1993

Concept Circle Diagrams: A Metacognitive Learning Strategy to Enhance Meaningful Learning in the Elementary Science Classroom.

Connie Sue Nobles
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Concept circle diagrams: A metacognitive learning strategy to enhance meaningful learning in the elementary science classroom

Nobles, Connie Sue, Ph.D.
The Louisiana State University and Agricultural and Mechanical Col., 1993
CONCEPT CIRCLE DIAGRAMS:
A METACOGNITIVE LEARNING STRATEGY TO ENHANCE
MEANINGFUL LEARNING IN THE ELEMENTARY SCIENCE CLASSROOM

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Curriculum and Instruction

by

Connie S. Nobles
B.S., Louisiana State University, 1971
M.A., Louisiana State University, 1990
August 1993
DEDICATION

This work is dedicated to my parents, Marjorie N. and Donnis Elton Honeycutt, Sr. Their financial and emotional support during my undergraduate education provided me with the foundation which this work has been built upon. My father's intense desire for all his children to attain a college degree kept me going during my first degree. Memories of his own personal pursuit of a college degree while raising a family and the many hours that he sat at our kitchen table studying while I was growing up have become even more precious to me the past five years. Therefore, to the continued support of my mother and the memory of my father, I dedicate this work.
ACKNOWLEDGEMENTS

In recognition of others’ valuable assistance, I express my deep appreciation and thanks. Numerous professional colleagues, personal friends, and family members supported and encouraged me.

My major professor, Dr. James H. Wandersee, supervised, encouraged, and guided my endeavors from the beginning. Dr. Donna Mealey was always sincerely interested and supported my research as it spanned across the disciplines of science and reading. Dr. Miles Richardson, my minor professor in anthropology, has and will continue to inspire me and provide depth for my professional and personal life. Dr. Gary Winston, my minor professor in science, was a dedicated scientist who never forgot what it was to also be a teacher.

Dr. Bonnie Konopak gave so unselfishly of her time as she guided and motivated me to finish the work I began. Her thought provoking questions helped to shape this research just as her respect for me enriched my experiences. I will always consider these professionals individuals who possess integrity and knowledge as well as educators who cared and believed in me.
Dr. Catherine Cummins and Dr. Deidre Frazier contributed greatly to this work. They were friends who had made a similar journey and frequently reminded me that I too could make it. In addition, the three of us were a team as we studied and analyzed the students' diagrams. The interactions among us as science and reading educators greatly enriched this work.

This research would not have been possible without the graciousness and enthusiasm of Ms. MiMi Weinstein. I want to acknowledge her dedication to teaching and her students as well as to me during this research. Her cooperation and kindness truly made this study possible.

Acknowledgements would be incomplete without expressing my gratitude to my Lord and friend, Jesus. Throughout my years of graduate school his support and my faith in his nature kept my footsteps on this path. The presence of the Spirit of God as she breathed upon me was always gentle reassurance of my direction during this season of my life.

As what has been a recurring pattern, my family is acknowledged last. Everyone in this family has paid a price and has an investment in this research. I thank our children, Tracy and Christopher, who will not fully appreciate this until they too become parents and travel further on their life's journey. Most of all I
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ix</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>x</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>1</td>
</tr>
<tr>
<td>Science Learning</td>
<td>11</td>
</tr>
<tr>
<td>Science Instruction</td>
<td>16</td>
</tr>
<tr>
<td>Metacognition</td>
<td>24</td>
</tr>
<tr>
<td>Metacognitive Strategies</td>
<td>27</td>
</tr>
<tr>
<td>Concept Circle Diagrams</td>
<td>35</td>
</tr>
<tr>
<td>METHOD</td>
<td>39</td>
</tr>
<tr>
<td>Participants and Setting</td>
<td>39</td>
</tr>
<tr>
<td>Materials</td>
<td>41</td>
</tr>
<tr>
<td>Instruction</td>
<td>42</td>
</tr>
<tr>
<td>Assessment</td>
<td>44</td>
</tr>
<tr>
<td>Procedure</td>
<td>45</td>
</tr>
<tr>
<td>Pretesting</td>
<td>46</td>
</tr>
<tr>
<td>Instruction</td>
<td>46</td>
</tr>
<tr>
<td>Posttesting</td>
<td>52</td>
</tr>
<tr>
<td>Scoring</td>
<td>52</td>
</tr>
<tr>
<td>RESULTS</td>
<td>60</td>
</tr>
<tr>
<td>Research Question 1</td>
<td>60</td>
</tr>
<tr>
<td>Concept Identification</td>
<td>61</td>
</tr>
<tr>
<td>Concept Learning</td>
<td>61</td>
</tr>
<tr>
<td>Research Question 2</td>
<td>62</td>
</tr>
<tr>
<td>Direct Explanation</td>
<td>69</td>
</tr>
<tr>
<td>Guided Practice</td>
<td>74</td>
</tr>
<tr>
<td>Independent Practice</td>
<td>81</td>
</tr>
<tr>
<td>Evolution of Individual Participants</td>
<td>84</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>1. Adjusted Means and Standard Deviations of Concept Learning Scores by Group and Level of Question</td>
<td>63</td>
</tr>
<tr>
<td>2. Percentages of Mastery of Technique Checklist Scores by Student Achievement Level, Instructional Sequence, and Concept Circle Diagram Set</td>
<td>64</td>
</tr>
<tr>
<td>3. Percentages of Graphic Complexity Checklist Scores by Student Achievement Level, Instructional Sequence, and Concept Circle Diagram Set</td>
<td>66</td>
</tr>
<tr>
<td>4. Percentages of Conceptual Sophistication Checklist Scores by Student Achievement Level, Instructional Sequence, and Concept Circle Diagram Set</td>
<td>68</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Example of a Vee diagram</td>
<td>30</td>
</tr>
<tr>
<td>2. Example of a concept map</td>
<td>33</td>
</tr>
<tr>
<td>3. Example of a concept circle diagram</td>
<td>36</td>
</tr>
<tr>
<td>4. Mastery of technique checklist</td>
<td>55</td>
</tr>
<tr>
<td>5. Graphic complexity checklist</td>
<td>56</td>
</tr>
<tr>
<td>6. Conceptual sophistication checklist</td>
<td>58</td>
</tr>
<tr>
<td>7. Set 1 diagram constructed by Rachel</td>
<td>70</td>
</tr>
<tr>
<td>8. Set 3 diagram constructed by Sharon</td>
<td>75</td>
</tr>
<tr>
<td>9. Set 3 diagram constructed by Paul</td>
<td>76</td>
</tr>
<tr>
<td>10. Set 3 diagram constructed by Mandy</td>
<td>77</td>
</tr>
<tr>
<td>11. Set 5 diagram constructed by Rachel</td>
<td>82</td>
</tr>
</tbody>
</table>
ABSTRACT

