b. Condensation on the glass <u>below</u> the level of the lemonade in the glass.
    c. Condensation on the glass <u>above and below</u> the level of the lemonade in the glass
    d. No condensation will appear

Appendix B
Teacher Map


WATER CYCLE
consists of
consists of
consists of
occurs in the presence of heat
leads to
EVAPORATION
in the presence of cold
leads to
CONDENSATION
in the presence of gravity
leads to
accumulates to cause
PRECIPITATION
is
LIQUID TO GAS
is
GAS TO LIQUID
in the form of
in the form of
in the form of
RAIN
SLEET
SNOW

Appendix C
Interview Questions

Interview Format

1. First, I would like you to tell me everything you know about the water cycle. Explain it as if you were explaining it to someone who had never heard about the water cycle before.

2. Is there anything else you would like to add?

3. (Hand student a copy of the map constructed at the conclusion of the unit) Here is a copy of your last map. Can you explain to me what you drew?

4. (Hand student a copy of the pre-test map) Here is a copy of your pre-test map. Can you explain to me what you drew?

5. Look at the copy of your last map and your first map. Do you see any differences? What are the differences?

6. Where in the unit did you learn each of these? Explain.

7. How much do you feel your group contributed to your understanding? Explain.

8. What are the differences that you see?

Appendix D
Permission Slips

University of Oklahoma
Informed Consent Form

The research described below is being conducted under the auspices of the University of Oklahoma, Norman Campus. This document is a formal request for permission form you and your child to have your child participate as a volunteer in the study described below.

I. TITLE: Concept Mapping and Conceptual Development Within the Learning Cycle

Investigator: Lisa J. McWhirter, Doctoral Candidate
Department of Instructional Leadership and Academic Curriculum
College of Education
University of Oklahoma
Phone: 325-1498

Faculty Advisors: Bonnie Konopak, Ph.D., Professor and Chairperson, Instructional Leadership and Academic Curriculum
and
Sara A. Beach, Ph.D., Assistant Professor, Instructional Leadership and Academic Curriculum
College of Education
University of Oklahoma
Phone: 325-1498

The principal investigator is a Doctoral student at the University of Oklahoma who is studying science education in the Department of Instructional Leadership and Academic Curriculum. Her research interest centers on how childrens' conceptual understanding develops within the learning cycle and how that understanding is mediated by the students' cooperative learning groups.

The study will take place in your child's regular science classroom. The study will include one two week science unit. Normal instruction will continue during the unit. In addition, several concept mapping activities will be added to the usual classroom routine. A concept map is a graphic representation of the main ideas of the learning unit and is a component of the normal instruction in your child's classroom activities. Your child will be observed and both audio and video taped as he/she engages in normal science instruction. He/she may also participate in an interview with the principal investigator at the conclusion of the science unit. Observations and interviews will not disrupt normal classroom instruction.

The result of all interview, observation, and concept mapping activities will be kept confidential and will not be used by the school district for evaluating the child's learning. As soon as your child's concept mapping activities are collected their name will be removed and replaced by the investigator with a code number. Only the investigator and the faculty advisors will have access to the identifying data. Any publications resulting from the study will use pseudonyms for the study's participants.

Since data collection involves commonly accepted practices, there should be no potential risk to the children. Potential benefits include an increased understanding of children's conceptual development in middle school science, specifically how their conceptual understanding develops during learning cycle instruction.

If you choose to volunteer your child for the study, please sign and return this form. If you choose to decline, there will be no penalty for your child. Furthermore, should you choose to participate, you or your child can refuse to answer any question at any time, or can totally withdraw from the study at any time without any penalty.

This is to certify that I,____________________________________

(print full name)

hereby give permission to have my child or legal ward,

____

(print child's full name)

to participate as a volunteer in a study as part of an authorized research program of the University of Oklahoma under the supervision of Lisa J. McWhirter, Doctoral Candidate. I understand that my chid or ward can refuse to answer any question at any time or can totally withdraw from the study without any problem.

____________________ ________________________

Date Parent/Guardian Signature

Student Consent Form

To the Student,

The study that will be conducted in your science classroom is being done to help educators to have a better understanding of how students your age learn about science. My name is Lisa McWhirter and I am also a student. I attend the University of Oklahoma and this study is part of my work as a Doctoral Candidate in the Department of Instructional Leadership and Academic Curriculum in the University's College of Education.

The study will take place in your regular science class during one learning cycle unit. During the study you will do the learning cycle as you normally do in class. In addition you will do several concept mapping activities. A concept map is a picture or diagram of the main ideas you know about a subject. During the study I will be observing you in the classroom and taking notes about the classroom activities. You will also be audio and video taped during class. This will help me remember what has happened during class. I will also interview you at the end of the science unit. The study will not disrupt your normal classroom activities.

