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MASTER AND NOVICE SECONDARY SCIENCE TEACHERS' UNDERSTANDINGS AND USE OF THE LEARNING CYCLE

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MASTER AND NOVICE SECONDARY SCIENCE TEACHERS' UNDERSTANDINGS AND USE OF THE LEARNING CYCLE

A dissertation APPROVED FOR THE DEPARTMENT OF INSTRUCTIONAL LEADERSHIP AND ACADEMIC CURRICULUM

BY

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Finally, my great thanks to my mother and sister for their patience and love through a difficult decade.

DEDICATION

This dissertation is dedicated to my father, Thomas Anthony Reap.

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ABSTRACT

The learning cycle paradigm had been used in science classrooms for nearly four decades. This investigation seeks to reveal how the learning cycle, as originally designed, is currently understood and implemented by teachers in authentic classroom settings. The specific purposes of this study were: 1) to describe teachers who use the learning cycle and compare their understandings and perceptions of the learning cycle procedure in instruction; 2) to elicit novice and master teacher perspectives on their instruction and determine their perception of the process by which learning cycles are implemented in the science classroom; 3) to describe the context of science instruction in the novice and master teacher's classroom to ascertain how the teacher facilitates implementation of the learning cycle paradigm in their authentic classroom setting. The study used a learning cycle survey, interviews and classroom observations using the Learning Cycle Teacher Behavior Instruments and the Verbal Interaction Category System to explore these features of learning cycle instruction. The learning cycle survey was administered to a sample of teachers who use the learning cycle, including master and novice learning cycle teachers. One master and one novice learning cycle teacher were selected from this sample for further study. Analysis of the surveys showed no significant differences in master and novice teacher understandings of the learning cycle as assessed by the instrument. However, interviews and observations of the selected master and novice learning cycle teachers showed several differences in how the paradigm is understood and implemented in the classroom. The master learning cycle teacher showed a more developed teaching philosophy and had more engaged, extensive interactions with students. The novice learning cycle teacher held a more naive teaching philosophy and had fewer, less developed interactions with students. The most significant difference was seen in the use of questioning and discussion. The master teacher used diverse questioning techniques and guided students in discussion of their findings while the novice teachers used more rote response questions and controlled the discussion. The findings of this study have implications for science teacher education, especially in the preparation of teachers in science methods courses and student teaching, and in in-service education programs.

CHAPTER I

Introduction

In a study of teaching two decades ago, deRose, Lockard and Paldy (1979) concluded that the teacher is a vital element in providing exemplary science education for students. The authors concluded that "a fruitful avenue for improving the quality of science education might be to identify the characteristics of exemplary science teaching" (p.31).

What progress has been made on this issue over the past twenty years? Have we gained an understanding of what it means to be an exemplary science teacher? Recent initiatives in science education (e.g. NRC standards) have emphasized inquiry-based teaching. Exemplary teaching is now viewed as teaching that utilizes constructivist, student-centered, inquiry teaching procedures. More contemporary questions center on exemplary teaching in the context of teachers' use of what is considered "best" practice. One such teaching procedure is the learning cycle (Marek & Cavallo, 1997; Lawson, 1995; Lawson, Abraham & Renner, 1989).

The learning cycle is a teaching procedure that promotes students' engagement in the kind of thinking constructivists would say is necessary to promote learning. Robert Karplus developed the learning cycle paradigm as a result of his work with the Elementary School Science Project at the University of California - Berkeley. Karplus concluded that elementary school science had to be simplified and reorganized to meet the needs of elementary school students (Karplus & Thier, 1967). From this work emerged the elementary science curricula Science Curriculum Improvement Study (SCIS), Science - a Process Approach (SAPA), Biological Science Curriculum Study (BSCS), and

Full Option Science System (FOSS). The learning cycle procedure was also extended into secondary science teaching (Lawson, 1994; Renner & Marek, 1990; Lawson, Abraham & Renner, 1989). Secondary school science learning cycle curricula are currently in use in many school districts nationwide.

One weakness of research on the learning cycle was that the procedure is often viewed as being implemented uniformly in classrooms and immune to sociocultural influences. In their review of research on the learning cycle, Tobin, Tippins and Gallard (1994) stated that "...teaching and learning occur in a culture in which the actions of teachers and students are inextricably linked. Thus, it does not seem prudent to question learners and learning roles without, at the same time, questioning teachers and teaching roles" (p. 45).

The literature lacked information on teachers' use of the learning cycle in general. Additionally, very little was known about the teacher's role in the learning cycle among teachers with different understandings and experience with the model. Research on teachers of differing classroom experience falls under the category of novice/master teacher studies. This research has generally found that novice teachers and master teachers differ in such areas as classroom management, student assessment, level of questioning, and course planning. However, it is not known how teachers new to a particular teaching procedure (e.g., the learning cycle) may differ in their implementation of this model relative to experienced teachers. Do similar patterns emerge between novice and master teachers in learning cycle teaching as with novice and master teachers in general? What unique patterns may emerge in these teachers' implementation of the learning cycle? How do novice and master learning cycle teachers view their teaching of this paradigm. Importantly, how do teachers implement the learning cycle in authentic classroom situations? These, and related, questions will be addressed in this research.

Statement of the Problem

The purpose of this research was to describe and explore the learning cycle teachers' use and general understanding of the teaching paradigm. This research also examines teaching characteristics and practices of a master and a novice learning cycle science teacher and identify possible patterns in their understanding and implementation of the paradigm in the classroom.

The specific objectives of this research were:

1. To describe teachers who use the learning cycle and compare their understandings and perceptions of the learning cycle procedure in instruction.

2. To elicit novice and master teacher perspectives on their instruction and determine their perception of the process by which learning cycles are implemented in the science classroom.

3. To describe the context of science instruction in the novice and master teachers' classrooms to ascertain how each teacher facilitates implementation of the learning cycle paradigm in their authentic classroom setting.

Significance of the Problem

The learning cycle has been used with success in classrooms for more than three decades. However, research on the learning cycle has largely focused on the students in the areas of achievement, science content knowledge, and attitude toward science. Little is known on how the learning cycle is performed by teachers in authentic classroom situations. Originally, the learning cycle was intended to attain many national goals and standards of science education for the twenty-first century (NRC, 1996; NSTA, 1989; Bybee, et.al, 1989). The learning cycle was designed to be consistent with the nature of science and to promote critical thinking through inquiry, collaborative grouping, and the construction of new ideas. Does this "ideal" model reflect the reality of how teachers teach in modern American schools? If so, how? Responses to these, and related, questions will help educators better understand how the theory of the learning cycle translates to classroom practice. Such information has implications for pre-service teacher education in university education programs, and for experienced, in-service teachers in professional development programs. Berliner (1986) recommended the study of expert teachers as a means of obtaining case material with potential applications in preservice and inservice courses for teachers.

With the results of this research, teacher educators will be better prepared to discuss some of the subtleties of using the learning cycle in classroom science teaching. Teacher educators will also gain a better understanding of how novice learning cycle teachers use this procedure relative to master learning cycle teachers. Such understanding will help teacher educators in guiding novice learning cycle teachers toward mastery and toward implementing the "ideal" learning cycle that is in accord with its original design and purpose.

Research shows that the learning cycle, if implemented as designed, promotes scientific understanding and thinking abilities among students (Brown, Weber & Renner, 1975; Lawson & Snitgen, 1982; Saunders & Shepardson, 1987; Schneider & Renner, 1990; Marek & Methven, 1991; Fuzzetti, Snyder, Glass & Gamas, 1993; Marek & Cavallo, 1995; Lavoie, 1999). Therefore, using the learning cycle promotes the goals of national organizations' initiatives for the twenty-first century. Exploring the extent to which teachers may support these goals in learning cycle teaching will help clarify the model and help educators better apply it in authentic classroom settings. The ultimate benefactors of such improvements will be the students in our science classrooms who may be better prepared with knowledge and skills needed for a scientifically literate society.

Definition of Terms

Several pedagogical terms will be used throughout this document. These terms are defined as follows.

Learning cycle: a constructivist teaching procedure that allows students to manipulate materials and generate data that they then analyze to construct a concept. The teacher acts as a facilitator, introducing terminology after students have constructed the concept. The learning cycle was originally developed for science education but is not limited to science teaching. The antithesis of learning cycle teaching in science is the inform-verify-practice approach. Still further removed from the learning cycle paradigm is pure expository teaching. For this research, the form of learning cycle teaching referred to is the three phase version: exploration, term introduction, and application.(Marek & Cavallo, 1997)

Exemplary science teachers: teachers who demonstrate exemplary teaching practices in the areas of planning, classroom management, curriculum implementation, student motivation, and assessment. An exemplary teacher may be a novice or master learning cycle teacher.

Master learning cycle science teacher: For this study, a master learning cycle teacher is a teacher who has taught science using the three phase learning cycle for a minimum of five years; has administrative and collegial support for using learning cycle science; and is acknowledged by peers, administrators, and university science educators as an exemplary teacher.

Novice learning cycle science teacher: For this study, a novice learning cycle teacher meets the requirements as listed for the master learning cycle teacher except that the teacher has used the learning cycle for less than five years. The novice learning cycle teacher may have many years teaching experience, but is new to the learning cycle procedure.

CHAPTER II

Review of the Literature

The literature review focuses on a discussion of three principle areas: (1) learning cycle theory and instructional procedure, (2) the effects of the learning cycle on classroom practice and (3) the characteristics and practices of master (exemplary) teachers. These areas are then linked to the goals of this study.

Learning Cycle Theory and Instructional Procedure

The learning cycle is a teaching procedure rooted in the discipline of science, the purpose of schools, and Piagetian development theory. The learning cycle allows students to become active participants in the process of science as they construct understandings of scientific concepts. The learning cycle, the theoretical underpinnings of the learning cycle (the nature of science, the purpose of schools, and Piagetian development theory), and how the theory forms this teaching procedure, are discussed in the following sections.

The learning cycle teaching procedure

The learning cycle teaching procedure has been used successfully in teaching elementary school science (Karplus & Thier, 1967), secondary school science (Abraham & Renner, 1986; Lawson, 1988; Renner, Abraham & Birnie, 1985 & 1988), and college (Lawson, Rissing & Faeth, 1990). Learning cycles consist of three phases: exploration, term introduction, and expansion. During exploration, collaborative student groups engage in a laboratory activity and generate data using scientific processes. The exploration is designed to stimulate student interest by producing some degree of disequilibration. The outcome of the learning cycle (science concept) should not be divulged to the students beforehand. During exploration, the teacher acts as a facilitator, providing materials and directions, and guiding the physical process of the experiment. The outcome of the exploration is typically a set of data for the students to analyze.

In term introduction, student groups present their data for class analysis and discussion. During this process the teacher guides the students' analysis of the data by questioning them in both group and whole class discussion (Lawson, Abraham & Renner, 1989; Marek & Cavallo, 1997). Finally, as a class, the students, using their own words, agree upon an explanation, or the concept of the learning cycle. This concept statement is usually posted to be visible to the students (e.g., on the blackboard, overhead, poster paper).

After the class has constructed the concept, the teacher, if appropriate, may introduce any scientific terms related to the concept. Naming these terms ends the second phase of the learning cycle (Lawson, Abraham & Renner, 1989; Marek & Cavallo, 1997).

The expansion or application phase allows students opportunities to use the concept of the learning cycle in different contexts (Lawson, Abraham & Renner, 1989; Marek & Cavallo, 1997). The purpose of this phase is to extend or expand students' understanding of the concept and help students understand its application to everyday life. The application may utilize additional laboratory activities, demonstration, computer programs, reading, video or discussion to help students expand their understanding of the concept. The use of the concept in the application phase completes the cyclical process, such that it leads to new explorations. Learning cycles are often viewed as spirals, as application activities lead to more topics to be explored and explained while building more complex concepts upon the foundation of simpler ones.

Theoretical Underpinnings of the Learning Cycle

The nature of science. The subject of science has often been viewed as a set of facts and the laboratory as an unvarying step-by-step, cookbook procedure. However, such views do not depict science as it is performed by scientists. As Albert Einstein stated, "The object of all science is to coordinate our experiences and bring them into a logical system"(Holton & Roller, 1958, p.4). This view implies that experience is important and that individuals must make meaning of experience while engaged in science.

Physicist/mathematician Henri Poincare stated, "Science is built up of facts as a house is with stones, but a collection of facts is no more a science than a heap of stones is a house"(Kelly, 1941, p.7). Thus, science is not the mere accumulation of facts, it is the intellectual use of those facts. Science is an active process of making sense of the world. Renner and Marek (1990) stated that, "Science is not only the facts, principles, generalizations and laws, but finding and ordering the data from our experiences which leads to facts, principles, generalizations and laws" (p.242). Similarly, historian of science Duane Roller (1970) defined science as "the quest for knowledge, rather than the knowledge itself".

Thus, science is more than a static collection of information; it is an active, dynamic process of discovering the world and how it works. To be consistent with the nature of science, science teaching must engage students in experiences that help them construct scientific understanding in an active way. Science teaching that promotes only the passive accumulation of decontextualized facts is the antithesis of science and does little toward helping students construct scientific understanding. The learning cycle teaching procedure was designed to match the experiential nature of the discipline of science, and thus is a highly advocated teaching procedure among science educators (Gabel, 1994).

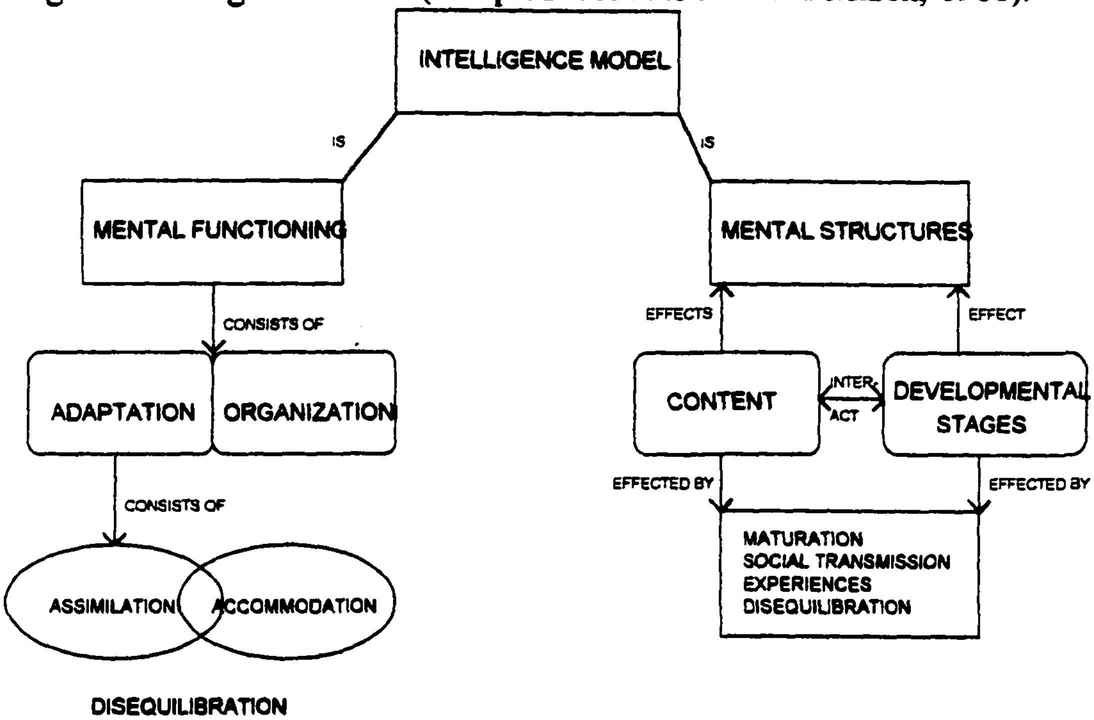
The purpose of schools. It has long been considered a major purpose of schools in a democratic society to promote independent thinkers (Educational Policies Commission, 1961). The ability to think independently allows individuals in our society to make choices and enjoy true freedom. As stated by the Educational Policies Commission of the National Education Association (1961): "The purpose which runs through and strengthens all other educational purposes - the common thread of education - is the development of the ability to think. This is the central purpose to which school must be oriented if it is to accomplish either its traditional tasks or those newly accentuated by recent changes in the world. To say that it is central is not to say that it is the sole purpose or in all circumstances the most important purpose, but that it must be a pervasive concern in the work of the schools. Many agencies contribute to achieving educational objectives, but this particular objective will not be generally attained unless the school focuses on it" (p.12).

The ability to think independently is based on the use of the rational powers of the mind (Educational Policies Commission, 1961). These processes should not be considered the only functions of the mind; they are, however, the "essence of the ability to think" (Educational Policies Commission, 1961). The rational powers include the processes of deducing and inferring, recalling and imagining, classifying and generalizing, comparing and evaluating, and analyzing and synthesizing. The learning cycle puts the rational powers of the mind into use by presenting the student with situations and problems that must be solved through the use of rational thinking processes. For example, as students engage in exploration they may use the powers of classifying, recalling and imagining. As they formulate the concept they may use inferring and deducing. As students apply concepts they use the power of generalizing.

Independent thinking does not negate the interdependence of people in modern society. Cooperation and interdependent activities are vital to the development of children into fully functional adults. However, the interdependence of human beings also does not negate the fact that each person must be able to make decisions for themself. In that function, the schooling must focus on nurturing the use of human reasoning in decision making.

Piagetian developmental theory. The theory of cognition upon which the learning cycle is based is a model of intellectual development advanced by Jean Piaget and his colleagues over many decades (Inhelder & Piaget, 1958; Piaget, 1964, 1967, 1973). The intelligence model consists of four components: mental functioning, mental structures, content, and developmental stages (Ginsberg & Opper, 1969; Bybee & Sund, 1982). The relationships among these components are depicted in Figure 1.

Figure 1. Flowchart showing the components and sub-components of the Piagetian intelligence model (Adapted from Renner and Marek, 1988).



Mental functioning

Mental functioning is the way in which information is processed by an individual (Piaget, 1964). Mental functioning is further divided into adaptation and organization.

Adaptation consists of two complementary processes: assimilation and accommodation. Assimilation is the process whereby an individual deals with an environmental event in terms of their current understanding of the world. Accommodation describes that individual's tendency to change or adjust that understanding in response to environmental demands. Assimilation and accommodation are not sequential processes; they occur simultaneously in response to the environmental demand (Ginsberg & Opper, 1969). During adaptation, the individual not only modifies mental structures in reaction to external demands (accommodation), but also uses these structures to incorporate elements of the external world (assimilation) (Ginsberg & Opper, 1969). A balance between assimilation and accommodation is needed for adaptation; there must be equilibrium. Adaptation then is an assimilation of external perceptions to cognitive structure and an accommodation of cognitive structure to the external reality (Bybee & Sund, 1982).