The purpose of this study was to explore the use of concept circle diagrams, a newly developed metacognitive strategy (Wandersee, 1987), for meaningful science learning. Two research questions were: (a) Do concept circle diagrams enhance the identification and learning of science concepts more than traditional learning methods? and (b) Do concept circle diagrams evolve in quality within and across three sequences of direct explanation, guided practice, and independent practice? This study builds upon earlier research on two important metacognitive strategies, Vee diagrams (Gowin, 1981) and concept mapping (Novak & Gowin, 1984), used in science education.

Participants were members of two fifth-grade science classes located at a suburban elementary school in southeastern Louisiana. Based on random assignment, classes were identified as the concept circle diagram (CCD) group and the traditional instruction (TRAD) group. First, all students completed two pretests, (a) identifying science concepts in a text passage, and (b) answering a multiple-choice test on their science unit. Then during an eight-week lesson on light and color, the CCD group constructed five sets of diagrams.
on concepts from science text materials, while the TRAD group completed study guides and participated in group activities. Finally, all students completed the same identification and multiple-choice tests as posttest measures.

Analyses of covariance were used to examine both identification and learning of science concepts measures. While there were no significant differences between groups on identification, the CCD group performed significantly higher on concept learning. In addition, qualitative analyses were used to address the evolution in quality of six students' diagrams. While these students demonstrated improvement on mastery of technique and graphic complexity, only the high achievers improved on conceptual sophistication.

These results provide some support for previous research on the use of metacognitive strategies for meaningful learning. That is, the CCD group may have outscored the TRAD group on the multiple-choice posttest due to their active involvement with this new learning strategy. However, while the two groups performed similarly on the identification measure, this may be due to the unfamiliarity of the text passage used and the task required.
CHAPTER I
INTRODUCTION

As the educational needs and interests of the global community increase, the importance of science education and reforms in this area also increases (Shymansky & Kyle, 1992). Historically, the United States has played a significant role in the advancement of the global community. However, with the launching of Sputnik in 1957 and the rise of the Soviet Union's scientific expertise, the United States sought to regain its leadership role through major changes in science education. One result was the creation and implementation of new science curricula in the 1960s; however, these programs have met with less success than expected. Recent reports still indicate "distressingly low" achievement scores for American students in science (NAEP, 1986).

For reform efforts in the 1990s, Shymansky and Kyle (1992) suggest three important factors for consideration: (a) a new view of curriculum, (b) an emerging consensus regarding the nature of the learner and the process of teaching, and (c) a new image of the role of the teacher. Their assertion stems from research evidence about inappropriate instructional practices and learning demands seen in science
education today. In particular, these practices include: (a) heavy vocabulary/concept demands (Yager, 1983), (b) overreliance on textbooks which are often inconsiderate of students' learning needs (Holliday, 1991), (c) emphasis on factual memorization and recall from the text (Lemke, 1990), and (d) instruction that supports this type of learning and assessment (Novak, 1989).

Science is one content area characterized by heavy demands on vocabulary development. Yager (1983) reported that the emphasis upon terms and definitions as the "primary ingredient of science" (p. 577) for most students was one major contributor to the crisis in science education. In addition, these demands increase as students continue through successive grade levels, as evidenced in K-12 texts. For example, Yager noted that the total number of science words found in elementary texts varied from 352 to 848 in the first grade to 1,643 to 2,746 in the fourth grade. Additionally, Hurd, Robinson, McConnell, and Ross (1981) found that the typical science course in middle/junior high school included 2,500 new and unfamiliar terms. Further, Brandwein (1982) reported that the typical high school chemistry course included in excess of 10,000 specialized terms.
To teach this vocabulary, as well as to present new content information, the primary tool continues to be the textbook. According to Harms and Yager (1981), over 90% of all science teachers use a textbook during 95% of the time allotted for instruction. Furthermore, teachers assign textbook sections on the assumption that they will provide students with much of the information needed for science learning and application (Finley, 1991). However, as many researchers (Davey, 1987; Sigda, 1983) have discovered, science textbooks do not generally reflect the goals of science education or meet the students' learning needs. As Holliday (1991) noted, "Texts are overloaded with verbatim recall questions, inadequate explanations, and irrelevant scientific jargon" (p. 38).

Given the heavy demand for vocabulary acquisition and an overreliance on the use of textbooks, student learning frequently becomes the memorization of words and facts with little attention to making meaningful connections or applications (Yager, 1983). Further, this learning is generally evaluated through literal-level instruments that merely ask the student to recognize or identify information. However, philosophers (Brown, 1979; Kuhn, 1962; Popper, 1982; Toulmin, 1972) have shown the inadequacies of rote memorization and assessment via objective testing.
That is, such measures "do not test students' ability to get beyond memorized words to meanings" (Lemke, 1990, p. 172). Unfortunately, too many students are still spending most of their time memorizing isolated facts without being given the opportunities to reformulate prior knowledge within new contexts (Holliday & McGuire, 1992; Lemke, 1990).

Although educators have recommended teaching science so that students learn new concepts and understand their relationships, class observations have shown that teachers are still product-oriented (Alvermann & Hinchmann, 1991). According to Alexander (1992), the more typical teachers still concentrate on the rote learning of content knowledge, rather than engaging and motivating their students. "The unfortunate reality is that most school instructional practices move children away from meaningful learning and toward essentially rote learning" (Novak, 1989, p. 4). Indeed, Yager (1992) reported that only 10% of teachers are even willing to "abandon their basic textbooks" (p. 907).

Recognizing the problems of vocabulary load, reliance on text, and learning and teaching for rote memorization, science educators have begun to address Shymansky and Kyle's (1992) reform elements. That is, "change begins when people decide to do things
differently" (Lemke, 1990, p. 167). In 1989, the American Association for the Advancement of Science proposed that the central goal of K-12 science education is for students to become scientifically literate. It asserted that to reach this goal, science instruction must involve much more than students' rote learning from textbooks. Consequently, Holliday (1986), Yore (1986), Lemke (1990), and others have been studying approaches which teachers can take to enhance science classroom instruction and to actively involve students in communication with their teachers and texts.