All of the information collected during the study including my observations, the concept maps, and interviews will not be used by your teacher and will not affect your class grade. As soon as you turn your papers in I will remove your name and replace it with a code number. Only my university teachers and I will have access to the identifying data. Any papers that I may write resulting from the study will use not use your real name.

If you would like to volunteer to take part in this study please sign the form below. If you decide to not volunteer it will not be held against you in any way. If you decide to volunteer you can refuse to answer any question at anytime, or you can withdraw from the study at anytime.

I, ________________________ volunteer to be a part of the study
(print your name)

on science learning. ________________________ ______________
Student Signature Date

Appendix E
Lab Sheets

TEACHER'S GUIDE : INVESTIGATION 15

CONCEPT: THE REPEATED PROCESS OF EVAPORATION, CONDENSATION, AND PRECIPITATION IS CALLED THE WATER CYCLE.

EQUIPMENT LIST:

per student
- 1 metric ruler

per group
- 1 small glass or plastic container (test tubes or medicine bottles work well)
- 1 working ecosystem model
- 1 piece of plastic wrap

per class -
- pitcher
- turkey baster
- food coloring
- 2 lamps
- field with a variety of organisms; pond or creek if possible

OBJECTIVES:

At the end of this unit, the student should be able to:
-observe and discuss the presence of condensation.
-construct a working model of a water cycle.
-conclude the presence of water vapor in the air.
-hypothesize that the repeated process of evaporation, condensation, and precipitation is called the water cycle.
-recognize evidence of interaction between water and organisms on the school grounds.
-invent a system to recycle water.
-compare water cycle to ecosystem to water cycle outside the classroom.
-experiment with evaporation and condensation.

VOCABULARY

PRECIPITATION- the depositing of moisture in the form of snow, rain, sleet, etc..
WATER CYCLE- the repeated process of evaporation, condensation, and precipitation.

EVAPORATION- change from a liquid to a gas.

CONDENSATION- change from a gas to a liquid.

TEACHER'S GUIDE : INVESTIGATION 15

EXPLORATION: PART A

EQUIPMENT:

per student
1 small glass or plastic container

per class
1 pitcher ice water
food coloring

PROCEDURE:

This activity will serve primarily as a review of the concepts in Investigation 4. If the students did not complete Investigation 4, be sure that you introduce the term condensation during this exploration. You may also want to allow the students time to explore the process of evaporation.

1. Add food coloring to your pitcher of water. This may prevent a student from thinking that the water "seeped" through the glass jar. Give each child a container.
   Fill the container about half-full of ice water using the turkey baster. Make sure the water is very cold. Students should observe water condensing on the outside of the container. (This activity works best in a warm classroom.) Have the students draw a model of what they observed.

2. Have the students answer the questions.

SUGGESTIONS FOR DISCUSSION:

Review the fact that when warm air hits a cold surface the water vapor in the air will condense on the cold surface.

Discuss the fact that the water had to come from the room.

Why does the water condense below the water level and not above?

Why do you think we used colored water?

Brainstorm ideas which explain the source of the water on the outside of the jar.

TEACHER'S GUIDE : INVESTIGATION 15

EXPLORATION: PART B

EQUIPMENT:

per group

1 working ecosystem model in container
1 piece of plastic wrap

per class

2 lamps

PROCEDURE:

1. Observe the water level in the groups' ecosystem model and the class aquarium, if you have one, for evidence of evaporation. The residue left on the sides of the container should help prove that the water evaporates and leaves minerals. Remind the students about the activities from Investigation #4. Generate a list of the liquids investigated and the rates at which they evaporated.

2. Be certain to question the students about how they might contain the moisture inside their ecosystem models. Plastic wrap taped down works well. Proceed with watering the models and securing plastic wrap over them. Be open to other ideas for covering the containers that the students might create. Be sure the lids on the ecosystem containers are covered tightly. Place the containers so that one end of the container is nearer to the light than the other. Do not use overhead fluorescent lamps for this exploration. Incandescent lamps will provide the best source of heat.

3. Have your students draw a model of their ecosystem container including the position of the light source. This will provide a good reference tool when they are asked which side was nearer the light. Students should see moisture on the sides or top of their container.

EXPLORATION: PART B (continued)

4&5. The majority of the condensed moisture will be located on the side of the container opposite from the light.

6&7. Discuss that the moisture came from the soil, pond, plants, and animals in the container. The water evaporated from these sources. Point out however, that this water was the water they put in the system. New water was not made, simply recycled.