Organization is the tendency of all species to order their processes into coherent systems, either physical or psychological (Ginsberg & Opper, 1969). The organizing process advances as a result of the person's interaction with things in the environment. Organization has also been defined as putting thought in accord with thought and thought in accord with things (Renner, 1982). Organization does not exist separately from adaptation. As with the subsets of adaptation, organization and adaptation are complementary processes.

Mental structures and content

Piaget looked at intelligence in terms of content, structures and function. Content is what the individual is thinking about, what interests him, or the terms in which he contemplates a given problem. Content may be defined as the sum of knowledge possessed by an individual. Mental structures are patterns formed by individuals to process and organize incoming data (Ginsberg & Opper, 1969). Piaget (1973) defined mental structures as systems of transformation. New structures, to be employed by the individual in their interaction with the world, are continually created from old ones (Ginsberg & Opper, 1969). Mental functioning will remain the same but mental structures will vary and appear in a fairly regular sequence referred to as developmental stages. Both mental structures and content are dependent upon the developmental stage of the person. As a person progresses through these stages, content and mental structures change as new data is received and incorporated (Ginsberg & Opper, 1969).

Developmental stages

Piaget described four developmental stages: sensorimotor, pre-operational, concrete operational, and formal operational (Ginsberg & Opper, 1969). During the sensorimotor stage the child interacts with her environment via her senses and muscles. She constructs broad categories, sometimes referred to as schemes, to organize her world. By the end of this stage she is capable of simple imitative play and is just forming the rudiments of representational thought (Bybee & Sund, 1982). In the pre-operational stage the child cannot perform complete mental operations. For example, children in this stage reason in one direction (irreversibility of thought), do not see states of transition, do not conserve volume, number, weight or area, and have an egocentric self concept and language. However, they are aware of past, present and future (Bybee & Sund, 1982). Concrete operational individuals are capable of logical reversible thinking but it is limited to concrete, non-abstract, situations. They can perform complete mental operations and are able to conserve such concepts as quantity, seriation, number, area and classification. The concrete individual understands cause and effect in concrete problems, They are unable to perform abstract reasoning and may be said to be "sense" bound (Bybee & Sund, 1982; Ginsberg & Opper, 1969). The final developmental stage theorized by Piaget is formal operational. In this stage the individual is able to use hypothetical-deductive reasoning, reflective abstraction, abstract language, and combinational and prepositional logic (Bybee & Sund, 1982).

Only the sensorimotor stage has a definite beginning; i.e., birth. Lawson, Abraham and Renner (1989) stated that they saw "no biological or psychological reason why a child as young as say six years could not begin to internally reflect upon his own thoughts given an environment in which such reflective behavior was strongly encouraged"(p. 35). Bybee and Sund (1982) felt that the terms *practical* and *reflective* were better descriptions of the thought processes of adolescents rather than the Piagetian terms *concrete* and *formal.* Lawson, Abraham and Renner (1989) saw the shift in thought patterns as the development of adult modes of thought from child like patterns and that this change was not based on formal logic but on the exposure to and use of "alternative ideas, predictions, evidence, and arguments, all mediated by language" (p. 35).

Movement through the stages is thought to be influenced by four factors: maturation, social transmission, experiences, and disequilibrium. Maturation refers to the physical growth of the child. Social transmission is the communication of modes and mores through the institutions of society (Marek & Cavallo, 1997). Experiences can be physical or logical-mathematical. Physical experiences include directly experienced phenomena or objects manipulated by individuals. Logical-mathematical experiences include solving problems related to the measurement of objects or making change in monetary transactions. It also includes the solving of mysteries and puzzles. According to Piaget (1964), in logical-mathematical experiences knowledge is not "drawn from the objects, but it is drawn by the actions effected upon the objects" (p. 179).

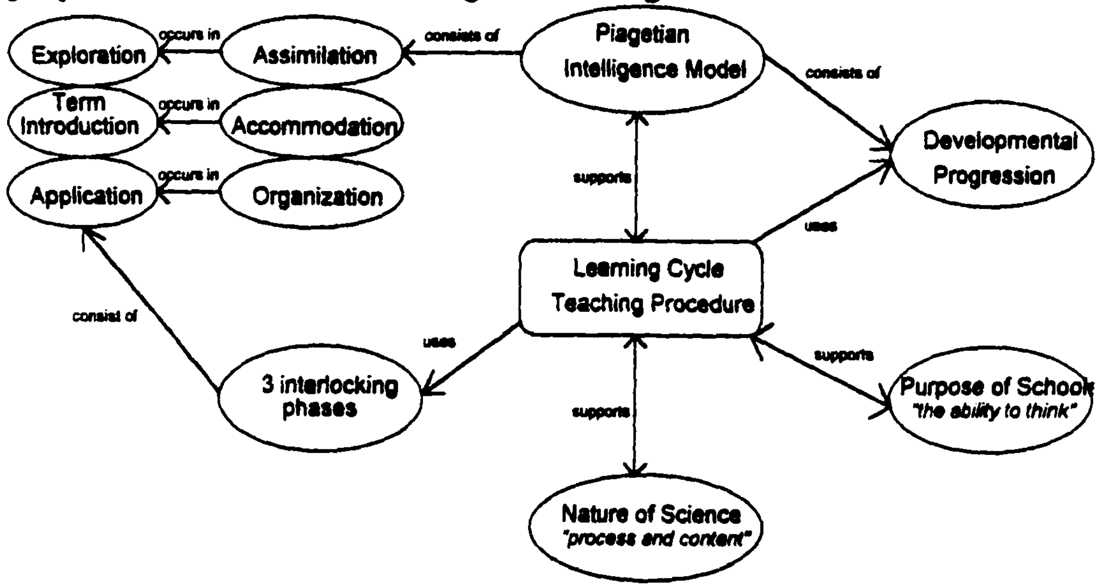
The fourth factor involved in helping individuals move through the stages is disequilibrium. Disequilibrium occurs when a person is presented with information or an event that does not fit into his mental structures. This causes confusion, cognitive dissonance, and an attempt to "fit" the data. When the data has been made logical to the person, re-equilibration occurs. The mental structures and content then change to take in the new data. Without the process of disequilibration and re-equilibration, learning does not occur because there has been no change in the student's mental structures (Lawson, Abraham & Renner, 1989; Renner & Marek, 1988).

In summary, the basic points of the Piagetian model of intelligence are that individuals inherit physical structures that set broad limits on intellectual functioning. Reflexes are rapidly transformed by individuals into structures that incorporate the results of experience. Mental functioning is unvarying and inherent in humans. While organization and adaptation are inherited, they are not structures but tendencies. The particular ways in which individuals adapt and organize their processes also depend on their environment and learning history. Accommodation is the tendency of individuals to change mental structures according to environmental pressures. Assimilation involves using current mental structures that can deal with the environment. The result is a series of structures that differ qualitatively from one another throughout a person's life.

Relationship of the Learning Cycle to the Nature of Science, the Purpose of Schools, and the Intelligence Model

The learning cycle procedure is a fusion of the nature of science, the purpose of schools, and the Piagetian intelligence model. Figure 2 illustrates this relationship.

Figure 2. The relationship of the learning cycle to the nature of science, the purpose of schools, and the Piagetian intelligence model.



The learning cycle is an application of the Piagetian intelligence model with the phases of the learning cycle corresponding to the subdivisions of mental functioning (Lawson, Abraham & Renner, 1989). The first learning cycle phase, exploration, brings about assimilation among students. Term introduction is designed to promote students' accommodation of the concept. The application promote students' organization of the concept into their mental structures. Disequilibrium runs throughout the three phases, being resolved by students during either the exploration, term introduction or expansion phases of the learning cycle. The students engage in social transmission by working in peer groups. During the learning cycle students manage in various physical and logical-mathematical experiences. The learning cycle also addresses students' developmental progression by using developmentally appropriate investigations as they engage in the science learning process. Students use their experiences to make sense of experiences and create logical systems. The nature of science is embedded in the learning cycle as students engage in inquiry-based science experiments, as scientists do, that are grounded in the students' everyday experiences. Finally, the ability to think is fostered through students' use of rational thinking processes throughout the inquiry-based learning cycle model.

The Learning Cycle and Teacher Classroom Practices

Historically, much of the research on the learning cycle has focused on content mastery, student attitudes, and how student thinking skills are related to curricula (Carlson, 1975, Lawson & Wollman, 1976; McKinnon & Renner, 1971; Purser & Renner, 1983; Saunders & Shepardson, 1987; Schneider & Renner, 1980). However, recent research has shifted to investigations of the learning cycle as an instructional procedure. For example, Scharman (1992) conducted a descriptive study to investigate the role of the learning cycle as a tool for identifying and addressing misconceptions. Scharman stressed the necessity of using "minds-on" as well as "hands-on" activities in the exploration phase. Activities described as "minds-on" included the use of analogies, the formation of opinion statements, and the formation of independent decisions.

Marek, Eubanks and Gallaher (1990) described a link between teachers' understanding of the Piagetian developmental model of intelligence, the learning cycle, and classroom practices. In their study of twenty-five teachers who had participated in an in-service program on the learning cycle, they found that those teachers who had a sound understanding of Piagetian theory were more likely to use learning cycle teaching in their classrooms and were more likely to implement it properly.

Research has shown that the sequencing of the phases revolves around the question of where the term introduction phase should occur. Renner, Abraham and Birnie (1985; 1988) examined the sequencing of the phases for physics and found that students favor discussion of the concept after they have collected their own data from an experiment, but that the sequencing was not important for achievement if all three phases were taught. Abraham and Renner (1986) studied sequencing in chemistry classes and concluded that students favored term introduction as either the second or third phase. In contrast, Lavoie (1992) compared a three-phase learning cycle model (exploration/term introduction/application) to a prediction/discussion learning cycle model that added two phases to the three phase model. In the prediction/discussion model, the students predicted the outcome of an experiment before doing it and then discussed why or why not the results matched their predictions. In the study, five biology teachers who were familiar with the learning cycle each taught ten learning cycle lessons in a prediction/discussion learning cycle class and a three-phase learning cycle class over three months. Lavoie discovered that student achievement in science process skills, logical thinking, and conceptual understanding was higher in the prediction/discussion classes. However, he did not state the level of understanding the teachers had of the theory base for learning cycle teaching and the possible implications this could have on their use of the learning cycle. If teacher understanding of the three phase learning cycle was poor, it is possible that the comparison was really made between teachers adept with the prediction/discussion learning cycle and those who poorly implemented the three phase learning cycle.

Studies have also investigated the necessity of including all three phases when using the learning cycle in chemistry and physics (Abraham & Renner 1986; Renner, Abraham & Birnie 1985; 1988). They concluded that indeed all three phases were needed for complete understanding of concepts. As stated in Lawson, Abraham & Renner (1989):

> "...instructional strategies utilized to teach science concepts are most effective when they consist of activities which serve three functions: (1)

explore and identify a pattern of regularity in the environment, (2) discuss the pattern and introduce a term to refer to that pattern and (3) discover/apply the concept in new situations. The learning cycle approach is an effective instructional strategy for at least two reasons. First, it utilizes all three of these activities; and second, it uses them in the correct sequence" (p.75-76).

In essence, to be effective a learning cycle must be sequenced properly and have both an exploration and term introduction.

Characteristics and Practices of Exemplary/Master Teachers

The study of exemplary or master teachers developed from criticisms leveled at American schools in the 1980s. Rather than focus on the negative, researchers began to look at the best cases and their applicability to other school situations. As Kennedy (1980, p.14) stated, "...rather than invest money in the untried and untested, we could invest resources in the dissemination of workable practices from one site to another or from a single site to national implementation". Consequently, research has looked at teacher planning behaviors, classroom management techniques, instructional strategies, classroom environment, collegiality, and administrative support, to begin to form a clearer picture of exemplary teachers' practice.

Tobin and Fraser (1987, 1990) studied twenty exemplary and twenty non-exemplary science teachers over hundreds of hours of observations. The qualitative data collection was augmented by quantitative data from questionnaires assessing the students' view of the classroom environment. The major findings of their research were that exemplary science teachers 1) used management techniques that promoted sustained student engagement, 2) used

strategies that broadened student understanding of science, 3) used strategies that motivated students to participate in activities, and
4) maintained a positive classroom environment. Tobin, Treagust and Fraser (1988) added a fifth factor - exemplary science teachers used the laboratory in an inquiry mode and as an integral part of the class (see also Treagust, 1991).

Building on Tobin and Fraser's research, Hofstein, Ben-Zvi and Carmeli (1990) studied exemplary and non-exemplary chemistry teachers. Using observational techniques, they looked at teaching strategies, cognitive demands and methods used to promote student understanding, use of models and audio/visual support, and student/teacher interaction. Using a 44-item Likert-style questionnaire, they questioned students on various aspects of the learning environment. Student responses were compared to observational data. Discriminant analysis methods were used to compare the two groups. Students taught by exemplary teachers had higher positive views of their classes and tended to be more satisfied. They also participated significantly more in classroom activities and discussions and valued laboratory work significantly higher than students in non-exemplary classrooms. Exemplary teachers and their students had quite similar perceptions of the classroom learning environment. Also, exemplary teachers kept pace according to the majority of the class but aimed class discussion to challenge cognitive levels. Overall, exemplary teachers used methods that made the lessons more interesting and were asking questions at a higher cognitive levels.

Brunkhorst (1992) compared known exemplary middle school/junior high science programs to programs from a national sample of middle/junior high science programs. The study presupposed that teachers associated with exemplary programs would have a different statistical profile with respect to personal characteristics, professional activity, and instructional practices than teachers in general. Comparing teachers in exemplary programs to teachers in the national sample the study found:

1. 91% of exemplary teachers conduct activity oriented classrooms compared to 35% of the national sample.

2. 45% of exemplary teachers use student projects/reports at least monthly; 25% of the national sample did.

3. Exemplary teachers use the library more often than those in the national sample (27% to 18%).

4. Exemplary teachers use student contracts more often than those in the national sample (55% to 20%).

5. Exemplary teachers use simulations more often than teachers in the national sample (73% to 27%).

The study concluded that teachers in exemplary programs involved students in a wider variety of activities and assessments and spent less time testing in a traditional manner than those teachers in the national sample.

Yager and Bonstetter (1990) used data from Project Synthesis, Educating Americans for the Twenty-first Century, National Science Teachers Association Excellence Programs, and the Iowa Honors Workshop to form general characteristics of exemplary science teachers. The authors concluded that teachers with exemplary techniques were able to stimulate students in domains other than mere concept mastery. Those domains were defined as concepts, process, creativity, attitude, connections, and applications.

Research on exemplary teachers extends to other disciplines. Little (1994) used qualitative methods to determine whether expert secondary art teachers share characteristics or experiences that contribute to their teaching success. He concluded that exemplary art teachers altered their instruction to meeting the needs of their students, thereby increasing their teaching effectiveness. In an earlier study, Walsh (1993) investigated the planning behaviors of exemplary art teachers. Using a mixture of qualitative and quantitative analyses, he divided his data collection into two phases. Phase one, the qualitative approach, used three case studies. Data was collected though semi-structured interviews, response inducing questionnaires, think aloud planning tasks, and planning profile discussions. The second phase used the data from the first phase to develop a questionnaire to prove/disprove the qualitative data. The questionnaire was given to 43 award winning high school teachers with a final sample of 36 individuals. Analysis of the questionnaire indicated that the exemplary teachers planned for instruction consistently, even in disruptive high school environments, integrated personal and organizational needs, and used planning strategies designed to reduce planning dilemmas.

In a study of high school history teachers, Wynne (1995) used four teachers from three suburban schools who were nominated as expert teachers by at least two professional judges. He used naturalistic methods, which included interviews, documentary analysis, structured surveys, and ten weeks of classroom field visits. The exemplary teachers were described as transformative intellectuals and as caring service professionals.

Thus, the characteristics of exemplary/master teachers described by science education researchers are supported by exemplary/master teacher research in other fields. We can conclude that the characteristics of these teachers are not domain specific. The characteristics that seem to prevail are exceptional classroom management, use of multiple strategies to maintain student motivation, creation of a positive classroom environment, presenting a challenging atmosphere with an awareness of individual abilities, and respect for the students as individuals. The question remains, however, as to whether there may be characteristics unique and specific to master learning cycle teachers.

As stated earlier, the ideal learning cycle places the student at the center of experience and the teacher in the role of facilitator. The teacher creates an environment in which students gather experiences and pull them together to come to a conclusion about a concept. The concept to be discovered, via experimentation, must be developmentally appropriate for the student. For example, concrete concepts are most appropriate for concrete learners. A formal concept, such as the formation of molecular bonds or the structure of DNA, could be taught to concrete learners but the understanding of these ideas would be poor or rote rather than meaningful (Marek & Cavallo, 1997). Thus, the ideal learning cycle will present students with experiential activities to perform that will lead them to an understanding of a developmentally appropriate science concept. The teacher guides the students through activities that facilitate their construction of understanding and avoids acting as the source of knowledge. Obviously, the manner in which the teacher implements learning cycles in her classroom would have a profound influence on the effectiveness of the lesson. Therefore, this study attempts to gain an understanding of how learning cycles are actually implemented in classrooms by teachers. Further, this study aims to discover if there may be differences in implementation of the model by master learning cycle teachers and novice learning cycle teachers. The study examines how closely to the ideal model master learning cycle teachers implement learning cycle curricula or how it may vary in the classroom context.