With respect to the present research, the purpose was to explore the use of a metacognitive learning strategy which emphasizes active student interaction with the text for meaningful learning. According to Baker and Brown (1984), there are complex intellectual activities involved in reading and studying content material. These require students to identify relevant information and selectively attend to it, monitor their own comprehension, and then decide on and take corrective action (Baker & Brown, 1984; Brown, 1980). If left to search independently and learn solely from reading, students may have difficulties in decoding scientific texts, understanding important new concepts, and integrating these concepts with relevant knowledge
they have already acquired. Thus, for students to maximize their learning from text, they need to become metacognitively aware of and active in their own learning (Fisher & Lipson, 1986; Johnson, 1985; Osborne & Wittrock, 1983; Wandersee, 1988).

In science education, Ausubel's (1968) research laid a foundation for facilitating students' active learning. In his assimilation theory of cognitive learning, he considered the role of prior knowledge and how students assimilate new conceptual frameworks into their existing ones. Further research by Novak and his colleagues led to the development of concept maps and continued research into their use (Novak, 1977; Novak, 1979; Novak, 1985; Novak & Gowin, 1984; Novak, Gowin, & Johansen, 1983; Starr & Krajcik, 1990). As a metacognitive strategy, concept maps help the learner produce a visual representation of new concepts as well as the hierarchical relationships between them. Thus, this strategy is "soundly based on Ausubelian learning theory and constructivist epistemology" (Wandersee, 1987, p. 11).

Building on this previous research, Wandersee (1987) proposed a new metacognitive strategy, concept circle diagramming. Related to concept maps, its major purpose was to assist students in reading science texts conceptually, rather than merely factually. However,
in contrast to concept maps, students draw concept
circles to indicate their knowledge of hierarchical
relationships, as well as to demonstrate inclusive-
exclusive relationships. Wandersee felt that, for
younger students, this new strategy was (a) a less
demanding introduction to concept learning and (b) an
improved visual representation of inclusive-exclusive
relationships. In addition, he suggested that these
diagrams might assist teachers in identifying students'
conceptual difficulties, facilitate students' learning
from science text, and help to assess students'
knowledge of particular science topics.

Specifically, then, the intention of the present
research was to examine the use of concept circle
diagrams on students' science learning within a regular
classroom context. For the purposes of this study, the
following terms are defined:

**concept** - a pattern or regularity in objects or
events designated by some label (Novak & Gowin, 1984);

**conceptual sophistication** - for the purposes of
this study, an implicit choice of content located in
the title, graphic, and explanation which demonstrates
an understanding of science concepts;

**graphic complexity** - for the purposes of this
study, a set of graphic representations that (a) shows
a range of conceptual relationships, (b) connects
individual diagrams via telescoping, and (c) illustrates via coloring exclusive/inclusive concept relationships;

**instructional sequences** - for the purposes of this study, three sequences for concept circle diagram instruction: (a) **direct explanation**: emphasizing teacher's explanation and modeling of the strategy and constructive feedback on students' diagrams, (b) **guided practice**: emphasizing teacher's review of the strategy and constructive feedback on students' diagrams, and (c) **independent practice**: emphasizing students' construction of diagrams without the teacher's assistance (adapted from Pearson & Gallagher, 1983);

**mastery of technique** - command of concept circle diagram conventions as evidenced by: (a) following rules of circle construction, (b) selecting a title appropriate for the diagram, (c) displaying concepts correctly, (d) writing an explanatory sentence that fits the diagram, (e) coloring the diagram correctly (Wandersee, 1987);

**meaningful learning** - learning new concepts by linking them to existing concepts in a nonarbitrary way, as a result of interaction among student, teacher, and text in order to promote the construction of personal meaning via collaboration (Gowin, 1981);
**metacognitive strategy** - a systematic way of learning how one learns, involving self-monitoring, fostering a quest for meaning, reflecting upon one’s knowledge, and searching for patterns that connect new knowledge to prior knowledge (Novak & Gowin, 1984)

In summary, Chapter I has introduced the importance of a metacognitive strategy to facilitate students' meaningful learning from text. Chapter II develops a theoretical framework to support this strategy, including pertinent research literature and the research questions that guided the study. Chapter III describes the method of comparing the use of concept circle diagram-based instruction with more traditional instruction, as well as examining the evolution of such diagram construction over time. Chapter IV presents the results of this examination, including parametric statistics to compare the two treatment groups and descriptive analyses to trace students' mastery of technique, graphic complexity, and conceptual sophistication with respect to concept circle diagrams. Finally, Chapter V discusses these results, suggests implications for teaching and learning in science education, and makes recommendations for future research.
CHAPTER 2
REVIEW OF LITERATURE

In science education, a primary goal is to engage students in understanding important ideas and solving problems at higher-order levels of thinking and application (Holliday, 1992). However, unless teachers understand the process of engagement and ways to enhance it, students will continue to comprehend without the benefit of consulting with their peers, reading word after boring word, taking indiscriminate notes, and indiscriminately underlining or highlighting all of the bold-type and their definitions, all of the topic sentences, and sometimes practically all of the text with little apparent purpose and understanding. (p.2)

The purpose of the present study was to examine the use of a metacognitive strategy, concept circle diagrams, for facilitating meaningful learning from science text. Its intent was to not only engage students in understanding important ideas but also to assist teachers in monitoring this understanding (Wandersee, 1987). To support this research, this chapter presents literature on (a) science learning, specifically students' alternative conceptions and a constructivist perspective; (b) science instruction, including facilitating conceptual change as well as the nature and function of texts; (c) metacognition, both knowledge of and regulation of cognition;
(d) established metacognitive strategies, specifically Vee diagrams (Gowin, 1981) and concept maps (Novak & Gowin, 1984); and (e) a recently developed metacognitive strategy, concept circle diagrams (Wandersee, 1987), the focus of this study.