SUGGESTIONS FOR DISCUSSION:

Discuss with the students the temperature difference.

Ask them which side of the container was coolest.

Ask them from where the water could have evaporated.

List these possibilities on the chalkboard. They should include the soil, "pond"(if they have a "pond" in their system), plants, and animals.

Select a few students to draw their models of what happened overnight, on the board.

CONCEPTUAL INVENTION - THE IDEA

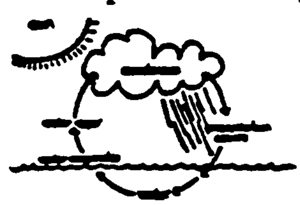
SUGGESTIONS FOR DISCUSSION:

1. Discuss with your students that heat is a factor in the evaporation of liquids. Ask students to provide examples of evaporation. Include in your discussion the fact that the students have observed the water level in an aquarium go down, and that they know that water which is spilled on the floor will disappear.

2. Discuss that liquids change into water vapor in the process of evaporation. You might ask why you can't see the water evaporate.

3. Discuss that the cooling of the air around the jar of cold water causes water drops to form. Ask for examples of when students have observed water condense.

4. Ask the students what happens to the water in the ground after a rainstorm. Have them name variables that might affect how fast the water will evaporate. Compare drawings of students' examples. Be sure to have them label each part of the diagram. For example:



5. Discuss that water is constantly being cycled from the atmosphere to the lakes, streams, and oceans. Evaporation returns it to the air. In the air, the water condenses. It falls to earth as rain, snow, sleet, or hail. These are examples of precipitation.

6. Be flexible in accepting student answers, as long as they're reasonable.

7. Compile a class list of answers from question #6 on the board. Summarize the list and guide the students to the concept.

   CONCEPT: THE REPEATED PROCESS OF EVAPORATION, CONDENSATION, AND PRECIPITATION IS CALLED THE WATER CYCLE.

TEACHER'S GUIDE : INVESTIGATION 15

EXPANSION OF THE IDEA: PART A

EQUIPMENT:

per class
field with a variety of organisms, pond or creek if possible

PROCEDURE:

Review with your class the idea of water cycle.

Explain that the following activities will expand upon that idea.

1. You will need an area preferably with a variety of organisms. Include a pond if possible. You might want to give an example before beginning. For instance, you might break a berry, the inside of it is moist. Explain that the moisture inside indicates that the plant had to take in water. Be sure to accept any answer within reason. After students have completed the table discuss their findings.

SUGGESTIONS FOR DISCUSSION:

Make a class chart on the board similar to the one in their handout.

Have students predict how pollution might affect the organisms on their chart, after the discussion. As students will be studying pollution in later lessons, accept any predictions. Do not press for a "right" answer.

EXPANSION OF THE IDEA: PART B

PROCEDURE:

1-4. Review observations taken on Table 15-1. Have students complete the questions on Part B.

SUGGESTIONS FOR DISCUSSION:

Discuss their answers.

Ask students to come up with any other examples of when they have observed water condense, like breathing on a mirror or a window.

To further the discussion, draw a schematic diagram of the water cycle on the chalkboard and discuss its circular, never-ending pattern.

Discuss that plants do not make water, they simply let out water that they take in. Even a cactus does not "make water." It stores what it has take in.

EXPANSION OF THE IDEA: PART C

EQUIPMENT:

per student
1 ruler

PROCEDURE:

1-3. After reading the directions ask students whether they have house plants at home. If their family were to go on a two week vacation and no one could water the plants, how would they deal with it? Remind them that they have been studying about the water cycle. Have them draw a model of what they would design to keep the plants watered. Explain that they may use any common household items. Allow plenty of time for interacting and drawing.

SUGGESTIONS FOR DISCUSSION:

Ask several students to draw their model on the board.

Allow students to explain their models to the class.
Explain that they may use any common household items. Allow plenty of time for interacting.

Inv. 15 Name____________________ Date__________ Hr.________

EXPLORATION: PART A

1. Observe carefully as your teacher pours cold water in a container. What do you observe happening on the outside of the container?

____

____

____

2. Draw a model of what you observed.

3. What caused the condensation on the sides of the container?

____

____

4. From where did this water on the sides come?

____

____

Inv. 15 Name_____________________ Date__________ Hr.______

EXPLORATION: PART B

1. Observe the water level in your ecosystem model and the class aquarium for evidence of evaporation. Record your observations.