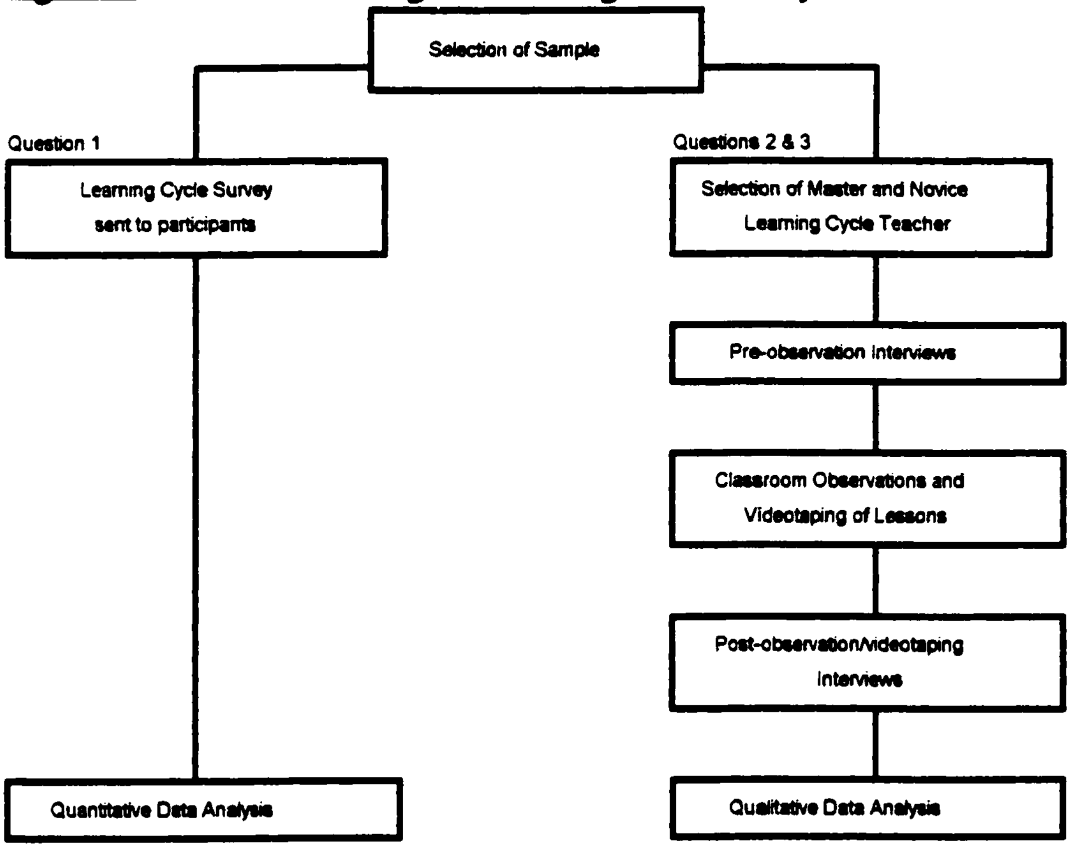
CHAPTER III

Design and Procedures

The purpose of this research was to describe and explore the learning cycle teachers' use and general understanding of the teaching paradigm. This research also aims to examine teaching characteristics and practices of a master and a novice learning cycle science teacher and identify possible patterns in their understanding and implementation of the paradigm in the classroom.

As with previous studies of master teachers that have used both quantitative and qualitative methods (Brunkhorst, 1992; Hofstein, Ben-Zvi & Carmeli, 1990; Little, 1994; Tobin & Fraser, 1987,1990; Tobin, Treagust, & Fraser, 1988; Walsh, 1993; Wynne, 1995; Yager & Bonstetter, 1990), this study used a combination of these methods. The first question of this research was addressed through a survey of teacher understandings of the learning cycle. The second and third questions were addressed through qualitative methods. Figure 3 gives an overview of the design of the study.

Figure 3. Flowchart showing overall design of the study.



The Sample

For the first research question, the pool of 70 participants consisted of experienced teachers in grades 6 to 12 who are part of a large network of learning cycle teachers within the state of Oklahoma. These teachers all worked in districts that support the application of learning cycle science and the use of published learning cycle curricula. Many of the teachers had attended college at the University of Oklahoma and had participated in the Science Education Center's learning cycle program and/or had attended summer in-service institutes at the Center specifically designed to prepare them for learning cycle teaching. These teachers also formed a cadre of instructors who taught the learning cycle to preservice or inservice teachers in science education. Several of these teachers had also been regular course instructors in the University's science education program. A number of these teachers collaborated with the science education program as cooperating teachers for student interns. Many had presented research and learning cycle curricula at state, regional, and national conferences.

For the second and third research questions, a master and novice learning cycle teacher was chosen from the pool of 70 participants. The master teacher met the following requirements:

1. A teacher who had taught science using the three phase learning cycle for a minimum of five years.

2. A teacher who had administrative and collegial support for using learning cycle science.

3. A teacher acknowledged by peers, administrators, and university science educators as an exemplary teacher as defined by this research.

4. A teacher willing to participate in the study.

The novice teacher met the requirements as listed above *except* that the individual had taught using the learning cycle for less than five years. Therefore, a novice learning cycle teacher might have had many years teaching experience, but was new to the learning cycle procedure.

Possible candidates were identified from the pool of 70 participants. Candidates were then contacted and interviewed about participation in this aspect of the study. Two candidates who met the criteria emerged from the pool of 70. Both candidates were willing to participate, taught the same classes (physical science/ninth grade), had students with the same demographic spred, and had schedules that allowed the time for the classroom observations and interviews.

Quantitative Data Collection

The Learning Cycle Survey

The Learning Cycle Survey was sent to all participants of the study. The survey consisted of two parts. The first part contained 17 items which obtained demographic and descriptive information about the learning cycle teachers. The second part consisted of 13 items which surveyed teachers' understanding of the learning cycle . The survey was based on a two-tiered test of pre-service teachers' understandings of the learning cycle developed and tested by Hampton, Odom and Settlage (1995) and further validated by Odom and Settlage (1996) and Marek (personal communication, 1997). Each item of the test is divided into a two-tier multiple choice format. The first tier is a question about propositional knowledge of the learning cycle . The second tier consists of four possible reasons for the first part answer. The four reasons include one preferred response and three alternative responses based on common misconceptions about the learning cycle. A reliability of 0.76 was determined by Odom and Settlage (1996) using the Kuder-Richardson formula 20. The authors also reported difficulty indices of 0.127 to 0.727, with a mean difficulty index of 0.58. Discrimination indices ranged from 0.157 to 0.692 with an average index of 0.51.

For this study, a third response section was inserted after the two-tiered question. This response section allowed participants to give explanations; which provided rich data for the analyses.

In the survey, the phases of the learning cycle were called *Phase One*, *Phase Two*, or *Phase Three*, rather than *exploration*, *term introduction*, and *concept application*. This measure was taken to minimize confusion about which phase is being referred to in the survey. For example, *term introduction* has also been called *conceptual invention* (Renner & Marek, 1990) and *getting* *the idea* (Renner & Marek, 1988). The survey, along with a background data form, is included in Appendix A.

For analysis, the questions were grouped according to the phase of the learning cycle that is the target of the questions. For Phase One, the questions included 6, 7, 11 and 12; for Phase Two questions 3, 5 and 9; for Phase Three questions 1, 2, 4, 8, 10 and 13. Questions were analyzed as in Odom & Settlage (1996), with an item considered to be correct if both the desired first and second tier answers were chosen.

Analysis of Survey Data

Descriptive statistics, including means, standard deviations, and correlations, were used to characterize the nature of learning cycle teachers surveyed. Statistical analysis of the data also used frequency distributions and Chi-square. Choice of analysis was dependent on the survey data, which was nominal in nature. Each item of the survey and master/novice status were used as variables.

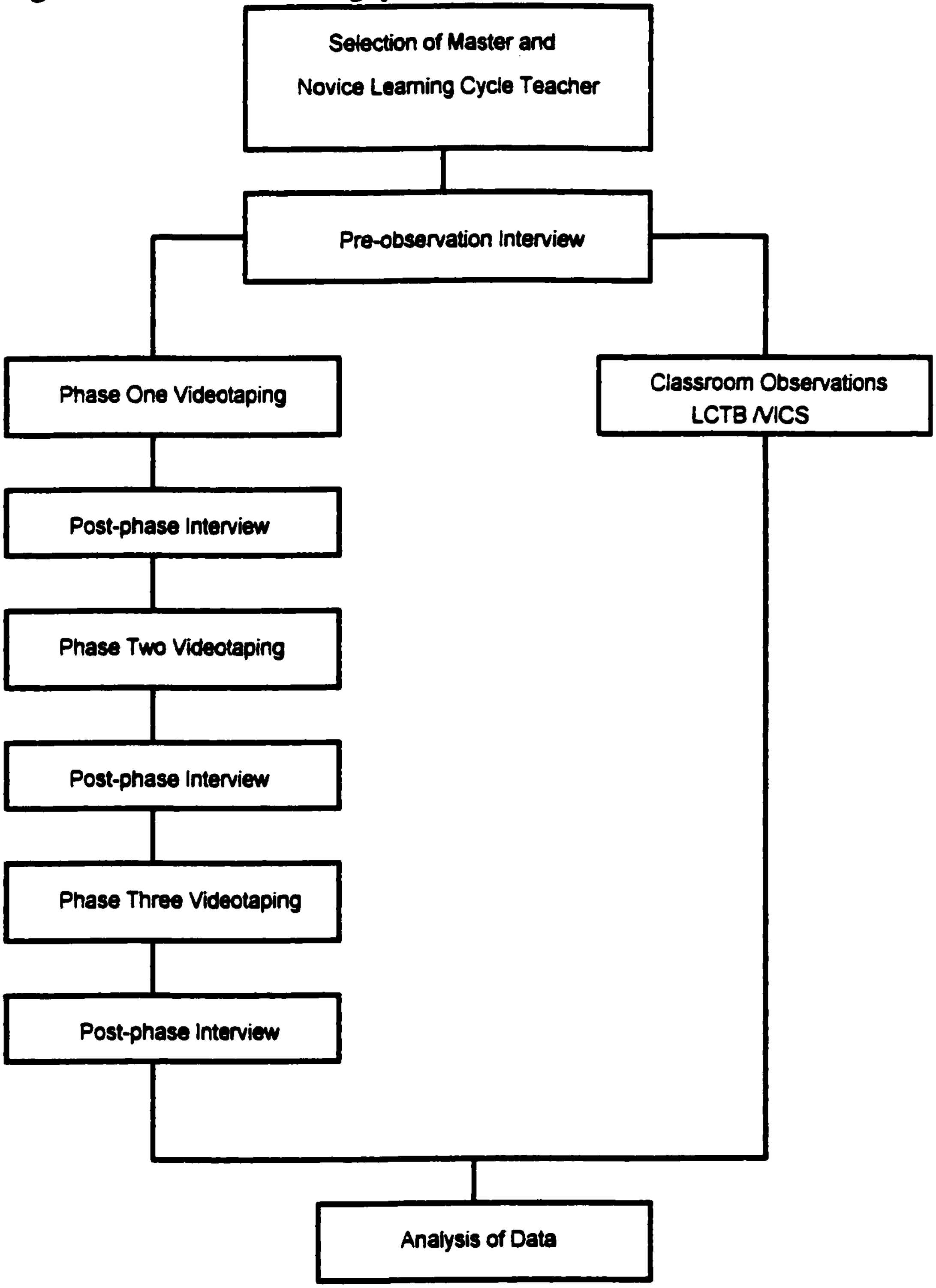
Qualitative Data Collection

Classroom Observations and Videotaping of Lessons

Two teachers, one novice and one master, from the pool of participants used for the survey, were selected for in-depth classroom observations. The selection was non-random to achieve parity in subject and grade level. The teachers were also willing to be observed and videotaped and were available for post-observation interviews. Figure 4 shows the qualitative data collection process.

Triangulation, a technique used to verify the trustworthiness of qualitative data (Langenbach, Vaughn, & Aagaard, 1994), was accomplished by using the following techniques. First, the researcher conducted interviews using open-ended questions to elicit the teachers' baseline views on teaching, science, and the learning cycle before the first observation (Rubin & Rubin, 1995). The question protocols for the pre-observation interview are given in Appendix B.

Figure 4. Flowchart showing qualitative data collection



Second, the researcher observed a complete three phase learning cycle unit for the master and novice learning cycle teacher. The researcher observed two complete learning cycle units (simple machines and optics) each consisting of three 90 minute classes. The researcher's observational field notes provided a thick description of the teachers' use of the learning cycle. Two instruments were used for observations along with field notes. Becasue of the physical limitations imposed by real-time concurrent use of two observational instrucments, the lesons were videotaped and the LCTB and VICS observations were made from the videotapes. The Learning Cycle Teaching Behaviors instrument (LCTB) identified teacher behaviors during the observations. These behaviors include providing appropriate materials for exploration, asking for both quantitative and qualitative reports of student data, and continuing to use the language of the concept in the third phase. Concurrent use of the Verbal Interaction Category System (VICS) provided a way to code verbal interactions between student and teacher during each phase such as the type of questions asked and type of response given. The LCTB/VICS instrument is in Appendix C.

The reliability and validity of the combined LCTB/VICS was established through field testing in learning cycle classrooms (Grzybowski, 1986; Marek, Eubanks & Gallaher, 1990). To bring the LCTB/VICS in line with current usage, the term *term introduction* was used instead of *concept invention* and the term *application* was used instead of *expansion*. No changes were made to the content of the instrument.

The videotapes were used during the post-phase interviews as a memory tool (Keith, 1988; Miles & Huberman, 1994; Pirie, 1996). The interviews focused on the teacher's actions during the learning cycle phase just completed. The tapes were stopped at various points for discussion with the teacher. These points included a) end of instructions to whole class, b) end of exploration phase, c) end of whole class discussion of data (term introduction), and d) end of application phase. The tape was also stopped at the discretion of the teacher or interviewer as the need presented itself; for example, if a topic of special interest arose or if clarification of an incident was needed. Questions for the post-phase interviews were based on observed patterns from the activity.

In addition, the teachers' responses on the Learning Cycle Survey were obtained for analyses. These data provided additional information on the teachers' understanding of each phase of the learning cycle paradigm.

Analysis of Qualitative Data

The research used analysis of idea units to describe and trace the process of learning cycle teaching in each classroom. Analytical induction (LeCompte & Preissle, 1993) was used to look for patterns or themes that emerged from the data. Interviews were transcribed and coded. Emergent patterns were used to develop coding categories for comparison among the teachers to determine the teachers' approaches and understandings of the learning cycle. Coding categories were verified though auditing by an outside researcher experienced in qualitative data analysis. The outside auditor was an experienced high school science teacher, had used the learning cycle extensively in classroom situations, had taught learning cycle theory at the University of Oklahoma, and had a Ph.D. in the areas of curriculum and instruction. The auditor had also used qualitative methods in her own research and had experience in the development of codes from interview data.

The researcher and outside auditor each developed proto-codes from a portion of the interviews. Portions of the transcipts of the interviews were read by the two auditors. Themes that emerged from this reading were used to establish proto-codes. he auditors then took the remaining portion of the interview and coded them with the proto-codes. At frequent intervals, the codes were compared and a final sequence of codes was agreed upon. The researcher and auditor then independently coded another section of the interviews and compared results. The process continued until the establishment of a 95% accuracy rate. As coding progressed, the accuracy reached 100%. The coding categories are shown in the results section.

CHAPTER IV

Results

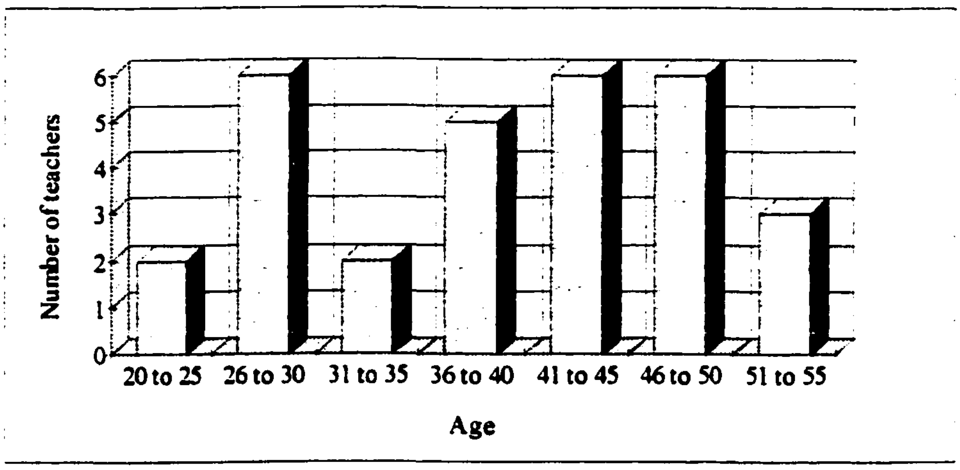
Objective 1. To describe teachers who use the learning cycle and compare their understandings and perceptions of the learning cycle procedure in instruction.

The first objective of this research was addressed through a survey of teacher understandings of the learning cycle. The cover letter, background data sheet, and learning cycle survey were sent to 70 secondary science teachers at the beginning of the spring semester. This pool included the known population of secondary science learning cycle teachers within the state of Oklahoma. Follow-up letters were sent at the end of the spring semester to all 70 teachers. Thirty-two teachers responded to the survey. Two respondents chose not to provide background information thus could not be included in these analyses. Therefore, the responses of 30 teachers were used in the analyses of the background data.

Background data

The background portion of the survey was designed to provide a profile of the pool of secondary science learning cycle teachers. Figures 5 through 10 show the demographic breakdown of the sample according to age, sex, grade level taught, subject taught, years teaching, and how they first learned of the learning cycle.

Figure 5. Number of learning cycle teachers by age.



As observed in Figure 5, the ages of the teachers ranged from early twenties to mid-fifties. The youngest were twenty-five and the oldest was fifty-five. The average age of the teachers was thirty-nine years.

Figure 6. Percentage of learning cycle teachers by sex.

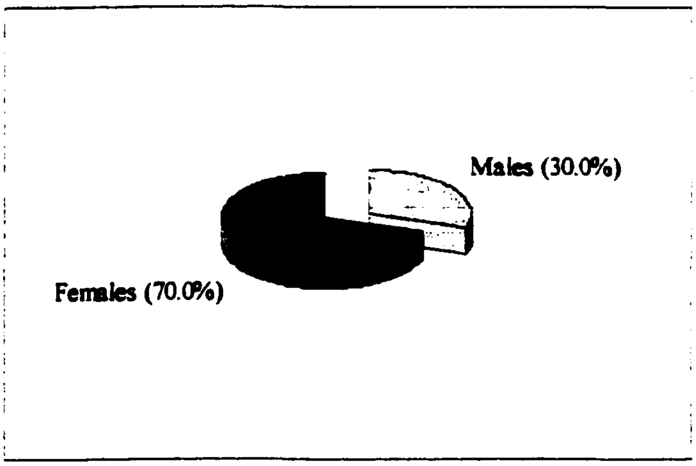


Figure 6 shows that females outnumbered males in the sample by almost a three to one ratio. Additionally, female and male teachers were distributed throughout subject and grade levels with no one area dominated by either sex.