Science Learning

Many studies have been conducted in different countries, in different disciplines, and at all educational levels on students' conceptions of natural phenomena (Albert, 1978; Driver & Erickson, 1983; Helm & Novak, 1983; McDermott, 1984; Nussbaum & Novak, 1976). Regardless of the specific area of study (biological, chemistry, earth, or physical science), the results have shown that students hold "a surprisingly wide range of ideas" (Hewson & Hewson, 1988, p. 604), both before and after instruction on a given topic. Further, their ideas not only differ from accepted scientific explanations but frequently are in conflict with them (Smith, Blakeslee, & Anderson, 1993).

Similarly, in their review of research on alternative conceptions in science, Wandersee, Mintzes, and Novak (in press) list eight knowledge claims which were most frequently found in the literature of the past 20 years. These are not considered as "isolated assertions, but as an integrated whole" and emerged
from their review of hundreds of studies in the area of alternative conceptions.

Claim 1: Learners come to formal science instruction with a diverse set of alternative conceptions concerning natural objects and events.

Claim 2: The alternative conceptions that learners bring to formal science instruction cut across age, ability, gender, and cultural boundaries.

Claim 3: Alternative conceptions are tenacious and resistant to extinction by conventional teaching strategies.

Claim 4: Alternative conceptions often parallel explanations of natural phenomena offered by previous generations of scientists and philosophers.

Claim 5: Alternative conceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture and language, as well as in teachers' explanations and instructional materials.

Claim 6: Teachers often subscribe to the same alternative conceptions as their students.

Claim 7: Learners' prior knowledge interacts with knowledge presented in formal instruction, resulting in a diverse set of unintended learning outcomes.

Claim 8: Instructional approaches which facilitate conceptual change can be effective classroom tools.

The cornerstone of this research rests on alternative conceptions and continues to be most intense in the area related to claim number one. Most researchers agree that while the alternative conceptions are diverse across the science disciplines, they are relatively small for a given science topic. The research reveals the remarkable consistency of the alternative conceptions irrespective of gender, age, culture, or ability (Bouwens, 1987; Champagne,
Research has also shown that these views parallel those explanations of scientists from previous generations and remain unaltered by traditional teaching strategies (Clement, 1983; Matthews, 1987; Wandersee, 1986). Often, adults, and thus teachers, hold some of the same alternative conceptions as their students. Even those teachers who hold sophisticated scientific views and present the same in their class instruction may find that learners' prior knowledge affects the outcome of their learning (Ameh, 1987; Bloom, 1989). Thus, traditional methods frequently do not move the learners from their alternative conceptions to more scientific ones; therefore, Claim 8 represents the growing body of research on instruction and strategies which facilitate conceptual change.

However, some science educators and researchers differ in their choices as to the names for students' conflicting views. Some are comfortable with considering these as errors or misconceptions (Clement, 1987; Fisher & Lipson, 1986; Fredette & Lochhead, 1981; Ganiel & Idar, 1985). The term misconception has become associated with a mistaken understanding and carries a negative connotation. However, the term is considered by an increasing majority of science
researchers as contradicting constructivist views of knowledge, as well as "erroneously implies that such ideas have a negative value, serve no cognitive purpose for the learner, and should be quickly eradicated" (Wandersee et al., in press).

Some researchers (Arnaudin, & Mintzes, 1985; Driver, 1981; Gilbert & Swift, 1985) have chosen to call their students’ views alternative conceptions for several reasons. The term itself has a more positive image as it refers to a learner’s explanation for natural phenomena based on their own experiences. It also demonstrates respect for the student's point of view as a position of importance. Once the alternative conception is acknowledged and shared, then the learner’s alternative view may eventually lead her or him to the current scientific conception (Smith et al., 1993).

Although these student responses generally deviate from the accepted scientific point of view, the constructivist perspective recognizes the student’s point of view as one that initially makes sense to that individual (Hewson & Hewson, 1984; Von Glasersfeld, 1984). Constructivists consider the individual and his/her social interaction with others as the basis for conceptual structures. Therefore, "Modern science does not give us truth; it offers a way for us to interpret
events of nature and to cope with the world" (Yager, 1991, p. 54). As individuals, we can only know what we construct ourselves, but much of our learning takes place in a social context, for example, the science classroom.

The science student interacts with new information in an active process of learning. This process does not depend upon the teacher or the text but is based on the learner’s personal knowledge, perception, and experience. The role of language and communication is of utmost importance as the learners share their explanations with others in the science classroom while challenges and negotiations guide the conceptual changes of the members of the class (Yager, 1991).

Therefore, from a constructivist point of view, science vocabulary cannot be memorized or simply transferred from teacher or text to the learner. Nor are there necessarily just right and wrong answers or only one correct answer. Instead, the learner becomes the language user who constructs meanings of words and sentences based upon shared experiences with teacher, text, and other learners. Self-organization and reorganization guide the student in their learning, and knowledge is actively acquired. According to Yager (1991), science teachers who are proponents of
constructivism use some of the following procedures in their classrooms:

1. Accepting and encouraging student initiation of ideas;
2. Seeking out and using student questions and ideas to guide lessons and whole instructional units;
3. Encouraging the use of alternative sources for information both from written materials and experts;
4. Encouraging adequate time for reflection and analysis; respecting and using all ideas that students generate; and
5. Encouraging self-analysis, collection of real evidence to support ideas, and reformulation of ideas in light of new experiences and evidence. (pp. 55-56)

Because students use their own conceptions to interpret and integrate new information, teachers need to explore and challenge their students' existing views of a topic (Driver & Oldham, 1986; Karplus & Stage, 1981). Thus, the teacher can provide instructional activities which consider the student's alternative views and which facilitate the integration of new information. Conceptual change will take time plus meaningful and insightful teacher planning.

Science Instruction

Although science education research is currently focusing on students' meaningful learning, the traditional teaching approach featuring rote learning of isolated facts and vocabulary with correct and incorrect answers still reigns in many science classes (Holliday, 1992). The traditional epistemological
method does not consider the prior knowledge of students nor the interaction of the students with each other, teacher, text, or environment. Students' views should be considered and can be useful both for discovering misunderstandings and constructing new understandings (Nussbaum, 1983; Piaget, 1972; Saltiel & Viennot, 1985). In order to access students' views, the classroom teacher must provide opportunities and encouragement for students to share their understanding in situations prior to formal instruction and assessment or test-taking.