____

____

2. Cover your ecosystem with plastic wrap.

3. Draw and label a model of your group ecosystem container which includes the position of the light source.

4. Place your ecosystem model near a lamp or window. Leave overnight.

Inv. 15 Name____________________ Date__________ Hr.______

EXPLORATION: PART B (continued)

THE NEXT DAY-

5. Observe the sides and top of your container carefully. Record your observations.

____

____

____

6. One side of your container was nearer the light than the other side. What difference do you observe in the amount of water you find on the sides of the container?

____

____

____

7. Why do you think this happened?

____

8. From where did the moisture that condensed on the sides of your container come?

____

____

9. Draw and label the model of what happened overnight.

Inv. 15 Name______________________ Date______________ Hr.______

THE IDEA

1. When there is rain, water soaks the ground. Puddles form in the mud and on the sidewalks. A few days later the ground and sidewalks are dry. Draw a model to explain what is happening. Label evaporation, condensation and precipitation.

2. Explain what causes water to evaporate.

____

3. When water evaporates, where does the water go?

____

4. What causes water vapor in the air to condense?

____

5. How does water in your ecosystem relate to water in a pond?

____

6. From your data, what conclusions can you make about what happens to the repeated process of water in nature?

____

7. What idea about the water process did your class invent?

____

Inv. 15 Name______________________ Date___________ Hr._______

EXPANSION OF THE IDEA: PART A

What was the idea your class invented?

____

____

1. You have been studying the water cycle. Collect evidence of interactions between water and organisms around your school grounds. List below in TABLE 15-1.

TABLE 15-1

ORGANISM	EVIDENCE OF INTERACTION WITH WATER

2. What do you predict would happen if these organisms did not receive clean water?

____

____

Inv. 15 Name____________________ Date__________ Hr._______

EXPANSION OF THE IDEA: PART B

1. You have probably seen dew appear on the grass in the morning. By noon the dew is usually gone. What causes the dew to be gone?

____

2. If you go outside on a very cold morning you will sometimes see "smoke" come out when you exhale. This is not smoke, however, that is going into the air. Explain what the smoke is.

____

____

3. You may have seen the moisture that forms on the insides of windows on winter mornings. What causes the moisture to condense in the winter but not in the summer?

____

____

4. When you go outside in the morning water appears on plants. Some people claim that plants can "make water". Explain what causes the water on the plants.

____

____

Inv. 15 Name______________________ Date____________ Hr.________

EXPANSION OF THE IDEA: PART C

1. Imagine that your family is going on a two week vacation. Your brother, who loves plants, is worried that the twelve potted plants in his bedroom will die. No one will be available to water them. Using your knowledge of the water cycle, draw a model below of what you could build to help him care for his plants. You may use any common household items. Remember that plants also need light and will die if they are over watered.

2. Label your model.

3. Explain your model in relation to the water cycle.

____

____

____

____

Appendix F
Student Scores

id	gender	ethnic	class	test1	test2	test3
101.00	1.00	1.00	1.00	17.00	17.00	7.00
102.00	2.00	1.00	1.00	7.00	11.00	15.00
103.00	2.00	1.00	1.00	17.00	19.00	17.00
104.00	2.00	1.00	1.00	18.00	15.00	16.00
105.00	1.00	1.00	1.00	13.00	17.00	13.00
106.00	1.00	1.00	1.00	16.00	18.00	18.00
107.00	2.00	1.00	1.00	10.00	16.00	13.00
108.00	1.00	1.00	1.00	8.00	18.00	8.00
109.00	2.00	4.00	1.00	10.00	17.00	17.00
110.00	2.00	1.00	1.00	12.00	13.00	17.00
111.00	1.00	1.00	1.00	16.00	20.00	16.00
112.00	2.00	1.00	1.00	18.00	19.00	18.00
113.00	1.00	1.00	1.00	10.00	16.00	2.00
114.00	1.00	1.00	1.00	19.00	18.00	17.00
115.00	2.00	1.00	1.00	15.00	19.00	16.00
116.00	1.00	5.00	1.00	16.00	18.00	13.00
117.00	1.00	4.00	1.00	15.00	19.00	18.00
118.00	2.00	3.00	1.00	13.00	18.00	15.00
119.00	1.00	1.00	1.00	8.00	9.00	7.00
120.00	2.00	1.00	1.00	17.00	19.00	17.00
121.00	2.00	5.00	1.00	11.00	18.00	14.00
122.00	1.00	1.00	1.00	11.00	17.00	15.00
123.00	2.00	1.00	1.00	14.00	15.00	19.00
224.00	1.00	5.00	2.00	9.00	18.00	12.00
225.00	2.00	1.00	2.00	18.00	20.00	19.00
226.00	2.00	1.00	2.00	12.00	16.00	19.00
227.00	1.00	1.00	2.00	11.00	15.00	15.00
228.00	2.00	1.00	2.00	17.00	19.00	18.00
229.00	1.00	1.00	2.00	16.00	15.00	19.00
230.00	1.00	1.00	2.00	10.00	16.00	10.00
231.00	2.00	1.00	2.00	14.00	17.00	16.00
232.00	2.00	1.00	2.00	13.00	19.00	15.00
233.00	2.00	1.00	2.00	19.00	20.00	18.00
234.00	1.00	1.00	2.00	13.00	17.00	14.00
235.00	2.00	1.00	2.00	12.00	12.00	8.00
236.00	1.00	1.00	2.00	13.00	15.00	15.00
237.00	1.00	1.00	2.00	8.00	16.00	11.00
238.00	2.00	1.00	2.00	14.00	15.00	15.00
239.00	1.00	1.00	2.00	12.00	14.00	12.00
240.00	1.00	5.00	2.00	9.00	11.00	13.00
241.00	2.00	1.00	2.00	15.00	19.00	17.00
242.00	1.00	1.00	2.00	7.00	13.00	12.00
243.00	1.00	1.00	2.00	13.00	13.00	10.00
244.00	1.00	1.00	2.00	18.00	18.00	18.00
245.00	2.00	1.00	2.00	13.00	18.00	16.00
246.00	2.00	1.00	2.00	18.00	18.00	18.00
247.00	2.00	5.00	2.00	17.00	19.00	16.00
248.00	1.00	1.00	2.00	12.00	19.00	18.00