Figure 7. Number of learning cycle teachers per grade level.

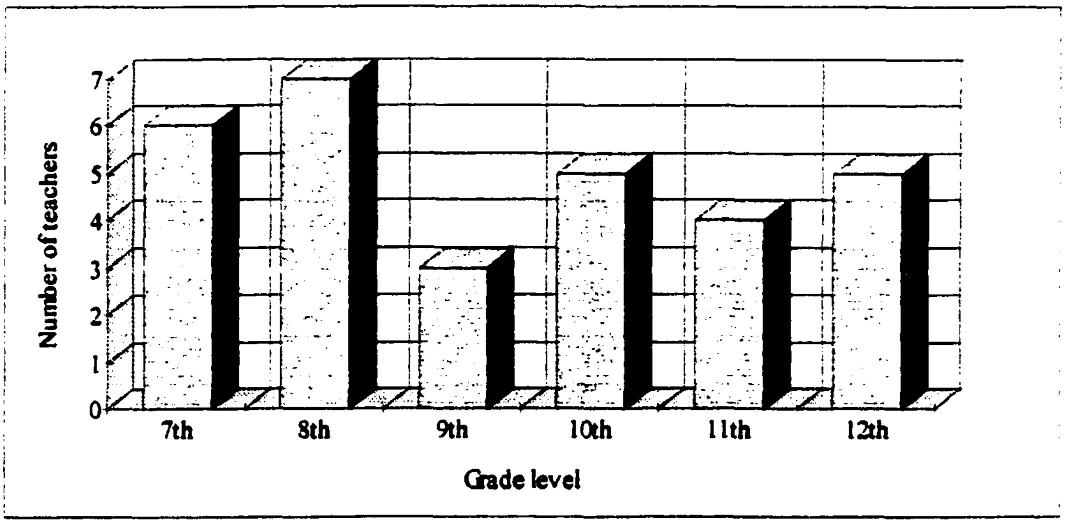
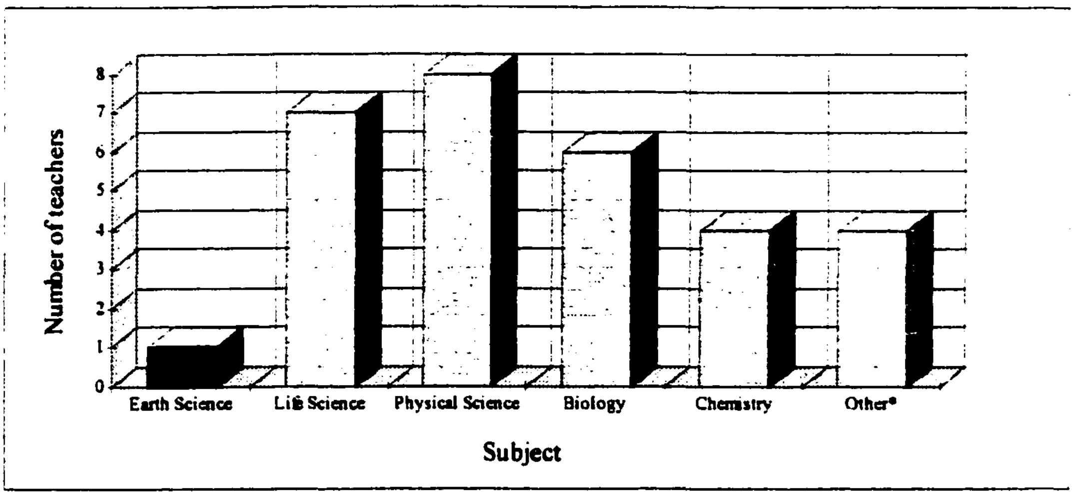


Figure 7 shows the distribution of teachers over the grade levels surveyed. Thirteen teachers taught in seventh and eighth grade; seventeen taught in grades nine through twelve.

Figure 8. Number of learning cycle teachers by subject taught.



*Included: astronomy, environmental science, and anatomy/physiology

Figure 8 shows that most of the possible science courses offered in the state of Oklahoma were taught. As indicated, fifteen of the teachers taught either life science or physical science while ten teachers taught biology or chemistry. Five teachers taught either earth science, astronomy, environmental science, or anatomy/physiology. Life science and physical science are traditionally taught in grades 7 to 9; therefore, the type of science taught by the teachers supports the grade level distribution observed in Figure 7.

Figure 9. Number of learning cycle teachers by total number of years in teaching.

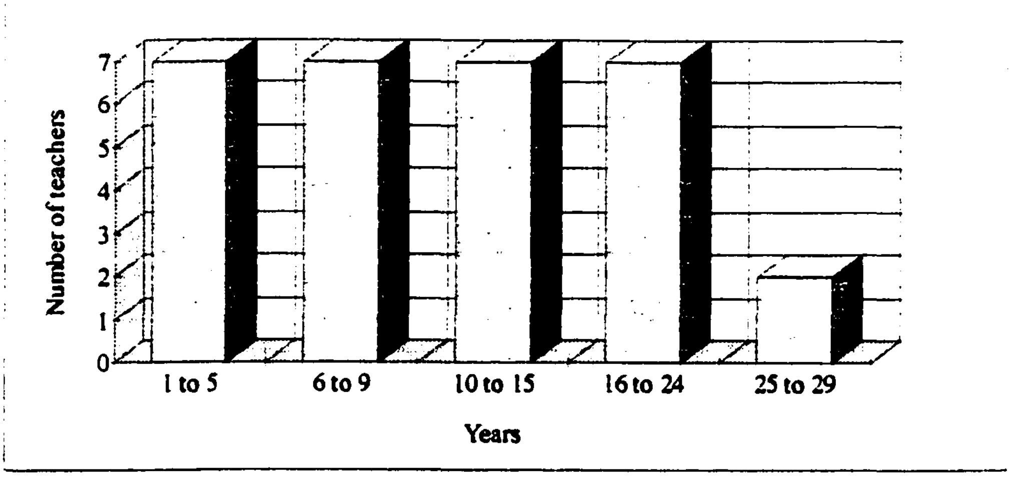


Figure 9 illustrates the distribution of teachers by number of years they had taught. The numbers were equitably distributed over one to twenty-four years of teaching experience. Only two teachers had taught more than twenty-four years.

Figure 10. Number of learning cycle teachers by how first learned learning cycle paradigm.

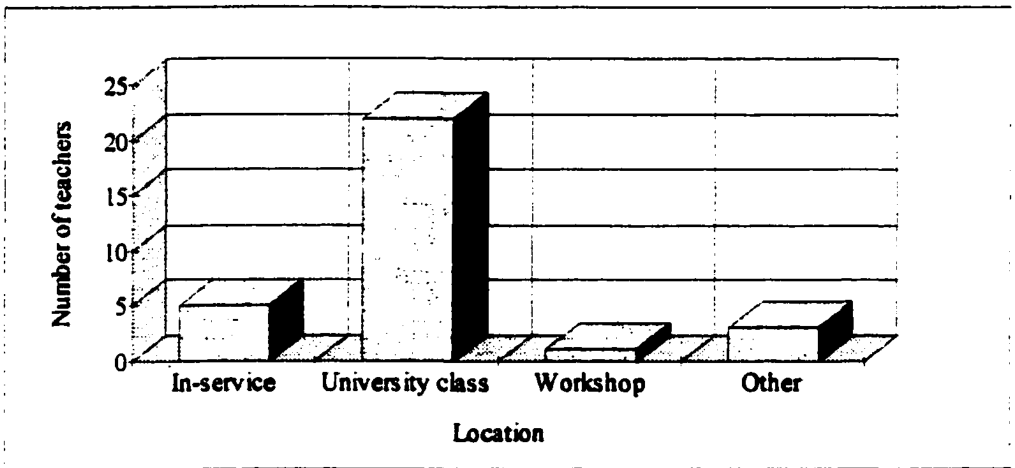


Figure 10 indicates that a majority of the teachers learned how to use the learning cycle paradigm in university classes. It is not clear from the survey whether these classes were during undergraduate or graduate studies; or if learning cycle teaching had been used as the organizing principle of the class or one of many methods presented. Five of the teachers first experienced the model through in-service education programs. The remaining four were instructed through workshops, district training sessions, and fellow teachers.

The background portion of the survey also contained questions to create a profile of the conditions in which the teachers taught. Figures 11 through 14 describe these characteristics and will be discussed together.

Figure 11. Percentage of learning cycle teachers by community type.

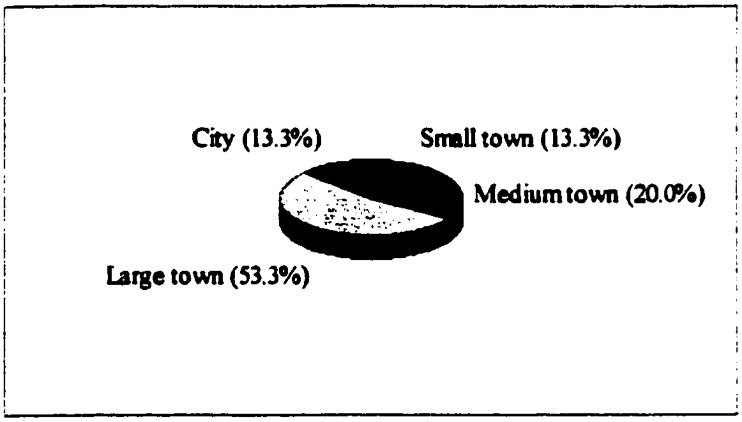


Figure 12. Percentage of learning cycle teachers by school size.

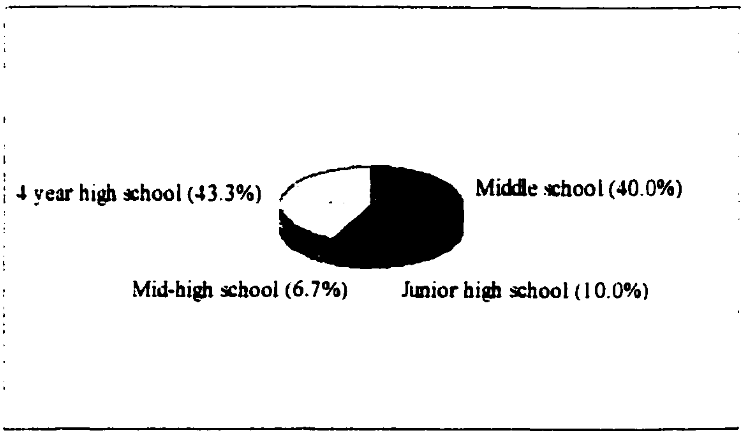


Figure 13. Number of learning cycle teachers by size of student body.

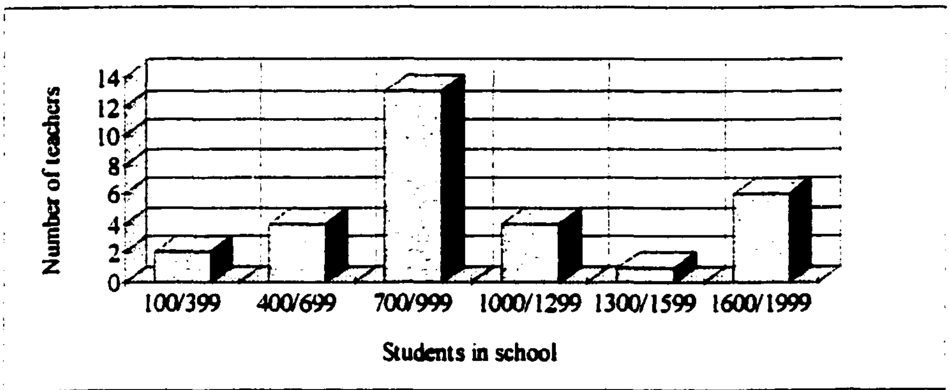
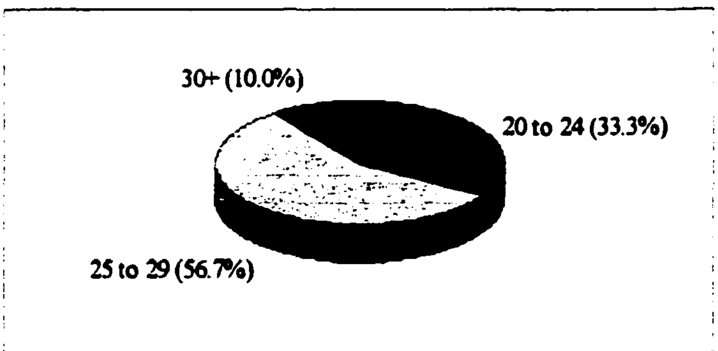


Figure 14. Percentage of learning cycle teachers by average class size.*

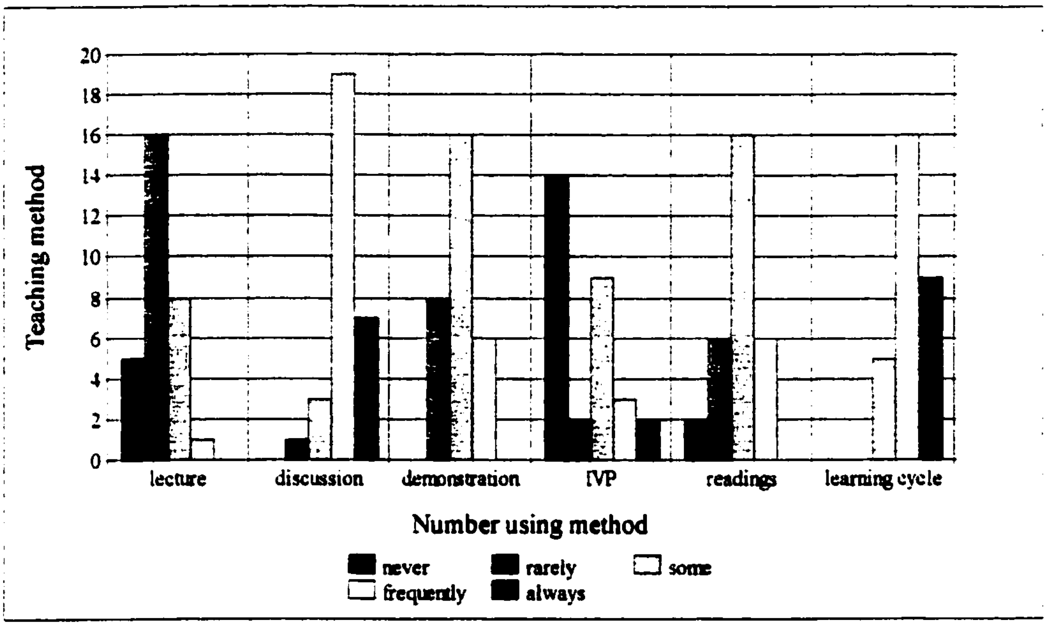


* Class size (percentage of teachers)

A wide sample of teaching situations were represented in the pool. Most of the teachers taught in large towns, which may also mean suburban districts. The sample was fairly evenly split between four year high school and middle school teachers. Medium sized schools of 700 to 999 students were the most common teaching venues. Class sizes were rather large with 56.7% of the sample reporting an average class size of 25 to 29 students and 10% reporting classes of 30 plus students.

The third segment of the background data portion of the survey profiled the teachers' frequency of using common science teaching methods. The methods cited were lecture, discussion, demonstration, inform-verify-practice laboratories, assigned readings, and learning cycle laboratories. Figure 15 shows the frequency of use of each of these methods reported by the teachers.

Figure 15. Frequency of use of common teaching methods by teachers.



Analysis of the frequency of common methods reported by the teachers shows a pattern that supports the use of learning cycle in their classrooms. Discussions and demonstrations were the most used methods other than learning cycle. Lectures and readings were used some, but to a lesser extent. Inform-verify-practice laboratories were never used by 14 of the teachers. Two teachers reported always using inform-verify-practice laboratories. However, these teachers had patterns of responses on the Learning Cycle Survey consistent with those teachers who reported using methods more conducive to learning cycle teaching. Therefore, the survey data from these two teachers was used in the analysis of the learning cycle questions.

Learning cycle questions

Due to their nominal nature, the learning cycle survey data for the study were analyzed by means of nonparametric statistics. A series of chi-square tests were used to determine whether the frequency of correct test responses on each question differed between master and novice learning cycle teachers. For the analysis, master teachers (n = 13) were defined as those with more than five years learning cycle teaching experience while novice teachers (n = 19) had less than five years teaching experience with the learning cycle. Five years represented a natural cut-off point for this study. Data from the 32 teachers who responded to the survey were used in these analyses.

On some tests more than one-fifth of the fitted cells were sparse (frequency < 5). Therefore, the Yates correction for continuity was used to prevent the chi-square tests from being too liberal (Huck, Cormier, & Bounds, 1974). Table 1 shows the results of the chi-square tests.

Table 1. Results of Chi-square analysis of responses to items on the Learning Cycle Survey for all respondants (N=32).

Item	N	Master	Novice	Pearson Chi2	Yates Chi2
1	32	10(3)*	13(6)	0.599	0.900
2	32	5(8)	6(13)	0.687	0.981
3	32	9(4)	11(8)	0.515	0.780
4	32	2(11)	2(17)	0.683	1.000
5	32	10(3)	18(1)	0.135	0.341
6	32	13(0)	19(0)	1.000	1.000
7	32	13(0)	19(0)	1.000	1.000
8	32	8(5)	7(12)	0.169	0.310
9	32	10(3)	18(1)	0.135	0.341
10	32	12(1)	16(3)	0.496	0.892
11	32	13(0)	19(0)	1.000	1.000
12	32	11(2)	17(2)	0.683	1.000
13	32	5(8)	9(10)	0.618	0.892

* Number correct (number incorrect) for each item

Note: all Chi square values p > .05

Results of the chi-square tests show no significant differences between master and novice teachers' answers on each question of the learning cycle survey. Master and novice teachers showed no difference in understanding of the learning cycle as assessed by this instrument.

As mentioned earlier, the Learning Cycle Test was a two-tier test (see Appendix A). Thus, the data were also examined by comparing the percentage of correct responses to the first tier questions and the combination first and second tier responses. The first tier presented questions about the learning cycle strategy and four choices of responses. The second tier presented four possible explanations for the first tier. The second tier responses had one correct choice and three alternative choices based on common misconceptions (Odom & Settlage, 1996). Table 2 shows the results of these analyses.