However, meaningful learning is not a simple process and facilitation of it in the classroom must involve instructional changes that encourage and provide for interaction among students, text, and teacher (Gowin, 1981). For several decades, some theorists have emphasized the necessity of considering the individual learner. Ausubel's (1963, 1968) assimilation theory of cognitive learning had the following as its fundamental assumption:

If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly. (Ausubel, 1968, Epigraph)

Learners use their existing knowledge to interpret new incoming information while trying to assimilate all of these messages and organize them into a body of
knowledge which makes sense to the individual learner (Hewson & Hewson, 1988). Because much of science instruction does not consider the prior knowledge of the learner, the development of appropriate teaching strategies is also not considered.

However, when students are given opportunities to construct meaning, they become actively involved in their own learning. Furthermore, these opportunities may include reading, writing, talking, listening, and/or interacting with a physical phenomenon. Regardless of the situation, the learner is actively participating in "making connections between aspects of that situation and his/her prior knowledge (Driver & Oldham, 1986, p. 110). Some science educators have studied and acknowledged the need for active involvement on the part of the learner (Champagne & Klopfer, 1991; Fisher & Lipson, 1986; Novak & Gowin, 1984; Osborne & Wittrock, 1983; Pope & Gilbert, 1983). Still others associate this active involvement directly with the constructivist perspective (Holliday, 1992; Yager, 1991) which not only includes active involvement, but also supports the view that students go beyond the text, applying and extending their (science) learning to the personal lives of each individual student.
Actively involving the student and ascertaining their prior knowledge and conceptions involves the teacher in sharing meaning and communication with the learner (Gowin, 1981). "Many scientific ideas cannot be left for pupils to discover for themselves" (Osborne & Wittrock, 1983, p. 500). However, research has shown that students' conceptions are surprisingly resistant to change (Champagne, Klopfer, & Gunstone, 1983) and supports the same view of Ausubel (1968) concerning the tenacity and resistance to change of children's views. In addition, learners in classrooms often even misinterpret new information so that it conforms to their earlier ideas (Freyberg & Osborne, 1981; Osborne, 1981).

Graphic Organizers. The tenacity and impact of students' prior knowledge on their future learning has also been studied by reading researchers (Alvermann, Smith, & Readence, 1985; Pearson & Johnson, 1978). A specific area which addresses the issue of prior knowledge in reading is the research on graphic organizers. Earle and Barron (1973) defined a graphic organizer as a visual aid which defines related concepts and shows the hierarchical relationships among them.

Readence and Moore (1979) found that graphic organizers worked particularly well in the teaching of
technical vocabulary. They may be used to introduce new information or to reinforce and summarize concepts after reading and discussion have occurred. However, Jonassen and Hawk (1984) found that there were advantages in the use of graphic organizers for immediate but not delayed recall.

Typical graphic organizers include semantic mapping, cognitive webbing, and semantic feature analysis. Studies (Anders, Bos, & Filip, 1984; Carr & Masur-Stewart, 1988; Konopak, 1991) have consistently shown positive results for graphic organizers like these on measures of text-specific comprehension.

Additional review of the research by Moore and Readence (1984) suggested that graphic organizers benefited those students who constructed their own organizers after reading a selection (Barron & Stone, 1974; Barron, 1979). These were also the findings of science education researchers, Novak and Gowin (1984), in their research with concept maps and Vee diagrams which are discussed later in this chapter.

**Conceptual Change.** Considering the learners' involvement in constructing their own knowledge (Magoon, 1977; Resnick, 1983) and personal efforts of interpreting new information so that it makes sense to the individual, some researchers in science education view science learning as a continual process of
conceptual change (Hewson, 1981; Hewson & Hewson, 1984; Posner et al., 1982). "To learn science in a meaningful way means, then, realigning, reorganizing, or replacing existing conceptions to accommodate new ideas" (Smith et al., 1993, p. 112).

In their model of conceptual change, Posner, Strike, Hewson, and Gertzog (1982) suggested four conditions were necessary for an individual's understanding to change and accommodation to occur. These include: (a) dissatisfaction with existing conceptions, (b) minimal understanding of a new conception, (c) plausibility of a new conception to solve problems and fit with other knowledge and experience, and (d) possibilities of the new conception for extension into new areas of inquiry.

Although these conditions do not explain the roles of teachers and students in the classroom, they do reinforce several issues which some current researchers in science education discuss (Driver & Oldham, 1986; Hewson & Hewson, 1988; Smith et al. 1993; Wandersee et al., in press). All agree that in order to successfully engage students in conceptual change, teaching strategies must be implemented which consider the four conditions, provide opportunities for students to express themselves and thus their alternative
conceptions, and recognize that changes in student conceptions require major conceptual reorganization.

**Science Textbooks.** A discussion of conceptual change must of necessity also include consideration of the role of textbooks in the science classroom. Harms and Yager (1981) found that over 90% of the teachers in their study used the textbook 95% of the time when teaching science. Such overreliance leads to an emphasis on the textbook as an unquestionable authority (Yager, 1983).

Recently, Yager (1991) stated that there are still many traditional teachers "who are convinced that the first step to learning science is to learn its special vocabulary--often by rote" (p. 55). Yet from a constructivist viewpoint, he believes that the specialized language of science should not be the source of meaning, but must within itself have meaning for those individuals who are attempting to understand and communicate using the language of science. Similarly, Herber (1978) also made a distinction between a word's definition and meaning believing that a definition is a start, but that meaning is connected with the user.

Finley (1991), a science educator, believes that two major goals of science education--students learning to describe and to explain natural phenomena--are not
met because of a fundamental difference between the nature of science textbooks and these educational goals. Students must frequently construct their own explanations for natural phenomena as well as develop an understanding of the structure of the scientific explanation because the texts have poorly written explanations.

Holliday (1991) also agreed that science texts contain inadequate explanations and irrelevant scientific jargon. But he also included an additional aspect which he describes as troublesome—the overloading of textbooks with verbatim recall questions. These problem areas directly affect students' perceptions of science and often are meaningless tasks.

In addition, Finley (1991) stated that the texts do not provide the proper context for the reader to be able to make sense of the key ideas. His statement that students are then expected to perform "a formidable task" which requires them to set aside their own ideas and accept new ones based on the text's authority is in direct agreement with the claims of Wandersee et al. (in press) and Yager (1991).