	map1	map2	map3	map4	map5
1	1.00	8.00	8.00	10.00	11.00
2	1.00	2.00	6.00	6.00	6.00
3	3.00	6.00	9.00	9.00	9.00
4	1.00	4.00	8.00	8.00	7.00
5	1.00	8.00	8.00	10.00	8.00
6	1.00	6.00	9.00	10.00	7.00
7	1.00	7.00	5.00	9.00	3.00
8	.00	5.00	5.00	4.00	4.00
9	3.00	9.00	8.00	11.00	9.00
10	.00	5.00	7.00	7.00	6.00
11	1.00	8.00	10.00	10.00	8.00
12	1.00	6.00	7.00	12.00	12.00
13	1.00	6.00	6.00	8.00	2.00
14	1.00	6.00	8.00	8.00	6.00
15	3.00	7.00	7.00	7.00	4.00
16	2.00	7.00	5.00	10.00	2.00
17	7.00	11.00	9.00	11.00	9.00
18	.00	6.00	6.00	8.00	4.00
19	1.00	6.00	1.00	11.00	2.00
20	4.00	7.00	9.00	11.00	10.00
21	1.00	4.00	5.00	10.00	10.00
22	1.00	8.00	6.00	11.00	10.00
23	6.00	5.00	8.00	15.00	9.00
24	3.00	7.00	4.00	7.00	4.00
25	1.00	6.00	6.00	11.00	9.00
26	1.00	6.00	6.00	9.00	7.00
27	.00	1.00	7.00	7.00	4.00
28	2.00	7.00	5.00	7.00	4.00
29	.00	.00	3.00	4.00	1.00
30	1.00	1.00	8.00	11.00	10.00
31	2.00	4.00	9.00	6.00	.00
32	.00	6.00	8.00	7.00	6.00
33	8.00	5.00	9.00	9.00	9.00
34	.00	4.00	6.00	6.00	6.00
35	1.00	5.00	5.00	5.00	6.00
36	1.00	6.00	3.00	6.00	.00
37	1.00	4.00	2.00	2.00	1.00
38	1.00	3.00	6.00	7.00	1.00
39	1.00	3.00	7.00	4.00	6.00
40	.00	4.00	5.00	6.00	6.00
41	1.00	8.00	6.00	6.00	5.00
42	.00	1.00	1.00	1.00	1.00
43	.00	7.00	7.00	10.00	5.00
44	1.00	7.00	10.00	12.00	7.00
45	1.00	6.00	4.00	9.00	8.00
46	.00	.00	.00	3.00	.00
47	4.00	11.00	11.00	13.00	9.00
48	1.00	8.00	8.00	9.00	7.00

Appendix G
Summary of Phases

Exploration Phase

Pretest concept maps where constructed prior to the start of the investigation.

Before the class began the exploration phase of the cycle the teacher lead a discussion about previous related investigations.

Water Cycle: No mention was made of predipitation.

Precipitation: No mention was made of precipitation.

Evaporation: The teacher made reference to the term evaporation, and had students refer to their notebooks for the definition of evaporation that had been constructed during a previous investigation. Evaporation was defined in the students notebooks as the process of turning a liquid, water, to a gas. This definition was stated by the students and then by the teacher during this discussion. A student also mentioned that heat was required for the process to occur, and this was restated by the teacher. The teacher also stated that the gas formed by evaporation is called steam.