Table 2. Percentage of teachers (N=32) selecting the desired first tier and combination of first and second tier choices (after Odom & Settlage, 1996).

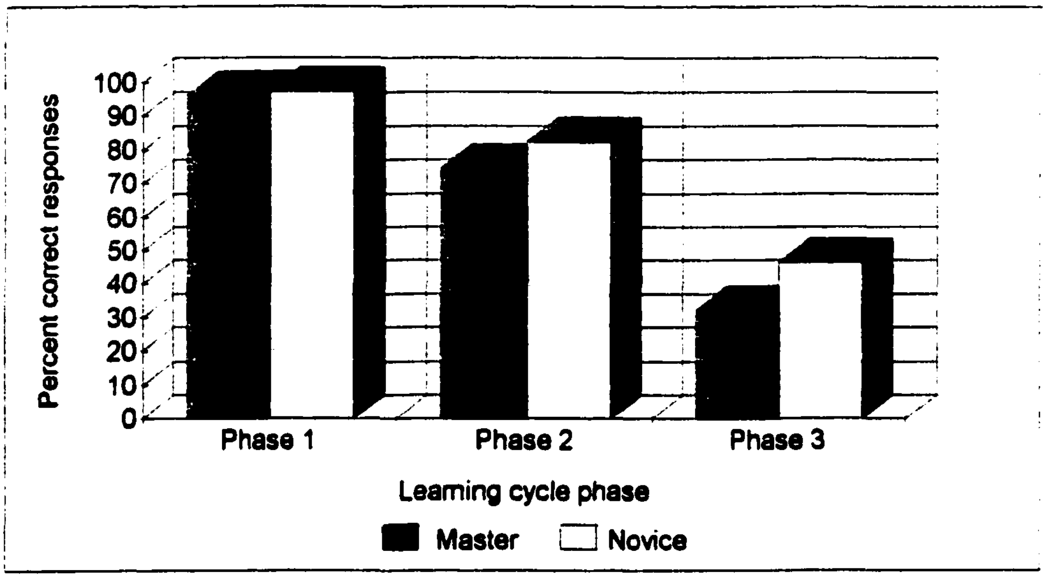
Item	First Tier	Combination
1	75	71.9
2	43.8	37.5
3	71.9	62.5
4	31.3	12.5
5	96.9	87.5
6	100	100
7	100	100
8	62.5	46.9
9	96.9	87.5
10	100	90.6
11	100	100
12	87.5	87.5
13	50	43.8

Items 6,7,11 & 12 pertain to Phase I; items 3,5 & 9 to Phase 2; items 1,2,4,8,10 & 13 to Phase 3

The response pattern was similar to that reported in Odom and Settlage (1996) with the highest percentage of correct combination scores in response to Phase 1 questions and the lowest correct combination percentages in response to

Phase 3 questions. Further analysis of responses to each phase is shown in Figure 16.

Figure 16. Percentage of correct responses to each phase level by master and novice status for all respondants (N=32).



* Phase 3 p < .05

On Phase 1 questions, master learning cycle teachers had 96.2% correct responses and novice learning cycle teachers had 97.4% correct responses. Phase 1 was covered by four questions (6, 7, 11, 12). Master learning cycle teachers responded correctly to 74.4% of Phase 2 questions (3, 5, 9) as compared to 82.5% of novice learning cycle teachers. The lowest correct responses were seen in Phase 3 (1, 2, 4, 8, 10, 13) with 32.3% of master learning cycle teachers and 46.5% of novice learning cycle teachers giving the expected response.

Objective 2 - Eliciting novice and master learning cycle teacher perspectives on their instruction and determining their perception of the process by which learning cycles are implemented in their classrooms

Objective two was addressed through interviews with one master and one novice learning cycle (LC) teacher chosen from the pool of survey teachers. One master and one novice learning cycle teacher were chosen from the pool of respondents. As stated earlier, the master LC teacher met the following requirements:

1. A teacher who has taught science using the three phase learning cycle for a minimum of five years.

2. A teacher who has administrative and collegial support for using learning cycle science.

3. A teacher acknowledged by peers, administrators, and university science educators as an exemplary teacher as defined by this research.

4. A teacher willing to participate in the study.

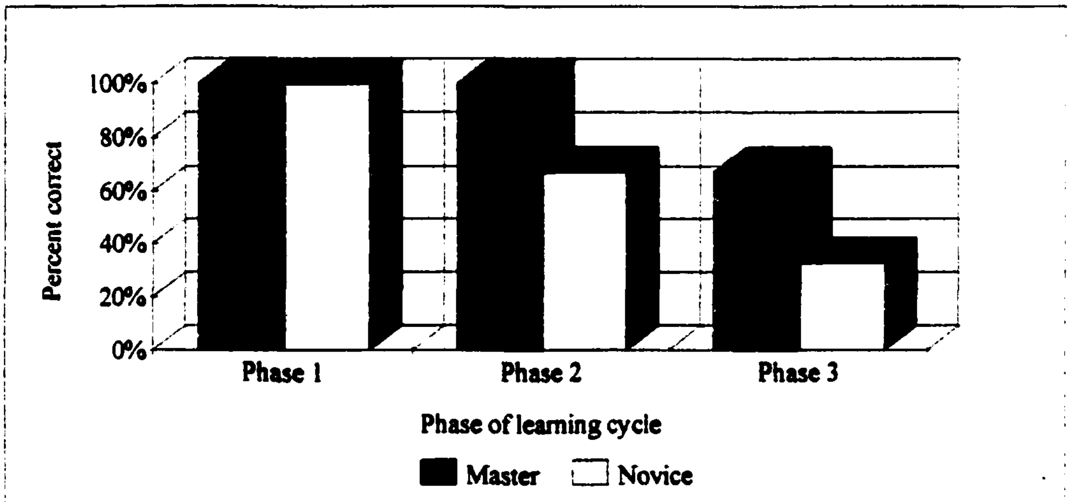
The novice LC teacher met the same requirements except that he had been teaching using learning cycle for less than five years.

Both teachers taught physical science in the same four year high school in a large, suburban district. The district in which the school was located expressly supported the use of learning cycle science and this was evident in the physical set up of the laboratory/classrooms. The master learning cycle teacher was an eight year veteran of learning cycle science teaching. She had taught at middle schools before coming to the high school. This was her third year at the high school. Her initial preparation for learning cycle teaching came through a university secondary science methods class and she had attended several in-service workshops on using learning cycle strategies. The novice learning cycle teacher had been teaching one and a half years at the time of observation.

After his student teaching in the fall of 1996, he was asked to take over a physical science class at the same high school that spring (1997). He was completing his first full year of teaching physical science as the sole teacher for the class when he was interviewed. He also learned to use the learning cycle strategy in his university science methods class. He had been recommended for the study by several colleagues who considered him to be a proficient teacher with the possibility of becoming exemplary.

On the Learning Cycle Survey, the master and novice teachers scored closely except in Phase 3. Figure 17 shows the responses for each phase in the survey.

Figure 17. Percentage of correct responses on the Learning Cycle Survey by the master and novice learning cycle teacher only.



Phase 3 - $p < .05$

The survey results show a solid understanding of Phase 1 as assesse d by the questionnaire. The master LC teacher also scored 100% in response to the three Phase 2 questions while the novice responded incorrectly to question number 3. A large difference appears in Phase 3 with the master LC teacher giving the expected response to 67% (4 out of 6) of the questions while the novice LC teachers responded correctly to 33% of the Phase 3 questions. The pattern of responses was opposite that of the master/novice LC teachers overall.

The interviews consisted of open-ended questions in three areas: philosophy of teaching, view of science, and the learning cycle. The full question protocol for the pre-observation interviews can be found in Appendix B. Analytic induction was employed for the analysis of the transcribed interviews. Emergent patterns were used to develop coding categories for distinguishing between the teachers to determine their approaches to, and understandings of, the learning cycle. Coding categories were verified though auditing by outside researchers experienced in the qualitative data analyses used in this study. Tables 3, 4, and 5 show the coding categories developed by the researcher and corroborated my the outside auditors. Table 3 represents categories related to teaching in general, Table 4 shows categories that emerged related to the discipline of science, and Table 5 reports categories related to the teachers' views of the learning cycle. These tables are presented sequentially, followed by supporting data, beginning with Table 3.

Table 3. Coding categories for Area One - Teaching Philosophy

Sub-area	Category	Sub-category	Master teacher mentioned	Novice teacher mentioned
philosophy:				
	changes		yes	yes
influences:				
	previous teachers		yes	yes
	mentors		yes	yes
	other teaching exp.		yes	yes
	neg. influence family		yes	no
	pos. influence family		yes	no
	professional orgs.		yes	no
roles of teacher:				
	instructional:			
		facilitator	yes	no
		disciplinarian	yes	no
	social:			
		counselor	yes	yes
		confidante	yes	yes
		advocate	yes	no
		role model	yes	yes
teaching skills:				
	life skills		yes	yes
	interpersonal communic.		yes	yes
	planning		yes	no
	class mgmt/discipline		yes	no

Area One (Table 3)

The first area addressed in the interviews was the teachers' view of teaching in general. The teachers' comments fell into four sub-areas: teaching philosophy, teaching influences, teaching roles, and teaching skills. Teaching philosophy seemed to permeate all of the comments within this area but was never clearly defined by either teacher. Generally, both the master and novice learning cycle teacher saw teaching philosophy as mutable; a philosophy that was in a constant state of development as they matured as teachers and experienced teaching in various facets.

Influences on teaching.

The next sub-area described by the data was that of influences on teaching. Six categories emerged from the data: previous teachers, mentors, other teaching experiences, negative family influences, positive family influences, and professional organizations. The following excerpts illustrate each of the categories.

Previous teachers

Master LC teacher:

" I had a chemistry teacher that taught learning cycle even before learning cycle was learning cycle. And it was all student directed learning. We negotiated contracts. There were certain experiments you had to conduct and explain. And it was team taught—a discussion room going at all times and an experimental lab at all times and you could move back and forth between the two."

Novice LC teacher:

"Oh...let's see. I guess the biggest influence would have been my teachers that I had going through high school and some of the coaches that I had in the classroom and they coached me in their sports."

Mentors

Master LC teacher:

"When I first thought about this, and I went back to talk to OU, I talked to Jack Renner there....And he was my first advisor. I talked to him and he got me all fired up. So that's where it went for me."

Novice LC teacher:

"There were a few individual teachers that I learned a lot from, but really once I got into it and started doing my student teaching, Jeff, he really influenced the way ... kind of opened my eyes about what really happens in the classroom as far as how much time you spend doing this, that, and the other. I did my student teaching with him and then this. Yes he's my mentor teacher. I've learned a lot from him. Especially it's really nice having him just right down the hall."

Other teaching experiences:

Master LC teacher:

"Well, I started teaching Sunday School [...] when I was 14. I lost interest in... I grew up... I was the youngest of four children by 17 years between me and the next youngest. I was born in the middle of the grandchildren, so I had way too many adults and I grew up very fast. So I outgrew my peers. And so I started teaching Sunday School at church when I was very young and decided, "This is cool." I wanted to be a teacher."

"Well, actually, there was a lot of alcoholism in my family, so I was directed to Al-Teen and Al-Anon. The twelve steps of spiritual program have directed me, probably as much as far as discipline. Treating others with respect and getting the same from them. Live and let live. Love. Accept people just as they are. And then go on."

Novice LC teacher:

"With ninth grade this year, I think it [coaching] really influenced a lot because the first day of school...you know, I had 32 students in my Physical Science class...of which I would know none of them except I had a pretty good relationship with almost every one of the football players that I had and that really helped a lot."

Negative influence of family

Master LC teacher:

"My family, however, being upper-middle class said, "Teaching does not pay. We're not paying for a college education for a teacher.""

Positive influence of family

Master LC teacher:

"So when my kids started pre-school, I started volunteering. I started going back and that rekindled my yearning for teaching. So, I made a decision when they were... Once they actually got in school and I was volunteering as a parent, when she got in kindergarten, I made a decision. [...] and my husband was committed. I decided to wait until I got them in school and I went back and got my teaching certificate. And science because I love science."

Professional organizations

Master LC teacher:

"I can't think of any [professional influences] in physical science right off the bat, other than Bill Nye the Science Guy...I really enjoy getting together and discussing with colleagues and sharing ideas. That's one of the reasons I go to NSTA every year. Because I get a chance to sit and be the student and listen to other people's best practices and get new ideas for how to implement it. I love that. I wouldn't trade that for anything. I get *Science Scope* and I was thinking about moving to the next level, *Science Teacher*, then I thought, "with ninth graders?" no."

Both master and novice learning cycle teachers listed previous teachers, mentors, and other teaching experiences as influences on their choice and style of teaching. The master considered her mentor to have been a university professor while the novice referred to a current colleague. Both referred to their high school science experiences as influential on their choice to enter teaching. The master learning cycle teacher found her experiences teaching Sunday School have been significant. An interesting point is her mention of Al-Teen and Al-Anon as programs that shaped her mental discipline and her interpersonal communications. The novice teacher found his experience with coaching to have been puissant.

Three other influences on teaching were mentioned only by the master learning cycle teacher: negative influences of the family, positive influences of the family, and professional organizations.

Role of teachers

Another sub-area that emerged was that of the role of the teachers. Again, several categories were present in the data: instructional roles and social roles. These categories were further subdivided into sub-categories. The several sub-categories in the first category are described in the following excerpts.

Instructional roles:

Facilitator

Master LC teacher:

"My perception of teaching is that it's guidance and facilitation more than directing or stating or regurgitation. That it's more a facilitator more of an advisor more of a role model and that students need to direct, as they get older, more of their learning and take over the share of directing their learning. So that by the time they get to the college level, when it's pretty much self directed, they'll be ready to pursue that on their own." [see next quote also]

Disciplinarian

Master LC teacher:

"I'm facilitator. With ninth graders, a parent I have to do a lot of parental discipline type things."

The teachers also saw that teaching required several social roles as well as instructional roles. Social roles were broken into several sub- categories.

Social roles:

Counselor

Confidant

Advocate for students

Master LC teacher: [this quote combines all three social roles]

"Sometimes there's all kinds of roles I take on in order to make kids open up so that they're teachable. And I think I'm an advocate for the students. Sometimes I see the students have needs that the district has missed, so I go to bat and try to get them the things they need. Yes, it's many roles and I've been a very active advocate for ninth graders because they were left out of so much this year because they were ninth graders. [researcher note: this was the first year for 9th graders to be at the high school] So they needed some advocates. Like I said, a facilitator. A guide. Someone to kind of keep them on the path and make sure it's like in lab—they're doing what they're supposed to be doing."

Novice LC teacher: [quote addresses counselor role only]

"As far as their asking me questions about school? About what should I do because of this? It's not just a role of the teacher, really. They'll ask you questions...they ask you questions and they want you to give your input on what you think they should do but they're really not sure. It's a lot of counseling, disciplining, a little bit of everything."

Role model

Master LC teacher:

"I had no idea of the amount of social training I'd have to do. I had no idea how much time a day would be spent in social behavior skills. I thought it was probably... I mean I knew that there would be some, but I thought the split would probably be 20/80, 20% behavior, 80% teaching. It turned about to be about...the other way around. 40% teaching, 60% modeling behavior—on a good day."

Novice LC teacher:
"Before I had any teaching experience, it was more get them, you know, to know the subject area and the content and to be able to take that information and use that information but it's not just that, it's a lot of socializing for the kids, getting them to interact with each other responsibly, you know, it's a lot of not necessarily parenting, but it's a lot more of that than what I had ever thought about before."

The excerpts showed that master learning cycle teacher was aware of a division between instructional roles and social roles. She explicitly saw herself as a facilitator, not a source of knowledge. The novice learning cycle teacher did not mention specific instructional roles he saw himself occupying. Both teachers saw themselves performing several social roles. The master learning cycle teacher placed herself in more social roles than did the novice. Both saw themselves as role models for their students.

Skills

The last sub-area under Area 1 was that of skills taught by teachers. Two categories appeared from the data: life skills and interpersonal communications.

Life skills

Master LC teacher:
"That I have them learn how to self-evaluate and become self-directed learners and know how to go out and search and research, and investigate, and draw things together as the content that I teach—making life-long learners."

Novice LC teacher:

"I would have to say it would be preparing them for the next step, whatever they intend to go on to doing. Just give the knowledge and the basis to be able to get along fine."

Interpersonal communication

Master LC teacher:

"Help them realize, not only through social issues like what we were talking about there, but through learning how their behavior and their choices are what determines largely their goals and the outcomes."

Novice LC teacher:

"Yes, it's not just teaching them the subject, it's also teaching them how to interact with each other and get along with each other and basically how it really works, not just in their little world, but how it works outside of the classroom."

The excerpts showed that both learning cycle teachers thought they modeled certain skills, other than science skills, for their students. A broad category, life skills, incorporated abilities needed to succeed outside of the school setting. The second category, interpersonal communication, included person-to-person and group communication skills. The master learning cycle teacher seems to have a better grasp on how students construct knowledge than the novice. That is, the master learning cycle teacher can better articulate this perspective, which is the foundation of learning cycle teaching. However, note that the novice LC teacher's response to life skills may illustrate an aspect of his teaching philosophy; for example, "Just give the knowledge...".

Area Two (Table 4)

The second major area discussed in the interviews was designed to elicit the teachers' views on science and science teaching. Four sub-areas were used: goals of science, definition of science, science education, and teacher responses to a quote about science.

Table 4. Coding categories for Area two - View of Science

Sub-area	Category	Master teacher mentions	Novice teacher mentions
goals of:			
	understand world	yes	no
	understand human role	yes	no
	understand technology	yes	no
	give needed information	no	yes
is (defined):			
	not facts and knowledge	yes	no
	problem solving	yes	no
	reasoning process	yes	no
	exploring universe	yes	no
	everyday	no	yes
	essential	no	yes
	different for different people	no	yes
science education:			
	all related to science	no	yes
	promote lifelong learning	yes	no
	needed. in technological society	yes	yes
	increase interest in science	yes	yes
Quest for knowledge:			
	too text-bookish	no	yes
	definition of science	yes	no

Goals of science.

The first sub-area, goals of science, was further divided into four categories. These categories are illustrated by the following excerpts.

Understand world

Master LC teacher:

"The goal of science is to help us understand the relationships between ourselves and everything in the universe."

Understand human role

Master LC teacher:

"How we can keep from interfering in the Laws of Nature, Laws of the Universe and how we can, I guess, better educate our selves to be a part of the system."