Meyer's (1991) study of science textbooks was based on Armbruster and Anderson's (1981) work on content area textbooks in determining characteristics
of considerate texts. Writers of considerate texts take the reader's background knowledge into consideration; arrange ideas in a systematic pattern (e.g., cause/ effect for science text); logically connect the ideas; and avoid irrelevant information. Although the results of Meyer's study on elementary science texts revealed more considerate texts than expected, it also reaffirmed the findings of other studies when it stated that students "cannot be expected to learn difficult science concepts on their own, with little or no teacher direction" (p. 36).

According to Gowin (1981), the sharing of meaning involves students, teachers, and texts. Therefore, any reforms in science education need to include not only the students and teachers but also the textbooks. Smith et al. (1993) reported that typical science texts do not include necessary information or support for teachers who want to teach for conceptual change. Roth (1991) also reported that science textbooks unintentionally reinforce ineffective reading strategies and limit conceptual change.

Metacognition

The results of students' work which reveal alternative views provide the teacher with needed information to involve the learners and the teacher in reflecting upon those areas which require conceptual
change. The ability to reflect on one's own cognitive processes, or metacognition, involves knowledge about cognition. In addition to knowledge or awareness, it also involves the ability to regulate one's own cognition (Baker, 1991; Baker & Brown, 1984).

The inability of some students to realize that a comprehension problem exists is associated with lack of metacognitive skills and is especially absent in poor readers (Bruce & Rubin, 1981; Collins & Smith, 1980; Ryan, 1982). Many learners, and in particular low-ability students, tend to rely on self-developed, rather simple strategies with varying effectiveness (Holliday, Whittaker, & Loose, 1984; Nist, Simpson, Olejnik, & Mealey, 1991; Nolan & Haladyna, 1990).

Furthermore, Baker and Brown (1984) stated that "any attempt to comprehend must involve comprehension monitoring" (p. 344). Wagoner (1983) described this process as "an executive function" and felt that it was essential as readers directed their cognitive processes while striving to make sense of incoming information.

Similarly, Roth's (1986) study with middle school science students resulted in the same conclusion concerning reading comprehension and the challenge students face when confronted with reading assignments. In addition, this study also confirmed the effect that prior knowledge can have on comprehension when it is
incompatible with currently accepted scientific conceptions.

Not only was there no evidence of conceptual change for his poorer readers, but those students who used more sophisticated strategies for linking prior knowledge with information in the text also distorted or ignored the text information. These students were able to complete their assignments and memorize definitions, but they isolated the ideas from the text as book knowledge while holding on to their own conceptions.

Baker (1991) stated that "the primary purpose of providing students with instruction in metacognition is to enable them to take responsibility for their own learning and comprehension activities" (p. 3). However, just as science education research shows that most instruction remains traditional and involves rote learning, reading research reveals that most teachers seldom engage in direct instruction of metacognitive strategies (Durkin, 1984).

Currently, science educators and researchers are promoting instructional methods which encourage the development of independent learners (Ault, 1985; Novak, 1990; Wallace & Mintzes, 1990; Watson, 1983). Although there are mixed views as to the teaching of science process skills (Yager, 1991), several authors believe
that there are close correlations between these skills and those of reading (Carin & Sand, 1985; Carter & Simpson, 1978; Esler & Esler, 1985; Resnick, 1983). Baker (1991) reported that many of the science process skills can be regarded as metacognitive skills.

One area in which all researchers and educators regardless of content emphasis agree is the difficulty which science students have with the textbook. As discussed before there are multiple causes for this difficulty, ranging from heavy vocabulary load to poor text structure. Although not considering the learners' prior knowledge in science content, teachers may also be ignoring problem areas in reading.

**Metacognitive Strategies**

In addition to the two areas of awareness and regulation, metacognitive research in science and reading also focuses upon intervention strategies. These studies have involved the use of different instructional strategies which promote students' expression of knowledge and control over their own reading and learning (Gowin, 1981; Holliday, 1992; Novak & Gowin, 1984; Vacca, Vacca, & Gove, 1991; Wandersee, 1987).

Two metacognitive strategies based upon Ausubel's (1968) and Novak and Gowin's theory of meaningful learning (1984) have been developed by science
educators. These strategies not only consider the students’ prior knowledge but access it through the individual’s construction of either Vee diagrams or concept maps. Both of these strategies foster interaction among the student, teacher, and science text. When constructed by the individual, such diagrams or maps are idiosyncratic representations of each student’s conceptual understanding at the time the graphics were made.

Novak and Gowin began their work based upon Ausubel’s (1968) assimilation theory of cognitive learning. The basic premise is that new concept meanings are acquired through the learner’s assimilation of new information into existing concept and propositional frameworks. Ausubel’s theory also asserts that cognitive structures are organized hierarchically. In addition, most new learning is the result of subsumption of new meanings under the learner’s existing frameworks. The challenge for Novak and Gowin was how to express these frameworks and then how to represent the changes within them.

The definition of a concept used in the construction of either of these diagrams is a regularity in events or objects, or records of events or objects, designated by a label (Gowin, 1981). Propositions are then two concepts linked together and
constitute the units of psychological meaning. Both of these metacognitive strategies are means of assessing the individuals' identification and understanding of those concepts chosen for their diagram (Novak & Gowin, 1984).

**Vee diagrams.** Gowin (1981) developed Vee diagrams which are ideally suited for use with science laboratory instruction, research paper writing, and research design. The student uses a large "V" to graphically represent the process of knowledge production. As noted in Figure 1, this graphic representation has both an epistemological and methodological side with the central investigative question as the base of the large "V". Of the two strategies, this is the most difficult one for students to master.

Alvarez and Risko (1987) used Vee diagrams with third grade students who were studying seed germination. All of the students were successful in constructing their Vee diagrams. Alvarez and Risko (1987) also had the same success with a class of first grade students. In both studies, there were no significant differences between the low and high achieving students on their Vee diagrams.

Ault, Novak, and Gowin (1984) utilized Vee diagrams to analyze their clinical interviews with
Figure 1. Example of a Vee diagram, illustrating a high school biology laboratory investigation of the microscopic organisms in pondwater. (Wandersee, 1990, p. 934--Permission to use granted)
middle school science students. This analysis used the interviewees' language and studied the conceptual structure held by the respondents on molecule concepts. These diagrams were not considered formal products but were part of the process of studying how students constructed meaning on these particular science topics.