Condensation: The teacher made reference to the term condensation, and had students refer to their notebooks for the definition of condensation that had been constructed during a previous investigation. Condensation was referred to as the "opposite of evaporation, when water as a gas in the air is changed back into a liquid" and as "water droplets in the air". The teacher also noted that condensation is caused by a change in temperature. During this discussion students made reference to the condensation that forms on the outside of a glass and also made the comment that condensation leads to rain.

Part A of the exploration phase involved the observation of a beaker filled with red colored ice water and the

condensation on the sides of the beaker.

Water cycle: During the exploration observation a student mentioned that condensation was part of the water cycle.

Precipitation: No mention was made of precipitation during this part of the investigation.

Evaporation: No mention was made of precipitation during this observation.

Condensation: Students identified the water droplets on the sides of the beaker as condensation. They again mentioned that the condensation was caused by the temperature change occurring when the cold beaker met the warmer air. One member of the group stated that the condensation was a result of water droplets in the air. However, Becky stated that she believed that the condensation on the outside of the beaker was a condensation of water that had evaporated from the inside of the beaker.

The teacher facilitated a discussion at the conclusion of the small group observation.

Water cycle: No mention was made of the water cycle during the discussion.
Precipitation: No mention was made of precipitation during the discussion.

Evaporation: During the discussion of the observation students mentioned that evaporation is caused by heat and leads to condensation. Students mentioned that the water in gas form in the air is call humidity. This was also restated by the teacher.

Condensation: The teacher facilitated classroom discussion again identified the droplets on the side of the beaker as condensation. Both students and teacher referring to the condensation as being a result of a temperature change which caused the gas or water molecules in the air to change into liquid droplets. However, during the discussion several students stated Becky's belief that the condensation on the outside of the beaker was a condensation of water that had evaporated from the inside of the beaker rather than from existing water vapor in the air. In an effort to clarify this point the teacher referred to the red color of the water in the beaker and asked students to identify the color of the condensation. This point was made so students would realize the condensation was not red and was therefore not from the dyed water in the beaker. Within the focal group however, Kevin voiced an alternate theory that "the red dye in the water was similar to salt in the ocean, and just like ocean water can evaporate and leave the heavier salt behind, the water in the beaker evaporated and left the heavier red dye behind." Since the teacher did not hear this comment she did not address the theory in the class discussion.

During Part B of the exploration phase students set up and observed a classroom ecosystem model which consisted of a terrarium filled with 7 cm. of water covered with plastic wrap. A heat lamp was placed at one end of the terrarium and the system was left overnight. The next day the small groups observed the ecosystem and noted the water level was 6.8 cm., and that there was condensation on the inside surface of the plastic wrap on the end away from the heat lamp.

Water Cycle: The small group did not mention the water cycle during this part of the investigation.

Precipitation: No mention of precipitation was made by the small group.

Evaporation: One student mentioned that evaporation was caused by heat.

Condensation: During the small group observation a focal student stated that the condensation came from gas in the air. The condensation was also referred to as moisture.

The teacher again facilitated a discussion at the conclusion of the small group observation.

Water Cycle: During this discussions students stated that the water cycle included precipitation, evaporation, and condensation.

Precipitation: Students mentioned that rain is precipitation and that precipitation leads to evaporation.

Evaporation: Students mentioned that evaporation is caused by heat.

Condensation: Students referred to condensation as being caused by temperature change. Students also pointed out that the condensation in the ecosystem became heavy and fell back down to the bottom of the terrarium.

Concept maps were constructed by the students at the completion of the exploration phase.

Term Introduction Phase

The term introduction phase began with a small group discussion of the idea page.

Water cycle: Kevin stated that the water cycle includes precipitation, evaporation, and condensation. An unidentified student also mentioned that the water cycle is an everlasting cycle.

Precipitation: No other mention was made of precipitation during this part of the investigation.

Evaporation: Becky mentioned that heat caused water to evaporate.

Condensation: Becky stated that "coldness" causes water vapor to condense.

The teacher facilitated a discussion at the conclusion of the small group observation.

Water cycle: The teacher stated that precipitation, evaporation, and condensation were included in the water cycle, which is a continuous cycle. She than stated that ". . .It runs into streams and lakes, rivers and ocean. The sun causes the water to. . . .(evaporate)." Later in the discussion a student stated that evaporation, condensation, and precipitation are called the water cycle. A different student stated that the water cycle never ends.