Understand technology

Master LC teacher:

"Technology. I think science is going to have to shift from, to include technology. That is where it's at. And if math and science don't move into the technological age, we're going to be an obsolete core curriculum."

Give needed information

Novice LC teacher:

"Well...I think there's a few different reasons. One, to just give them a background that they should know about." [Novice teacher does not mention further reasons]

As was seen on the excerpts, the master and novice learning cycle teachers saw different goals for science. The master learning cycle teacher viewed science as a means to understand the world, humanity's role in the world, and a means of understanding emerging technologies. The novice learning cycle teacher saw the goal of science as providing background information; information for students to know for their futures.

Definition of science.

The second sub-area within Area 2 addressed the teachers' definition of science; science in general, not specifically science education. Again, several categories developed from the data: not facts and knowledge, problem solving, reasoning process, exploring the universe, everyday, essential, different things for different people.

Not facts and knowledge
Problem solving

Master LC teacher:

"I'm like... I told Jeff like... I want to give them materials and say, like when they were talking about erecting things at Stonehenge, here's the job—get it done...safely, and monitor them. Have them work on a group project. Problem solving. And that's how I view my role in science. Science is not facts and knowledge. It is problem solving."

Reasoning process

Master LC teacher:

"It's how we get there and knowing how to sequence things so that you don't make long-term assumptions or set yourself up so that you don't have accurate data or you're not testing what you think you're testing. Which they do all the time, and its still something I still see with the kids. They don't know how to test. You give them a problem, they have no clue like on how do I test it?"

Exploring universe

Master LC teacher:

"What is science? To me science is exploring the universe we live in. Period. Everything."

Everyday

Novice LC teacher:

"...it's just trying to familiarize yourself with your surroundings and learn about the processes that happen around you is basically what I think. That's pretty general, but I don't think you can get too specific on that type of definition."

Essential

Novice LC teacher:

Like I said, they encounter science every single day when they go home, when they're doing anything...little things such as measuring something."

Different things for different people

Novice LC teacher:

"You know, like I said, I don't really think that you can define "what is science" just in general terms because it can mean a lot of different things for a lot of different people.

As shown, there were differing opinions between the teachers about the definition of science. The master LC teacher saw science as a reasoning process geared towards problem solving and as a way to explore the universe we live in. The novice LC teacher saw science as an everyday thing that was different for everyone yet an essential field.

Science education.

The third sub-area looked at science education or why science should be taught in schools. Four categories were seen to emerge: science is taught because everything is related to it, to promote lifelong learning, science is needed to function in a technological society, and to generally increase interest in science.

Teach because everything is related to science

Novice LC teacher:

"Everything that happens around them has to deal with science, especially with all this technology and everything. It's all science-related or discovered by a different scientist or something like that."

Lifelong learning (to promote)

Master LC teacher:

"I think we teach... My goal is to teach kids how to continually be a life-long scientific learner."

Need science to function in technological society

Master LC teacher:

" So they'll have the tools and the skills, so if they really want to move into any of those areas, they'll know exactly how to go about it."

To increase interest in science

Master LC teacher:

"In other words, my goal is to get them interested enough that they take the basics so that when they see something happen, they can then relate that to the big picture."

Novice LC teacher:

"But, it just kind of gives them a background and also it can get them interested in going into different fields of science. Even if they don't like science, they still, you know, its with them every single day."

The excerpts illustrated a diversity of opinion on the need for science education. The master teacher saw science education as promoting lifelong learning and as providing skilled needed in a technological society. The novice teacher's rationale for teaching science was predicated on the assumption that "everything' is related to science. Both teachers viewed science as a way to increase interest in science.

"Quest for knowledge".

The final sub-area of Area 2 records the teachers' responses to a quote about science. The quote used was "Science is the quest for knowledge, not the knowledge itself" by historian of science Duane Roller (1970). Two responses in this area were observed.

> "Yes, this is the definition"
>
> > Master LC teacher:
> >
> > "Exactly. It is the process that you go through learning about the universe, not the actual facts. That's what Oliver's [sic] reference manual and the CRC Handbook is for. Somebody already did that fact finding and put it down for me. So if I really need it when I'm doing theorems, I can go look it up."
>
> "It's a text-book definition"
>
> > Novice LC teacher:
> >
> > "Some of them [the students] have heard "a quest for knowledge" or something like that and some of them will write that down just because they've heard it before. It's a definition I guess. It's a text-book definition."

It is evident that the master and novice differed in their responses to the quote. The novice LC teacher thought it was a "text-book" response; one given on a test but not reflective of real classrooms. He did not seem to think it was an adequate definition but did not provide an alternative. The master LC teacher expressed the feeling that the quote adequately summed up her view of science as an investigation of the world and our place in it.

Area Three (Table 5)

The final area addressed in the interviews looked at the teachers' views about the learning cycle as a teaching procedure. Two sub-areas emerged from the data and addressed the advantages and disadvantages of using the learning cycle. Each sub-area was divided into the master teacher's and novice teacher's responses. Several sub-categories emerged under the master and novice teachers' responses.

Table 5. Coding categories for Area Three - Learning Cycle

Sub-area	Category	Master teacher mentions	Novice teacher mentions
advantages:			
	instinctual	yes	no
	builds connections	yes	no
	increases st. motivation	yes	no
	St. ownership/self-esteem	yes	no
	relates to prior knowledge	yes	no
	ease of concept mapping	yes	no
	hands-on"	no	yes
	laboratory based	no	yes
	concrete for concrete learners	no	yes
disadvantages:			
	preparation time	yes	no
	funding	yes	no
	class management	yes	no
	class size	no	yes
	group size	yes	yes
	class length	yes	no
	hard on new students	yes	no
	equipment shortage	no	yes
	unclear curriculum	no	yes

Advantages.

Master LC teacher's view

how learning occurs ("instinctual'):

"The learning cycle. I think you should follow some logical progression of people experiencing, interpreting, and assimilating knowledge of information or experience into their being. I just think that's the way everything works.[Interviewer: In an organic way?] Exactly. I think everything in the universe works that way. I don't think it's really unique to humans. Dogs do it real well. [laughter] And I just think it is...it's instinctual. I think that my kids respond well to it. Because it's living it and living it is so much more meaningful than viewing or hearing or reading about it"

build connections:

"The teacher has more time to actually interact with the kids and help them build connections when they're not so busy monitoring all of the other things that you have to do."

increases student motivation:

"Student motivation is much higher when it's student directed."

student "ownership" and increases student self-esteem:

"For the students' perspective, there's ownership. That builds self-esteem, that builds... I can't say it's easy. It's experiential. I get to see what throws them. I get to look at the funny faces, you know, when they get lost. They get that sort of glazed look."

relates to prior knowledge:

"See, I can map it to previous experiences. If they've had other experiences."

easy to concept map:

" And well, sometimes I teach things and I go, "Doh!" and it's because nobody every helped me map my own brain. And so, with the learning cycle it makes it so easy to concept map and build things so the kids actually understand how the whole enchilada works."

stop misconceptions:

"And when it's student based, the teacher has more freedom to clear and find misconceptions and make sure that they're not passed."

Novice LC teacher's view

hands-on:

"I think learning cycle is just basically more of a hands on approach, more lab-based where they can actually do the experiments, we can talk about them, and then they an expand on what they've learned to bring it into their everyday use."

laboratory based:

"I don't see how you could teach very effectively, I'm sure it can be done, but I mean as far as some of the things that we do like optics or anything like that, trying to have them (and I'm sure it's a little bit more formal anyway) but having them just read something like that or doing something just out of a plain textbook, it would be really hard to get them to understand what's really happening. So I think that the learning cycle really helps a lot since it is a lot of lab-based, hands-on activity."

concrete for concrete learners:

"I think it does help, especially those ninth graders, since they're so concrete about taking in all this information, if they can actually get their hands on it and see what's going on, visualize it, and then when we talk about it or they read about, they can remember back to, "oh yes, this is what we did".

The excerpts show that the master and novice LC teachers saw different advantages to the learning cycle . The master LC teacher looked at its impact on student learning. The master LC teacher had more categories with more complex and varied roles for the learning cycle in promoting learning. The novice LC teacher focused on the learning cycle as one teaching strategy rather than an overarching paradigm, and did not emphasize its impact on student learning. The novice's categories were less varied, less developed; so the full benefits of teaching with the learning cycle seem not yet realized or experienced.

Disadvantages.

Master LC teacher's view

prep time:

"It takes a lot of prep time"

funding:

" It takes a lot of money for equipment. Most districts I don't think have the funds to adequately fund learning cycle."

class management:

"To do the learning cycle, those smaller classes of 18-20 kids, you can interact with them and one can really get the inhibitions down for kids who will really open up. You can get discussions going. It's hard to get around the room in a class of 30 kids. It's impossible to call on every kid during every discussion and still make strides in your curriculum and it's frustrating. It's very frustrating not to be able to gather them all in and get them all involved."

group size:
"Working at this age level in groups 4, 5, and 6 this year is ridiculous. Two or three per lab group is optimal."

class length:
"I think there's advantages and disadvantages (to block scheduling of 90 minute classes). The amount of time is, to me, I know people probably disagree, I feel like students have more retention. Getting the lab, process the lab, bring the lab to conclusion and then take it from there in one sitting. There I can deal with what they go away and forget. It was really hard to have the lab one day and maybe get it finished right before the bell. Then expect them to remember what they did the day before."

hard on new students unfamiliar with learning cycle:
"They can tell you a lot more terms and facts. But when you put them in a lab space, they stand back, they're intimidated by the lab space. They're not real comfortable interacting as a group. They're kind of timid and shy about jumping in and putting their hands in and touching and doing at the beginning. And I find that those are often the kids who do my terms when the packets are handed out before the discussion. But they don't have any idea what it means."

Novice LC teacher's view:

equipment shortages:
"Some of the disadvantages are it's hard to get some of the equipment that you need or set it up in the correct way."

written labs not clear enough:
"Sometimes... if the labs aren't written perfect, they'll have a little bit of gray area or something like that in

> there. At the ninth grade level, they're not really, like I said, they're really concrete, so if there's a little bit of something that's a question mark there, they're going to go haywire. They want to know exactly what they're going to do, when they're going to do it, the steps they're going to do it in, and if something goes wrong, they just kind of freeze up."
>
> class size and group size:
> "...and the class size would be a disadvantage, too. I think to do this effectively, you have to have a smaller class size than 32. You can't have 5 students at every...we've got 6 lab stations, actually we've put in a 7th one and I've got at least 5 kids at every one and it's hard to keep going around the room from table to table to keep everyone on task with that many in the group. It's just kind of hard to keep control of the larger sized group."

The excerpts illustrate that the master and novice LC teachers differed in their view of the disadvantages of using the learning cycle teaching procedure. The master focused on disadvantages that effected student learning. The novice saw disadvantages in terms of what problems were created for the teacher (equipment shortages, sequencing) and for class management (noisy, less control of students). Both teachers voiced concern about class size and the learning cycle.

Objective 3 - Describing the context of science instruction in the novice and master learning cycle teachers' classrooms to ascertain how learning cycle implementation is facilitated by the teacher

The intent of objective three was to characterize the science instruction in the novice and master teacher's classroom. The researcher observed and videotaped the teachers teaching two complete learning cycle lessons in consecutive units. A lesson on levers from the Simple Machines unit was observed and from the Optics unit, a lesson on refraction of light. The same learning cycles were used by both teachers; only the order of the two units differed due to availability of laboratory equipment. One teacher taught the Simple Machines unit while the other taught the Optics unit and then the units were swapped. The observations took place over four weeks during the spring semester.

The Learning Cycle Teacher Behavior Instrument (LCTB) and the Verbal Interaction Category System (VICS) were used to record the classroom instruction. As described earlier, the Learning Cycle Teacher Behavior (Grzybowski, 1986) instrument is a check-sheet style instrument used for quick recording of teacher behaviors. The categories on the LCTB refer to accepted behaviors and actions for teachers during each phase of a learning cycle. The Verbal Interaction Category System (Marek, Eubanks & Gallaher, 1990; Grzybowksi, 1986) also allows a quick recording of teacher verbal statements and interactions during a lesson. The complete LCTB and VICS may be found in Appendix C. Tables 6, 7, and 8 show the results of these analyses.

Table 6. Master and novice teaching behaviors during two learning cycles.

	Novice Teacher		Master Teacher	
	Simple Machines	Optics	Simple Machines	Optics
LCTB**				
Exploration:				
provide materials	yes	yes	yes	yes
minimal guidelines	yes	yes	yes	yes
move from grp to grp	yes	yes	yes	yes
questioning groups	yes	yes	yes	yes
Term Introduction:				
qualitative reports	no	no	yes	yes
quantitative reports	yes	yes	yes	yes
assist summary	no	no	yes	yes
use student data	yes	yes	yes	yes
use concept language	yes	yes	yes	yes
Expansion:				
laboratory concept	yes	no	yes/yes*	yes
demonstration	no	yes	no/no	no
reading/AV	no	no	no/no	no
questions/problem set	yes	no	yes/yes	yes
use concept language	yes	yes	yes/yes	yes
assist summary and closure	yes	yes	yes/yes	yes

* Time allowed for two expansions for the learning cycle observed to be done in the master teacher's classroom.
** LCTB = Learning Cycle Teacher Behavior

The master and novice LC teachers were quite similar in their implementation of the two learning cycle lessons. The master and novice LC teachers differed, however, in the implementation of phase 2 (term introduction). The novice teacher did not include qualitative reports during this phase. Also, the novice did not "assist" in the summary of the data, he led the summary of the data.

The second instrument used to describe the teaching in the classrooms was the Verbal Interaction Category System. Table 7 shows the VICS results for the master teacher. A complete description of the code categories is found in Appendix C.

Table 7. Master learning cycle teacher verbal exchanges during two learning cycles.

Simple Machines unit	VICS													
	1	2	3	4	4b	5a	5b	5c	6a	6b	6c	11	12	13
LC Phase														
Exploration	3	20	0	20	11	0	7	2	0	0	12	0	0	0
Term Intro.	0	0	2	23	16	0	0	10	0	0	2	3	0	0
Expansion	0	0	0	8	1	1	0	6	0	1	0	0	0	0
	0	0	0	12	6	0	0	11	0	0	0	0	0	0

Optics unit	VICS													
	1	2	3	4	4b	5a	5b	5c	6a	6b	6c	11	12	13
LC Phase														
Exploration	1	7	6	11	0	7	4	8	3	0	4	0	0	0
Term Intro.	8	3	9	15	17	0	0	7	3	0	15	2	0	0
Expansion	3	7	13	7	2	0	0	8	0	0	0	0	0	0

The verbal interactions of the master teacher were concentrated in areas 4 and 4b: asks broad questions and asks probing questions. Additionally, she followed up her questioning with responses that stressed the cognitive content or context of the event (5c) or with negative responses for cognitive management (6c). Also, the master teacher tended to confine her verbal direction giving to the exploration phase, primarily at the beginning of class to instruct students in the setting up of laboratory equipment.

The VICS was also used to describe the novice teacher's verbal interactions. Table 8 shows the results of the VICS for the novice teacher.

Table 8. Novice learning cycle teacher verbal exchanges during two learning cycles.

Simple Machines unit	VICS													
	1	2	3	4	4b	5a	5b	5c	6a	6b	6c	11	12	13
LC Phase														
Exploration	3	22	15	0	0	0	0	0	0	0	0	19	0	0
Term Intro.	0	28	25	0	0	0	0	0	0	0	0	0	0	5
Expansion	0	65	18	0	0	0	0	2	0	2	0	12	0	10

Optics unit	VICS													
	1	2	3	4	4b	5a	5b	5c	6a	6b	6c	11	12	13
LC Phase														
Exploration	0	50	23	0	0	0	0	0	2	0	0	0	0	0
Term Intro.	0	11	18	2	0	0	0	10	0	0	4	7	0	3
Expansion	0	20	13	1	0	0	0	5	0	0	2	9	0	6

The novice LC teacher's verbal interactions were concentrated in areas two and three. Area two (gives directions) predominated in all three phases of the novice's classroom instruction during the learning cycles observed. The novice LC teacher was observed using narrow questions (i.e., recall, simple knowledge, yes/no) almost exclusively. Very little feedback, negative or positive, was given. Finally, the novice LC teacher had more responses which neither accepted nor rejected the occurrence. Rather, he withheld comment or ignored questions and/or behaviors in his classroom. Also, the novice teacher had more incidents of non-directed talk; that is, talk not related to the lesson or science.

CHAPTER V

Summary and Discussion

Purpose of study

The purpose of this research was to describe and explore the learning cycle teachers' use and general understanding of the teaching paradigm. This research also examined the teaching characteristics and practices of a master and a novice learning cycle science teacher and identify possible patterns in their understanding and implementation of the paradigm in the classroom.

The specific objectives of this research were:

1. To describe teachers who use the learning cycle and compare their understandings and perceptions of the learning cycle procedure in instruction.

2. To elicit novice and master teachers' perspectives on their instruction and determine their perception of the process by which learning cycles are implemented in the science classroom.

3. To describe the context of science instruction in the novice and master teacher's classroom to ascertain how learning cycle implementation is facilitated by the teachers.

Research Method

The study utilized a three-pronged research design to address the objectives. First, background questionnaires and a learning cycle survey (Odom & Settlage, 1996) were sent to seventy known secondary science learning cycle teachers. Second, two teachers from the pool of seventy, one master and one novice, were selected to be interviewed. The interview probed the teachers' views on, and perceptions of, teaching, science, science education, and the learning cycle strategy. The third area was addressed via observations of the master and novice teachers in their classrooms during two full learning cycle lessons in physical science. The Learning Cycle Teacher Behavior instrument and the Verbal Interaction Scale were used to record the teachers' implementation of the learning cycle strategy during the lessons.

Objective One

The first objective was to describe teachers who use the learning cycle and compare their understandings and perceptions of the learning cycle approach to instruction. The set of respondents to the survey (N=30) were a sample of learning cycle teachers in the state. All of the science course divisions in 6th to 12th grades were represented, including environmental science and astronomy. Although they were distinguished by being part of the total known set of secondary science learning cycle teachers in the state, they were not unusual in most aspects to non-learning cycle secondary science teachers. They were from cities, large towns and small towns. They taught in large and small schools with varying class sizes. They covered a range of teaching experience from 1 to 24 years and ranged in age from 25 to 55.