Concept Maps. The second metacognitive strategy used by science educators is concept mapping which was developed by Novak and has the larger research base of both strategies. After a 12-year longitudinal study, researchers used concept maps to illustrate the interviews with the same student in the second and twelfth grades. This early work confirmed that children were more limited by experience and instruction than by their own cognitive or developmental capacity as previously indicated in Piaget’s work (Novak, 1977).

Cardemone (1975) and Bogden (1977) prepared concept maps for their college classes and while some students found them useful, others expressed confusion. The primary benefit of these maps were for the teachers who prepared them and thus research began on using concept maps constructed by the students themselves.

Concept maps represent hierarchical organization of concepts chosen by the individual. The individual first identifies the superordinate concepts and then
arranges them from general to specific. Each concept is centered within a circle or ellipse and joined using linking words. As noted in Figure 2, the final map graphically depicts concept relationships as understood by the person constructing the map.

Additional research by Novak (1982) showed that elementary age children were not only capable of constructing concept maps, but they could also intelligently explain their diagrams. Then, Novak, Gowin, and Johansen (1983) studied the use of concept mapping and the vee heuristic with seventh and eighth grade students as they were taught the strategies by their teachers. The major findings included continued improvement of the diagramming skills over the school year. Although there was low correlation between achievement test scores and strategy skills, the strategy students outperformed other students on a problem-solving test. Novak’s work (1985) continued to show concept maps as a significant means of helping students and teachers to learn and teach more meaningfully.

Extensions of this research include multiple grade levels from elementary through graduate college courses and also international studies. Two studies involving the use of concept mapping in teacher education have shown its use in encouraging teachers to learn and
Figure 2. Example of a concept map, illustrating the design of a pencil. (Wandersee, 1990, p. 933—Permission to use granted)
practice more meaningfully (Beyerbach & Smith, 1991; Hoz, Tomer, & Tamir, 1990). Through construction of their own concept maps, teachers emphasized the meanings and relationships of concepts and felt more confident in using this metacognitive tool with their students.

Concept maps have also been used for curriculum development. Posner and Rudnitsky (1986) and Novak and Gowin (1984) suggested the utilization of concept mapping in the development of curriculum. Starr and Krajcik (1990) actually had teachers construct concept maps for this purpose, but in addition stressed revision of maps. With each meeting the teachers continued to revise and then share their maps as the process of curriculum development progressed.

Wandersee et al. (in press) suggested that the strategies which will be most successful in fostering conceptual change will rely on multiple techniques used in a variety of combinations. Concept maps and vee diagrams have been two strategies instrumental in accessing students’ alternative conceptions. They have also been used in conjunction with laboratory activities to externalize and then modify the learner’s knowledge (Taylor, 1985).

Furthermore, because they are constructed by the individual, each diagram is idiosyncratic which
supports the constructivist model of learning (Novak, 1987). A student constructing a Vee or a map must think about concepts and their relationships. The individual interacts with the text as well as works with his/her own prior knowledge. The student is intellectually involved as he/she thinks about his/her own thinking and then organizes what is known into a Vee diagram or a concept map. After sharing this knowledge with the teacher through one of these metacognitive tools, then class discussion and additional activities may lead to reorganization of knowledge and conceptual change.

**Concept Circle Diagrams**

Wandersee (1987) developed *concept circle diagrams*, similar to concept maps, as graphic representations of hierarchically ordered concepts. Concept circle diagrams are easier than concept maps and depict the inclusive and exclusive relationships between five concepts or less. This strategy is also based on Novak and Gowin's theory of meaningful learning and uses the same definition for a concept--a regularity in an object or event, designated by a label (Novak & Gowin, 1984).

As noted in Figure 3, a concept circle diagram includes a title, graphic, and an explanatory sentence. The largest circle represents the general science
The matter in living things recycles—e.g., water, carbon, and nitrogen are not used up.

Most of the world's water (97%) is in the sea or in ice (2%).

Figure 3. Example of a concept circle diagram, illustrating the concept biogeochemical cycles. (Wandersee, 1990, p. 932--Permission to use granted)
concept and is labeled with the name of the concept. More specific concepts are drawn inside the larger circle and relationships may be expressed by overlapping or circle sizing. The diagram may also be colored using contrasting colors for the different circles. However, an uncolored large circle implies that other subordinate concepts exist but are not included in the diagram. Further, diagrams may be connected through a telescoping technique that allows closer examination of a selected subordinate concept.

Hettich (1992) included concept circle diagrams as a learning strategy in his book Learning Skills for College and Career. A basic format called concept circles was also included in Reading and Learning to Read (1991) by Vacca, Vacca and Gove. They suggest simply drawing a circle and putting words or phrases in sections of the circle. Students then engage in conceptual thinking concerning the categorized words inside the circles.

To date, only one research study has examined the use of concept circle diagrams for instructional purposes. In Wandersee and Nobles' (1990) exploratory study, a trained instructor taught sixth-grade and seventh-grade science classes the use of concept circle diagrams twice a week for approximately four weeks. Based on classroom observations and interviews, these
researchers concluded that the students not only mastered the technique but enjoyed using it, particularly the aspects of coloring and telescoping.

Given the enthusiasm and interest expressed by the students, the potential for using concept circle diagrams in the science classroom was recognized. In addition, the two classroom teachers positively commented on the amount of time the students spent in reading and then constructing their diagrams. Therefore, based on the previous research and success with two established metacognitive strategies, the need for additional research with concept circle diagrams was evident.

Therefore, the purpose of this present research was to support and extend Wandersee and Nobles' (1990) work by exploring the use of concept circle diagrams in a fifth-grade science class during an eight-week unit. Specifically, the research questions were:

1. Do concept circle diagrams enhance the identification and learning of science concepts more than traditional learning methods?

2. Do concept circle diagrams evolve in quality (i.e. mastery of technique, graphic complexity, and conceptual sophistication) within and across the three sequences of direct explanation, guided practice, and independent practice?
CHAPTER 3
METHOD

Participants and Setting

The participants selected for this study were members of two fifth-grade science classes located at a suburban elementary school in southeastern Louisiana. The school chosen had approximately 500 students in grades kindergarten through 5. Its population was racially diverse, with approximately 55% white and 45% black students. In addition, approximately 33% of the students participated in the school's free lunch program.