Precipitation: Students stated that rain is precipitation. The teacher stated that precipitation occurs when "water molecules (become) heavy and gravity pulls them down."

Evaporation: During the discussion of the idea page a student mentioned that evaporation is caused by heat and leads to condensation. The teacher stated that evaporation is a liquid turning to a gas, this was later repeated by a student.

Condensation: The teacher stated that condensation was caused when
". . . water as a gas cooled". This was later restated by the students in a class response. A student also stated that condensation led to precipitation and that condensation was a gas changing to a liquid.

Concept maps were constructed by the students at the completion of the term introduction phase.

Expansion Phase

Part A of the expansion phase began with a teacher introduction of the expansion phase of the investigation. Students were given a chart with spaces for each student to list six organisms and the evidence of the organism's interaction with water. Students were then allowed to go outside for this phase of the investigation.

Water cycle: No mention was made of the water cycle during this part of the investigation.

Precipitation: No mention was made of precipitation during this part of the investigation.

Evaporation: While observing a bloated dead bird a student mentioned that the bloating was a result of the water inside the bird turning to gas.

Condensation: No mention was made of condensation during this part of the investigation.

The teacher facilitated a discussion after students returned to the classroom.

Water cycle: When the teacher asked "The water cycle is the repeated process of . . ." students responded "precipitation, evaporation, and condensation." When the teacher asked "What do
you predict would happen if these organisms did not receive clean water?" A student responded that they would die.

Precipitation: When students were asked "What is precipitation?" Students responded "rain, sleet, snow, hail."

Evaporation: Students stated that evaporation was a liquid changing to a gas in the presence of heat.

Condensation: A students stated that condensation is a gas changing to a liquid in the presence of "coolness."

Part B of the expansion phase was a small group completion of a worksheet page of questions. The questions were: (1) You have probably seen dew appear on the grass in the morning. By noon the dew is usually gone. What causes the dew to be gone? (2) If you go outside on a very cold morning you will sometimes see"smoke" come out when you exhale. This is not smoke, however, that is going into the air. Explain what the smoke is. (3) You may have seen the moisture that forms on the insides of windows on winter mornings. What causes the moisture to condense in the winter but not in the summer? (4) When you go outside in the morning water appears on plants. Some people claim that plants can "make water". Explain what causes the water on the plants.

Water cycle: No mention was made of the water cycle during this part of the investigation.

Precipitation: No mention was made of precipitation during this part of the investigation.

Evaporation: During this small group discussion of what happens to dew a student stated that evaporation was when water turns to gas in the presence of heat.

Condensation: During the discussion of what the "smoke" on your breath is a student said it was the "steam" coming from the "hotness" of your breath. That it is the "hot of your breath and the cold air mixing together". Temperature change effects on condensation were also mentioned in the discussion of the question concerning moisture on windows.

The teacher facilitated a discussion at the conclusion of the small group discussion of Part B.

<u>Water cycle</u>: No mention was made of the water cycle during this part of the investigation.

<u>Precipitation</u>: No mention was made of precipitation during this part of the investigation.

<u>Evaporation</u>: Students stated that evaporation changed water to gas in the presence of heat. They also stated that this was the cause for dew on the plants "to be gone" .

<u>Condensation</u>: Students stated that dew and "smoke" leaving your mouth are condensation of water droplets or water molecules in the air. They also stated that these are a result of temperature changes.

Part C of the expansion phase was an assignment for individual students to use their knowledge of the water cycle to construct on paper a self-maintaining system to water potted plants. Student 1 was absent and did not complete this part of the expansion phase.

<u>Water cycle</u>: None of the focal students mentioned the water cycle in their models.

<u>Precipitation:</u> Van made no mention of precipitation. Kevin and Lora both illustrated and named precipitation as a component of their model.

<u>Evaporation</u>: Van and Lora made no mention of evaporation. Kevin illustrated and named evaporation as a component of his model.

<u>Condensation</u>: Kevin made no mention of condensation. Van and Lora both illustrated and named condensation as a component of their models.

The expansion phase concluded with a Bill Nigh video.

Water cycle: Precipitation, evaporation and condensation were given and part of a continuous water cycle. It was also stated the water cycle iscleansing, providing the water needed for life. The cycle was also explained as precipitation going to rivers, lakes, etc., which flows into -oceans were it evaporates.