Analysis of the learning cycle survey showed no significant difference in master and novice understandings of the learning cycle as assessed by this instrument. The length of experience using the learning cycle does not seem to translate to differential understanding of the paradigm among teachers. Analysis of the combined correct responses of the experienced teachers (master and novice) as compared to the responses of pre-service teachers (Odom & Settlage, 1996) showed that the experienced teachers had a pattern of responses similar to the pre-service teachers. When the experienced teachers' scores are broken into master/novice categories and compared to each other we see an interesting pattern with the novice teachers scoring higher than the master teachers. Looking more deeply at the experienced teachers' responses showed a difference occurring in the alternative responses given to the questions. It was apparent that the master teachers tended to want to give more broad, inclusive responses; that is, to see more than one purpose or reason for their practice. This was seen in Phase 2 questions and was especially evident in their responses to Phase 3 questions. Phase 3, in general, was the portion of the learning cycle that was most likely to yield greatly differing opinions among the teachers. This finding was also reported by Odom and Settlage (1996) for their pre-service teachers.

The Learning Cycle Test has been reported to be an efficacious way of assessing practicing teachers' understandings of the learning cycle. Teacher education has prepared teachers to use the learning cyle in their classrooms but has tended to unequally emphasize theoretical underpinnings and practical applications of the model. With increased understanding of the theory that undergirds learning cycle teaching, teachers may better understand the reason and importance of each phase, as it was designed to be implemented in the original paradigm. Teachers with only a rote or superficial knowledge of the model may have difficulty implementing the model - they have not sufficiently "accommodated" the model or "organized" it into their concept of teaching. The differences observed in this study are most likely due to the constraints of the classroom situations rather than a misunderstanding of the learning cycle itself. The apparent consensus on interpretation of the phases of the learning cycle between novice and master teachers may be valid. However, it is also possible that differences may be subtle and not readily assessed with such an instrument. The restriction of range phenomenon was observed with the data since possible response scores for each item went from 1 to 4. Therefore, there may have not been enough variability recorded by this instrument to detect any differences. Also, the survey forces the respondant to choose between answers that may not be satisfactory to the respondant. Analysis of the "wrong" asnswers and comments showed that the master teachers wanted to interpret Phase 3 more broadly and holistically but were forced into choosing the "best" response from those given.

Objective Two

Objective two was investigated by examining the master and novice LC teachers' responses on the Learning Cycle Survey. Personal interviews with the master and novice teacher completed the data.

Comparison of the master LC teacher and the novice LC teacher on their survey results showed a reversal of the pattern seen with the larger group. The master LC teacher demonstrated considerable understanding of Phases 1 and 2. Likewise, the novice LC teacher scored perfectly on Phase 1 dropping to 67% on Phase 2 questions. However, Phase 2 was covered by just three questions; missing one, as did the novice LC teacher, dropped the score significantly. Both master and novice LC teachers' scored low on the questions about Phase 3 (67% and 33% respectively) but especially the novice. If analysis of the teachers had stopped here, it would have seemed that possible weaknesses with implementation of the learning cycle would be observed in Phase 3. However, interview and observation data revealed other information, which will be discussed later.

The interviews were divided into three areas. Each is considered here in turn.

Area One. The teachers had several influences on their teaching: previous teachers, mentors, other teaching experiences, negative and positive influence of family, and professional organizations. The influence of previous teachers seems to have been quite significant for both master and novice. High school science teachers were cited by both teachers as being of the greatest influence on their choice of going into science education. It cannot be over emphasized that both teachers had, if not learning cycle science, then inquiry-based high school science experiences. These experiences have clear implications for the teacher's role in affecting promising students in high school science classes and guiding them towards careers in science.

Both teachers mentioned mentors as positive influences. The novice LC teacher's mentor was a fellow science teacher in the same school. His mentor would have been considered a master learning cycle teacher by the criteria of this study. The connection between a novice and master teacher may be of importance to the efficient and accurate implementation of the learning cycle paradigm in schools. Although the state has entry year supervisors who are faculty members in university departments of education, the relationship between a novice teacher and a mentor that prevails beyond that entry year would be beneficial in the long term development of the novice LC teacher. The master LC teacher listed a university professor as her mentor. The important connection that can exist between master learning cycle teachers and university science educators is underscored by this study. In the ideal collaborative relationship between teacher and university professors the master teachers would benefit from the professor's knowledge and updates on LC curricula, while the university professors would be kept abreast of the current state of school science and everyday workings in secondary schools.

Both novice and master LC teachers had previous teaching experience which they stated as a positive influence on them. The master learning cycle teacher was drawn to teaching quite early, age fourteen, and had extensive

Sunday School teaching experience. She also discussed the influence of various 12-step programs (Al-Teen, Al-Anon) on her teaching. This influence could be seen most clearly in her discipline policies and in her one-to-one relations with her students. Her classroom was a nurturing environment that gave her students the sense of safety needed to fully utilize the constructivist learning cyle model. Her expectations were very high and clearly communicated to her students. She held them to high standards of work and they responded. This type of classroom is necessary to foster the atmosphere needed to engage in the type of discussions required by the learning cycle teaching procedure to help students fully develop a concept. The novice LC teacher referred to his high school teachers but emphasized his coaching experiences. Although this was useful in breaking the ice with his students, it seems to have been of limited use in the implementation of the learning cyle in his classroom. There was an emphasis on teamwork and the meeting of goals, but in more of a "let's get it done" manner than in the spirit of true inquiry. The influence of coaching on the novice teacher's teaching style was evident. He was used to having his athletes take his commands and enact them. He was in control as an athletics coach. It may have been difficult for him to relinquish this control and effectively create the community of inquiry needed for successful learning cycle science.

Only the master LC teacher mentioned the family as having any influence on her teaching. Both master and novice were married. The master LC teacher had difficulty with her parents in gaining support for her decision to teach and this led her to enter pharmacy school and delay entering teaching. The support of her husband and children gave her the emotional strength and resolve to return to school to pursue a career in education. The master LC teacher entered teaching as a fully realized goal and not as an after thought for a career. This focus transferred to her classroom and her teaching style. The novice LC teacher, by contrast, seemed less sure of his goal in entering teaching. He liked science, he liked teaching, but seemed to be torn between being a science teacher or being a coach. He was being heavily influenced by his successes in coaching which were providing more immediate feedback on his efforts than he was receiving teaching ninth grade physical science. This division of focus was seen in his classroom and teaching style. The master learning cycle teacher had a clearer view or understanding of what teaching means within a constructivist paradigm. The novice learning cycle teacher showed signs of emerging understanding of constructivist teaching philosophy. Perhaps this clarity of focus is a characteristic that distinguishes master learning cycle teacher from novice learning cycle teacher. Future research should further explore such distinctions. Another possible avenue for future investigation would be a study of athletic coaching and its influence on teaching philosophy and practice.

Professional organizations were mentioned only by the master LC teacher. This level of participation with one's colleagues shows a commitment to science teaching beyond average. It shows the teacher's initiative and desire to enrich knowledge and skills on a large scale, as compared to, for example, attending required in-service education. It also demonstrates a higher sense of professionalism and the teacher's realization that learning continues beyond the university and confines of the school. This is especially true for constructivist science education and the use of the learning cycle paradigm.

The roles of teachers provided another rich area of discussion in the interviews. The roles were broken into two large categories: instructional and social. However, only the master learning cycle teacher saw herself in both social and instructional roles. She specifically mentioned herself as a facilitator; an important concept for a learning cycle teacher to understand. She also saw that one goal was to shape students who were "self-directed" learners. This view has implications for the type of science taught in a classroom. If self-directed learning is a specific goal, then a traditional lecture or didactic classroom would hinder attainment of this goal. Therefore, the belief in self-directed learning as a teaching goal would support the use of the learning cyle paradigm .

Both teachers saw several social positions for themselves. The master teacher, however, saw herself occupying more positions. Both teachers viewed themselves as role models for the students, which was taken very seriously by them. The idea of being an advocate for the students was evident in both teachers. The image of being a go-between and representing the needs of the students to administration can be very empowering for the teachers. This type of connection between student and teacher can only exist in an atmosphere of respect; respect of teacher by students and students by teacher. This translates to the classroom and creates a nurturing atmosphere which could help the formation of a community of inquiry (Noddings, 1992).

The role of skills taught by the teachers took an unexpected track. The comments of the teachers fell into two categories: life skills and interpersonal communication. Both teachers saw their role in teaching skills to extend beyond their contact with students in ninth grade physical science. This implies a view of teaching that is not limited to the time a teacher has a student in their classroom but extends the impact of that interaction to non-educational settings. These findings support the notion of the "hidden curriculum" responsibilities of teachers in addition to the academic curriculum (EPC, 1961; Martin, 1994).

Area 2. Area two was designed to elicit the teachers' views on science and science education. As in area one, area two fell into several categories.

The goals of science were interestingly divergent between master and novice LC teacher. The master learning cycle teacher saw more diverse goals of science. This was perhaps due to her greater experience in science. But this also has implications for how she represents science to her students. She viewed science as more encompassing; as a vital component of knowledge necessary to understand the world, the human role in the world, and technology. The novice learning cycle teacher seemed to limit the goals of science to the process of providing needed information to people. By limiting the goal of science to the passing of facts the novice LC teacher's teaching style could be influenced and may have an impact on his delivery of the learning cycle curriculum. Learning cycle curricula are designed to create opportunities for students to discover concepts through experimentation and discussion (Lawson, Abraham & Renner, 1989). Importantly, the second phase, term introduction, really implies that students interactively construct the concept, followed by the introduction of terminology. If teachers view science as a body of facts only (excluding the view of science as a process) then delivering a learning cycle curriculum as designed could become problematic. Teachers may be apt to over emphasize students "having the facts", rather than constructing understanding.

When we examine the definitions of science given by the teachers, we again see divergent ideas which could have implications for teaching using the learning cycle paradigm. The master LC teacher defined science as a problem solving or reasoning process used to explore the universe and not just facts. This view supports the philosophy that science knowledge is constructed and mutable. The novice LC teacher defined science as everyday, essential, and different for different people. This view also supports the constructivist philosophy but presents science in a limited way. The novice did not focus on the thinking processes involved in science or the activity of science. He used more of a surface definition that was not as sophisticated or developed as the master learning cycle teacher's description. Such a limited view could effect the process of science education in the novice learning cycle teacher's classroom if his actions as a science teacher communicates to the class members that they are "students of science" learning what has already been discovered rather than "scientists" discovering science. If science is presented as an everyday phenomenon, as both teachers did in this study, can students be inspired to pursue science as a career? Future research should examine this question.

Science education was defined by each teacher in ways that were supported by their definitions of science. For the novice, science is taught because "everything is related to science". For the master, science education promotes lifelong learning and is needed to function in a technological society; two ideas found in her definition of science and statement of the goals of science. Both teachers saw science education as a process to increase interest in science, which implies a view that would allow students to develop the skills necessary to use science in their lives. It has been shown that inquiry science increases student appreciation of science (Gallagher & Tobin, 1987; Lazarowitz, et.al, 1988). Thus, experiencing inquiry science with the learning cycle should lead to a pattern of lifelong use of science process skills.

The teachers were asked to respond to a quote about science: "Science is the quest for knowledge, not the knowledge itself." (Roller, 1970). The teachers expressed different opinions on this quote. The master teacher saw the definition as a summation of her view. This quote is compatible with her view of teaching in general, her view of science, and her concept of science teaching. Her philosophy is constant and reflects her personal experiences with science and teaching. She translates this philosophy into her classroom practice.

The novice teacher viewed the quote as a pat answer. He referred to it as a textbook quote. This could reflect the closeness of his experience in secondary science methods courses where such quotes were used. His reticence in accepting this quote is, however, consistent with the views he expressed about teaching, science, and science education. He seems to be trying to reconcile his methods class theory with the reality of the classroom; something the master teacher has accomplished.

Area 3. When assessing the advantages of the learning cycle strategy, master and novice learning cycle teachers offered nearly the same categories of advantages yet with some fundamental differences. The master learning cycle teacher saw more intrinsic than extrinsic values to the learning cycle strategy; that is, how it affected the students. This view was consistent with the master LC teacher's philosophy. Her entire process of teaching was focused on the students and how her teaching and her actions effected their achievement and learning. The novice teacher saw superficial or obvious advantages. He gave responses which showed he looked at the learning cycle only as a teaching tool and did not fully consider its impact on student learning.

The teachers also differed in their perceptions of the disadvantages of using the learning cycle paradigm. Again, the master teacher referred to class and group disadvantages in terms of their effects on student learning and achievement; for example, large class size means that students may not be able to discuss concepts as well as in a smaller class. Her concept of disadvantages of using learning cycle curricula is very consistent with her stated teaching philosophy. The novice teacher referred to class and group disadvantages in terms of his control of the class. For example, "...it's hard to keep control." This focus on the external influence may be reflective of the novice LC teacher's inexperience with class control rather than disadvantages inherent with the learning cycle paradigm. He may see these as problems with the learning cycle rather than with his developing class management abilities. Such views are characteristic of novice teachers and are not unique to learning cycle science teachers (Keys, 1993; Hofstein, Ben-Zvi, Carmelli, 1990; Yager & Bonnstetter, 1990). However, this naiveté about classroom management could color the novice teacher's opinion of the learning cycle (for example, learning cycle leads to hard to control classes, it is too noisy) and reduce his use of the learning cycle in favor of a teaching strategy that he feels allows him to have more control of the class.

Objective Three

The context of science instruction in the teachers' classrooms was described using the Learning Cycle Teacher Behavior instrument (Marek, Gallaher, Eubanks, 1990) and the Verbal Interaction Category System (Amidon & Hough, 1967). The researcher observed two full learning cycles in physical science, the same for each teacher, with the teachers' same class each time.

Analysis of the data from the Learning Cyle Teacher Behavior instrument showed similar patterns of implementation for Phase 1 (exploration) and Phase 3 (application), which were consistent with the learning cycle paradigm used. But in Phase 2 (term introduction) the teachers differed in fundamental ways. The master LC teacher used qualitative descriptions of the data as a further dimension of the data reported by the groups. Summary of the data was student driven and was much more of a discussion with the master teacher asking questions but providing very little direct information. The master teacher modeled learning cycle practice that was highly consistent with the "ideal" paradigm (Marek & Cavallo, 1997; Lawson, Abraham & Renner, 1989).

However, during this phase the novice LC teacher did not ask students for qualitative data reports and relied exclusively on numerical data. The summary of the data was also much more teacher driven in the novice teacher's classroom; at times approaching a direct lecture. The use of exclusively numerical data and the emphasis on the "correct" data may give us a clue to the novice LC teacher's view of concepts. He exhibited the view that students could only derive concepts from "correct data" rather than the process of analyzing all data and looking for patterns. Learning cycle theory defines concepts in a specific way: a concept is "a mental pattern (i.e., a pattern in one's mind) that is referred to by a verbal label (i.e., a term)" (Lawson, Abraham & Renner, 1989, p. 5).

The novice learning cycle teacher, although he may believe he is correctly implementing the learning cycle curriculum, was presenting concepts as the acquisition of a correct answer to a proposal, which is contrary to learning cycle theory. The novice teacher was also using a more didactic approach for data summary than would be expected in the learning cycle paradigm. In the learning cycle, summary of the data must be student driven and students must construct the concept in their own words. Having the teacher lead the analysis of the data may save time, but it denies the students the opportunity to invent the concept and fully accommodate the mental patterns (Lawson, Abraham & Renner, 1989). It seems that the novice LC teacher had good declarative knowledge of the learning cycle strategy, as we saw in his scores on the Learning Cycle Survey, but may have lacked sound procedural understanding (Anderson, 1980; Lawson, Abraham & Renner, 1989). If the Learning Cycle Survey had been used alone, we would have had an incomplete, and incorrect, view of how the novice LC teacher implemented learning cycle curricula in his class. The survey pointed to an adequate understanding of Phase 2, when in fact he did not implement Phase 2 in the manner intended by the paradigm.

This pattern was supported by analysis of the Verbal Interaction Scale data. The master learning cycle teacher used far more broad and probing questions than the novice teacher who primarily used narrow or recall/knowledge type questions. In essence, the master LC teacher expected her students to respond to broad/probing/high order questions *and* provided feedback, negative and positive, to the students. The verbal interactions in the master LC teacher's classroom were much more of a discussion between fellow investigators rather than teacher to student talk. The novice LC teacher, by contrast, asked low level questions and provided little feedback of any kind. Overall, the novice LC teacher's classroom was more teacher oriented with more direct teacher talk rather than a teacher/student discussion.

Phase 2 seems to have been the point of separation between master and novice learning cycle teacher. The points on which they differed were few yet very significant. Questioning and discussion are the foundational techniques of the learning cycle. The use of proper questioning and discussion are especially vital to Phase 2 of the learning cycle. Without the appropriate use of these techniques, the rich learning cycle paradigm is replaced by a more routine laboratory based teaching technique.

Limitations of the study

This is a new area of research and as such the data are exploratory. This study was the first time the learning cycle questionnaire had been used with in-service teachers. It is still unclear whether the tool is valid for the assessment of teachers' understandings of the learning cycle. It is apparent that there can be a distinct difference between a teacher's score on the questionnaire and the implementation of the learning cycle within a classroom. Both the master and novice learning cycle teacher in this study had good scores on the survey. The larger group of master teachers did not differ significantly from the larger novice group. Therefore, while the efficacy of such a questionnaire for the assessment of teachers' understandings of learning cycle theory may be valid, this type of questionnaire does not give a clear indication of the way in which the learning cycle is used in a classroom.

There are several limitations to the use of interviews in situations such as this. Only two teachers were interviewed; therefore, comparisons may only be superficial and could reflect other processes. The differences observed may be due to the age difference of the teachers; or possibly to the gender difference. Also, it is not clear if the differences are in personal or professional philosophy; or the extent to which personal experiences have influenced the views.

This study had a limited time of interaction with the focus teachers. Optimally, a longer time period could be spent observing the culture of each teachers' classroom. The interviews were done at a rather hectic time of the school year near the end of the spring semester. While both teachers put much effort into the interviews, it was apparent that their time was limited. A more relaxed atmosphere could have yielded additional observations. The interviews could have been divided into three parts given at different times of the school year. As in any qualitative interview, there is always the possibility of unknown, and therefore, uncontrolled, interviewer bias and influence. This bias could have been implied by the choice of interview topics. The topics were chosen to be as broad as possible but still support the theory base of the learning cycle. However, more narrowly focused questions would have elicited less expansive answers. Two teachers were chosen to be observed and interviewed. This was sufficient for the purposes of this study; however, more observations of different teachers would yield additional information for the formation of a profile of the master learning cycle teacher.