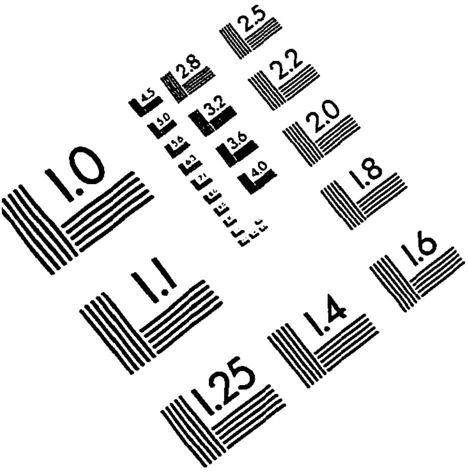
Precipitation: Rain, Snow, sleet, and hail were given as examples of precipitation. It was also stated that precipitation leads to evaporation.

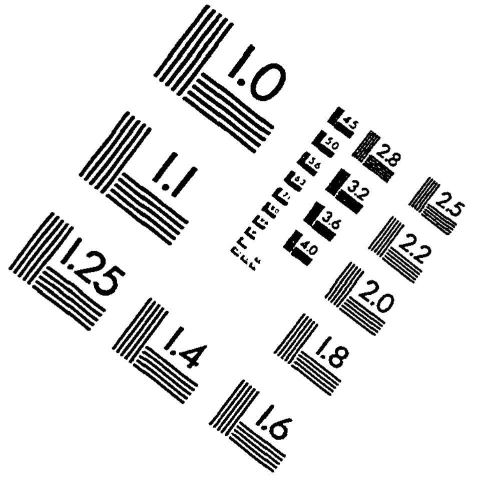
Evaporation: Evaporation was explained as heat turning water into gas were it rises to the sky and leads to condensation.

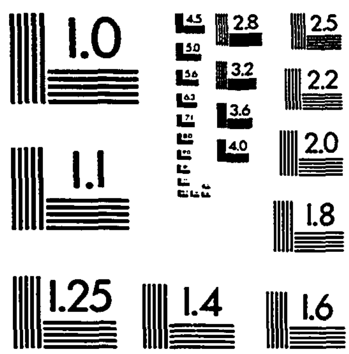
Condensation: Condensation was explained as a temperature change causing water molecules or vapor to change from a gas to a liquid. This condensation then moves with the wind, gathers as clouds, becomes heavy, and leads to precipitation or rain. Sweat on the side of a glass was also given as an example of condensation.

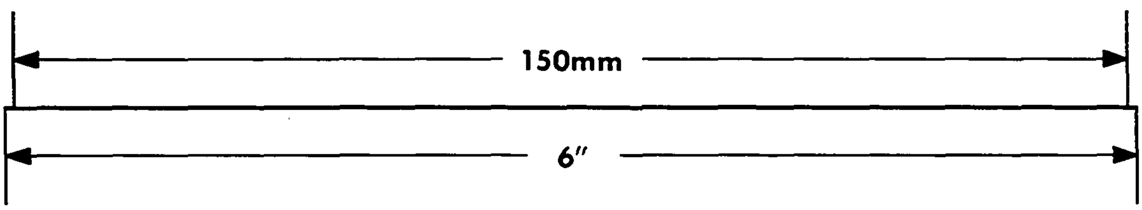
Concept maps were constructed by the students at the completion of the expansion phase and review of the investigation.

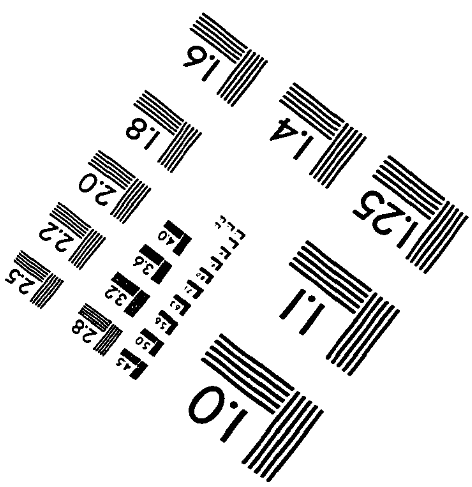
IMAGE EVALUATION TEST TARGET (QA-3)

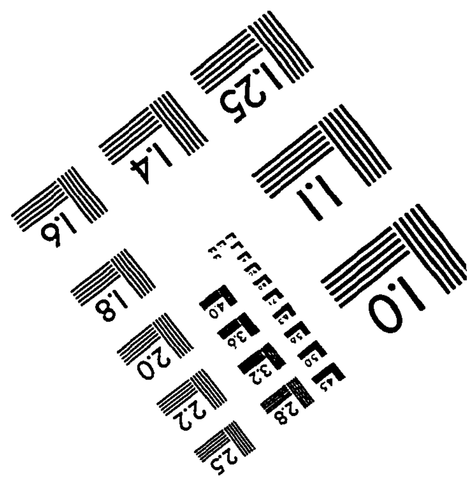












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