Implications of the study

There seems to be several marked differences between the implementation of the learning cycle paradigm in a master learning cycle teacher's classroom and a novice learning cycle teacher's classroom. What is not clear is how these differences arose. Are they personal or professional differences? What role, if any, do gender differences have? What was the influence of coaching on the novice teacher's implementation of the learning cycle? These questions should be addressed in further research.

It is also clear that these differences could not be adequately assessed through the use of a questionnaire. Unique patterns and differences emerged only after direct observation of the teachers and discussion of their teaching techniques and philosophies. The differences do appear to effect the way the learning cycle is implemented in the classroom. An essential element that emerged was the role of mentors in the teachers' professional development. The need to establish collaborative relationships between novice teacher and master teachers in the same field and between schools and universities is critical to the professional development of both novice and master learning cycle teachers.

Question and discussion techniques represent the greatest area of difference between the master and novice learning cycle teacher. These skills can be taught in methods classes and their obvious importance in the learning cycle indicates that much more emphasis should be placed on the practice of these skills in pre-service methods classes, field experiences, and student teaching. In-service teachers would benefit from refreshing these skills through in-service education and workshops. The role of mentors in cultivating question and discussion skills in new teachers is an area that could yield rich results. Student intern supervisors and entry-year teacher supervisors must also be aware of the level of development of these skills and counsel new teachers accordingly.

It is also evident that even in schools with a commitment to learning cyle science, there are some difficulties in using the paradigm that must be considered. Primary among the difficulties are the wide differences in learning cycle delivery between teachers. Secondarily, the allocation of resources for the laboratories can put significant stress on the teachers. Without proper resources teachers may feel obliged to use less constructivist, or more direct, methods of instruction in order to move the equipment from teacher to teacher in a timely manner. The bottleneck in laboratory resources is influenced by class size. Large class size is a serious threat to the proper implementation of learning cycle science. It is understandably difficult or impossible to hold a discussion with thirty or more students in a class, as was noted by the master LC teacher. If a district is going to commit to the use of learning cycle science, it must take supplies, space, and student numbers into account, and provide these support mechanisms as needed.

Finally, we must consider the apparent dichotomy between understanding of the learning cycle theory base and implementation of the learning cycle strategy in a classroom. The master learning cycle teacher barely referred to the theory base unless prompted; the novice evaded theory based questions altogether. Neither referred to leading theorists of learning cycle teaching or constructivism, even such obvious ones as Piaget or Vygotsky. Both teachers had completed a higher educational program that addressed the theory base of learning cycle teaching explicitly and both teachers scored very well on the test of learning cycle understanding. Yet the master LC teacher implemented learning cycle procedures well in her classroom while the novice LC teacher, although he felt he was correctly using the procedures, varied from the model. This leads to questions on the role theory plays in the use of the learning cycle paradigm in classrooms. What quantity and quality of instruction forms an adequate foundation in learning cycle theory? Why is it seemingly so difficult to translate theory into practice in a meaningful way? What are the long term implications for the effective use of the learning cycle in classrooms if there is a rift between apparent understanding of the theory base and implementation of the model learning cycle? Responses to these questions in the future will lead to a more effective use of the limited time for instruction during pre-service methods classes and will make more salient the need for continued in-service development and collaboration with teacher preparation institutions for teachers using learning cycle curricula.

The model set forth by Karplus and Thier hasn't changed but it is obvious that classroom use and technology has changed the outward features of the model. The core philosophy has remained remarkably intact. Classroom teahcers adjust the model to meet immediate classroom demands. Even though the survey showed differences in Phase 3, the real difference is in Phase 2. The understadning of what happens in Phase 2 was sound according to the survey, but the teahcers were not able to put this into practice. Teachers were still struggling with the use of questioning and discussion. This is the only area in which the master and novice differed greatly. Researchers must work more closely with classroom teachers to understand how theory is used and influences. Theory does, indeed, inform practice; but practice must inform theory if the theory is to be vital and useful in the changing environment of the classroom.

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Appendixes

A - Learning Cycle Survey

B - Interview Protocols

C - LCTB/VICS Form

Appendix A

Learning Cycle Survey

Teachers' Understandings of
the Learning Cycle
Survey

Background Information

Instructions: Answer the following questions by circling the appropriate letter or writing in your response where indicated.

1. Age:______

2. Sex: (a) male (b) female

3. Grade level you teach most often (circle one):
   (a) 7 (b) 8 (c) 9 (d) 10 (e) 11 (f) 12

4. Ethnicity:
   (a) African-American (b) Asian-American (c) Caucasian (non-Hispanic)
   (d) Hispanic (e) Native American (f) other________________

5. Subject you teach most often (circle one):
   (a) Earth science (b) Life science (c) Physical science (d) Biology I
   (e) Biology II (f) Chemistry I (g) Chemistry II (h) Physics I
   (i) Physics II (j) Other ________________________

6. Do you teach AP sections? (a) yes (b) no

7. Highest degree earned: B.S./B.A. M.S./M.A. Ph.D./Ed.D.

8. Further science teaching education since graduation (for example: workshops, in-service, coursework):

____
____
____
____
____

9. Number of years you have been teaching (at end of this year):
   (a) 1 - 5 (b) 6 - 9 (c) 10 - 15 (d) 16 - 24 (e) 25 - 29 (f) 30+

10. Type of community in which you teach:
(a) rural (population less than 1,000)
(b) small town (population less than 10,000)
(c) medium town (population less than 50,000)
(d) large town (population less than 100,000)
(e) city (population more than 100,000)

11. Type of school in which you teach:
(a) middle school (6-8)
(b) junior high (7-9)
(c) mid-high (9 -10)
(d) high school (2 year)
(e) high school (4 year)
(f) other ____________________

12. Approximate number of students in your of school:
(a) less than 100 (b) 100 to 399 (c) 400 to 699
(d) 700 to 999 (e) 1000 to 1299 (f) 1300 to 1599
(g) 1600 to 1999 (h) more than 2000

13. Average class size you teach:
(a) 1 - 9 students (b) 10 - 14 students (c) 15 - 19 students
(d) 20 - 24 students (e) 25 -29 students (f) 30+ students

14. Frequency of use of learning cycles in your science teaching:
(a) daily (b) weekly (c) monthly (d) several times a year

15. Where did you learn about learning cycle teaching?
(a) in-service session (b) workshop (c) university course
(d) other ____________________________

16. When did you learn about learning cycle teaching?
(a) 0 - 3 years ago (b) 4 - 6 years ago (c) 7 - 10 years ago (d) 10+ years ago

17. *The following is a three-part question. Read the entire question before responding.*

A. How often do you use each of the following teaching methods or techniques?

	always	never	rarely	sometimes	frequently
(a) lecture	1	2	3	4	5
(b) discussion	1	2	3	4	5
(c) demonstration	1	2	3	4	5
(d) verification laboratory	1	2	3	4	5
(e) reading	1	2	3	4	5
(f) learning cycle	1	2	3	4	5

B. Circle the **one** method that you **most prefer** to use in your teaching.
(a) lecture (b) discussion (c) demonstration
(d) verification laboratory (e) reading (f) learning cycle

C. Why do you prefer this one method over the others?

Teachers' Understandings of
the Learning Cycle
Survey

Instructions

In the following questions you will be asked to respond to a statement about the learning cycle and then give a reason for your choice. Answer the questions based on **your experience** with the learning cycle. In addition to the printed responses, space has been provided for you to comment on the question or clarify your response. The written responses are as important as the multiple choice responses.

****

1. During what phase of the learning cycle are students given the opportunity to organize the concept that they have just learned with other phenomena related to this concept?
   A. Phase One
   B. Phase Two
   C. Phase Three
   D. This is true for more than just one phase.

The educational reason for my answer is:
   A. after the information is given to the students, they are given the opportunity to make connections to new concepts.
   B. after the teacher explains the new concept, the students must be given time for free exploration.
   C. after the concept is presented, appropriate activities are provided to apply the concept to a new situation.
   D. the new learning cycle is all inclusive and develops new concepts during each phase.

Comments:

2. If you were properly using the learning cycle to teach students about metamorphosis, during the **third** phase an appropriate activity would be to·

A. extend the concept of metamorphosis to concept of migration.
B. examine the phenomenon of metamorphosis with as animal different from the one studied during the **first** phase.
C. Using either A or B or both would be in keeping with the learning cycle philosophy.

The educational reason for my answer is:

A. the purpose of the **third** phase is to facilitate the students' making connections among related concepts.
B. students need experience with the same concept in a different context.
C. connections among various concepts help reinforce student learning.
D. teachers should implement various strategies as they help to extend students' understandings.

Comments:

3. During what phase of the learning cycle is the main purpose to lead students to build meaningful understandings about their experiences (this is what Piaget called "accommodation")?

A. Phase One
B. Phase Two
C. Phase Three
D. This is true for more than just one phase.

The educational reason for my answer is:

A. hands-on experiences provide concrete understanding
B. schema need to be adjusted so that the principle can be incorporated.
C. students are guided to construct knowledge based upon their experiences.
D. teacher-guided concept construction is essential during each phase.

Comments:

4. The purpose of the <u>**third**</u> phase of the learning cycle is to:
   A. expand the lesson into other science concepts.
   B. extend the previously developed concept in a new context.
   C. Both A and B are legitimate purposes.

The educational reason for my answer is:
   A. this is when connections to new but similar concepts are made providing cognitive linkage between lessons.
   B. new knowledge becomes more useful when applied to new situations.
   C. old concepts must be integrated with new concepts for accommodation to occur.
   D. All of the above are true.

Comments:

5. During the <u>**second**</u> phase of the of the learning cycle:
   A. the teacher explains what happened during the previous phase.
   B. students answer questions in writing to reinforce scientific vocabulary.
   C. data are compared and terms are introduced.

The educational reason for my answer is:
   A. the teacher acts as a guide, but students must be allowed to verbalize the data and terms for meaningful learning to occur.
   B. this is the time traditional instruction plays a role; many labs are complex and the teacher must explain what happened.
   C. vocabulary words are key to learning science and students must practice the concepts after exploring them during the hands-on activity.
   D. the teacher should allow students to freely explore data and terms; teacher intervention is not necessary.

Comments:

6. During the **first** phase of the learning cycle, the teacher should give directions and explain the concepts that the students are investigating.
   A. This is a TRUE statement.
   B. This is a FALSE statement.

The educational reason for my answer is:
   A. students should be told why and what they are investigating so they understand the reason for the activity.
   B. the lesson will not have focus unless the teacher explains the concept they are investigating.
   C. the concept should be derived from the activity because the telling is not as powerful as the actual experience.
   D. the teacher should not introduce the students to the concept but you can tell them the results they should expect.

Comments:

7. Which teaching behavior listed below is appropriate during the **first** phase of the learning cycle?
   A. Explaining the concepts that the student will be investigating.
   B. Describing the procedures the student should use.
   C. Defining the lesson's vocabulary words and giving examples.

The educational reason for my answer is:
   A. students must understand the concept before they can investigate it.
   B. students should be given a brief and simplified definition of the concept to allow a pre-exploration mind set to develop.
   C. lab procedures are given in order to provide guidance about the activity and the data that should be collected.
   D. the intention is for the students to verify redefined vocabulary words in a hands-on setting.

Comments:

8. A major role of the **third** phase of the learning cycle is to:
   A. aid students in exploring new science concepts.
   B. aid students in deepening their understanding of a concept.
   C. Both A and B are appropriate

The educational reason for my answer is:
   A. students may be exploring new concepts at the same time they are reinforcing other concepts in order to help for connections.
   B. for meaningful learning to occur, students must apply previously introduced concepts to new situations.
   C. integration of old and new concepts is essential to promote higher-order learning.
   D. according to learning theory, new concepts are explored to prevent false accommodation.

Comments:

9. During the **second** phase of the learning cycle, the teacher helps with which of the following?
   A. Additional phenomena are discussed and explored.
   B. Students investigate phenomena first hand.
   C. Students report their data to the class and analyze it.

The educational reason for my answer is:
   A. students verbalize what they experience under guidance of the teacher.
   B. the teacher will interpret the data for the students.
   C. the teacher lets the students work individually to construct meaning about the concept.
   D. hands-on activities are essential for those students who have a concrete learning style.

Comments:

10. During the **third** phase of the learning cycle:
A. new concepts are discussed and/or explored.
B. additional phenomena are discussed and/or explored that involve the same concept.
C. data are reported to the class and terms are introduced.

The educational reason for my answer is:
A. new concepts are assimilated during the new activity.
B. slightly different types of activities are used to investigate various concepts.
C. students continue to use the concept under different circumstances.
D. the discussion of data is needed to support the presentation of additional vocabulary.

Comments:

11. During the **first** phase of the learning cycle, the teacher:
A. demonstrates and explains a basic science concept.
B. observes, questions and assists the students as they work.
C. introduces the skills and vocabulary that will be practiced during the activity.

The educational reason for my answer is:
A. the teacher must provide a mental framework for the students before that begin exploring.
B. students must have a sound understanding of a concept before they are presented with the hands-on materials.
C. the teacher's role is to provide help with equipment and may guide students in their collection of data.
D. the teacher has the responsibility of providing the scientific terms when the students are confused.

Comments:

12. During the **first** phase of the learning cycle , the teacher:
   A. is a major informational resource for the students.
   B. facilitates the process of observing and recording data.
   C. keeps the students on-task and manages their behavior.

The educational reason for my answer is:
   A. students must have the important concepts defined at the same time that they are working with materials.
   B. the teacher may provide the data to the students for them to analyze.
   C. students should be provided with the materials from which they are to gather data.
   D. students should be prevented from sharing their ideas with others prematurely.

Comments:

13. Suppose that you were using the learning cycle to teach students about the concept of mass. During the **third** phase of the lesson, an appropriate activity would be to:
   A. extend the concept of mass into the concept of weight.
   B. explore mass with different materials from what were used during the **first** phase.
   C. Both A and B would be appropriate.

The educational reason for my answer is:
   A. during this phase, a new activity is supposed to extend the same concept.
   B. the purpose is to move the student ahead to consider the more abstract concept of weight.
   C. this phase is when existing and emerging concepts are connected for the first time.
   D. both mass and weight should be explored to establish scientific understandings of the relationship between the concepts.

Comments:

Appendix B

Question Protocol for Pre-observation Interview

Question Protocol for Pre-observation Interview

The questioning protocol follows the "tree and branch" model of Rubin and Rubin (1995). Three areas of focus were used for the formation of initial questions. Discussion and follow-up questions will be based on responses elicited from the teachers by the main questions.

Area: Philosophy of Teaching

1. Define teaching for me: in a general way, not specifically science teaching.
2. How has your definition of teaching changed over your teaching career?
3. What have been the influences on your view of teaching?
4. What roles do you occupy as a teacher? *(Prompt if needed - For example, facilitator, disciplinarian, mentor...)*

Area: View of Science

1. What is science?
2. What is (are) the goal(s) of science?
3. Why do we teach science in schools?
4. Respond to the following quote:

"Science is the quest for knowledge, not the knowledge itself."

Area: Learning Cycle

1. In your own terms, define "learning cycle" for me.
2. How does use of a learning cycle approach to science teaching fit with your philosophy of teaching?

3. What are the advantages of using learning cycles for science teaching?

4. What are the disadvantages of using learning cycles for science teaching?

Appendix C

LCTB/VICS

The Learning Cycle Teaching Behaviors Instrument

Exploration
Does the teacher:

YES/NO	BEHAVIOR	VICS
	provide materials from the environment of the classroom for the students to manipulate?	
	provide minimal guidelines such as how to use the equipment without telling the students the concept they are supposed to learn?	
	move from one student group to the next and question the learners to give more directions as needed?	
	interact with students (individuals and laboratory groups) asking questions concerning the meaning of the data being gathered?	

Term Introduction
Does the teacher:

YES/NO	BEHAVIOR	VICS
	ask for qualitative reports of tests from each laboratory group?	
	ask for quantitative reports of tests from each larboratory group?	
	assist students in summarizing information gained from their interaction with the materials used in exploration?	
	use student data to develop the concept?	
	introduce the language of the concept?	

Application
Does the teacher:

YES/NO	BEHAVIOR	VICS
	provide laboratory activities which allow the students to use the concept?	
	use demonstration laboratories to enable the entire class to observe an application of the concept?	
	provide readings and/or audio-visual aides which apply the concept to other situaitons without introducing new concepts?	
	provide questions and/or problem sets to reinforce the concept?	
	continue to use the language of the concept as the concept is expanded and applied by the students?	
	assist students in summarizing information gained from their interaction with the materials (closure)?	

The Verbal Interaction Category System (VICS)

Teacher Initiated Talk

1. **GIVES INFORMATION OR OPINION**: presents content or own ideas,explains, orients, asks rhetorical questions.
2. **GIVES DIRECTIONS**: tells pupils to take some specific action; gives orders, commands.
3. **ASKS NARROW QUESTIONS**: asks drill and factual questions, questions requiring one or two word replies or yes-or-no answers: questions to which the specific nature of the response can be predicted from previous instruction (convergent)
4. **ASKS BROAD QUESTIONS**: asks relatively open-ended questions, questions which are thought provoking. Apt to elicit a longer student response than 3 (divergent).

4b. **ASKS PROBING QUESTIONS**: asks questions of a convergent nature in response to a student's reply to a category 4 question.

Teacher Responses

5. **ACCEPTS (5a)** Affective management - teacher responses which stress the affective content of context of the occurrence.
   ACCEPTS (5b) Behavior management - teacher responses which stress the physical conduct or behavior of the occurrence.
   ACCEPTS (5c) Cognitive management - teacher responses which stress the cognitive content or context of the occurrence.
6. **REJECTS (6a)** Affective management - teachers responses which stress the physical conduct or context of the occurrence.
   REJECTS (6b) Behavior management - teacher responses which stress the physical conduct or behavior of the occurrence.
   REJECTS (6c) Cognitive management - teacher responses which stress the cognitive content or context of the occurrence.

Other

11. **SILENCE**: pauses or short periods of silence during a time of classroom conversation or a busy noise and return to topic.
12. **CONFUSION**: considerable noise which disrupts planned activities. This category may accompany other categories or may totally preclude the use of other categories.
13. **WITHHOLD OR IGNORE**: teacher responses which neither accept nor reject the occurrence.