Based on random assignment, two intact classes were identified as the concept circle diagram group, which had 23 students, and the traditional instruction group, which had 22 students. Both classes (a) had nearly equal proportions of females and males; (b) were heterogeneous, ranging from low to high achievement levels; and (c) were representative of the school in terms of racial and socio-economic diversity. The two classes met with the same teacher during 105 minutes per day for science and math instruction, with approximately half the period allocated for each subject. The concept circle diagram group met in the afternoon from 12:45 p.m. to 2:30 p.m.; the traditional
instruction group met in the morning from 9:00 a.m. to 10:45 a.m.

In addition, six students from the concept circle diagram group were selected for indepth analyses of their concept circle diagrams constructed during the experimental period and for informal interviews following administration of the posttests (described below). These included two students from three achievement levels: high, average, and low. The main criterion for selection by the classroom teacher was the students' achievement in science learning that school year; in addition, the teacher attempted to select students representative of the class in terms of gender and racial/ethnic backgrounds. High achievers were (a) Sharon, a black female and (b) Nickie, a white female. Average achievers were (c) Paul, an hispanic male and (d) Rachel, a black female. Low achievers were (e) Mandy, a white female and (f) Doug, a black male.

The science teacher held a bachelor's degree in elementary education, a master's degree in supervision and administration, and an education specialist's certificate in reading and learning disabilities. She had 20 years of teaching experience in grades 3 through 6, with the last 13 years spent teaching grade 5. She
had been a math/science specialist at this elementary
school for 4 years.

This teacher was deliberately chosen from a pool
of 30 elementary teachers who had participated in a
three-year National Science Foundation (NSF) project
preparing mathematics-science specialists, held 1989-
1991 at Louisiana State University. During the summer
of 1990, these teachers were educated in the use of
concept circle diagrams; furthermore, this teacher was
one of five who implemented the strategy voluntarily in
her classes during the following school year.

Materials

The participating teacher included five major
science units for instruction during the school year.
The units were matter, electricity and magnetism, light
and color, earth history, and transportation systems of
the body. Each unit included topics which took
approximately 2 1/2 weeks of class time. These units
and topics are mandated by the state’s curriculum guide
for fifth-grade students, although the instructional
sequence is generally determined by the school and/or
classroom teacher.

For the present study, the science unit focused on
light and color. Within this unit, three topics were
included: (a) refraction and reflection, (b) lenses and
light, and (c) the electromagnetic spectrum. This
sequence of topics was determined by the fifth-grade teacher, thus maintaining ecological validity in curriculum planning.

**Instructional**

**All students.** For this study, students in both the concept circle diagram and the traditional instruction groups received the same expository and laboratory materials but different instructional activities. The expository materials included photocopies made from various science textbooks that were selected by the teacher as appropriate for each topic. In addition, all students received a teacher-generated, typed summary for each topic intended to emphasize the main points addressed in the expository materials. A single textbook is not used by this teacher, because she believes none adequately discusses all of the units and topics mandated by the curriculum guide.

In addition to the expository materials, all students used the same laboratory materials. These included (a) flashlights and dark surfaces (e.g., blackboard) for the refraction and reflection topic, (b) different optical objects such as mirrors and glass for the lenses and light topic, and (c) prisms and flashlights for the electromagnetic spectrum topic.
**Concept circle diagram group.** Instructional materials for the concept circle diagram group included the template specifically designed for construction of concept circles (Wandersee, 1987). This template consisted of a 16 1/2 cm x 21 cm plastic sheet with five holes arranged in descending order of size (8 cm, 6 1/2 cm, 5 1/2 cm, 5 cm, and 3 cm). All students received a template for their individual use throughout the light and color unit.

In addition, a set of overhead transparencies designed by the researcher were used by the teacher to introduce concept circle diagraming as a metacognitive strategy. These transparencies included (a) examples and nonexamples of concepts (e.g., food types), (b) a science text passage on thermometers and an example of a concept circle diagram with accompanying title and explanatory sentence, and (c) a sample diagram on the concept of insects, with the graphic convention of telescoping one subordinate concept, social insects. (See Appendix A.)

**Traditional group.** Instructional materials for the traditional group included study guides for each topic. These guides consisted of fill-in-the-blank and short answer questions that addressed important concepts and supporting details from the expository texts used in class. In addition, this group used a
game format for reviewing each topic; these formats included student-generated questions and competitive teams (e.g., similar to the television game show \textit{Jeopardy}).

\textbf{Assessment}

\textit{All students}. Materials included two separate tests for assessing (a) identification of science concepts, and (b) learning of science concepts. Each test served as both a pretest and posttest. For identification, a text passage on earthquakes was selected from a state-approved science textbook \cite{Hackett1989}. This passage was drawn from the unit on earth history and was selected because students had not yet studied this topic. Students were asked to identify all of the science concepts in the passage by circling them on a copy of the text passage (see Appendix B).

For assessing the students’ learning of science concepts, a test was developed collaboratively by the researcher and teacher that included (a) 10 multiple-choice questions and (b) 2 short-answer questions (see Appendix B). The multiple-choice questions addressed five science concepts drawn from the unit on light and color, while the short-answer questions addressed two science concepts of natural light and artificial light.
The test included two levels of questions: (a) literal understanding and (b) inferential understanding.

A panel of experts, including a science education professor, a reading education instructor with a science education background, and the fifth-grade teacher, was asked to evaluate the multiple-choice questions for content accuracy, literal- and inferential-level distinction, and grade level appropriateness. Based on the panel’s comments, the following changes were made: (a) a drawing of light reflection was substituted for a written description on one of the inferential questions, (b) minor wording changes were made on three inferential questions, and (c) the two short-answer questions were included at the request of the teacher.

**Concept circle diagram group.** Assessment also included evaluating the quality of concept circle diagrams of six students identified a priori by the teacher as representing low, average, and high achievement levels. This diagram evaluation involved issues of (a) mastery of technique, (b) graphic complexity, and (c) conceptual sophistication.

**Procedure**

Data were collected over the 8-week science unit during the second semester of the school year. The unit was divided into three topics, each requiring
approximately 2 1/2 weeks to complete. The classroom teacher administered the pretests and posttests, as well as provided instruction for both groups. The researcher observed the classes, interviewed the teacher and students, and collected artifacts throughout the study.

Pretesting

Both groups were given the two pretests during the week prior to the unit on light and color. The concept identification test was given on one day, while the concept learning test was given on the following day. On the identification test, students were asked to circle all the science concepts in the passage; each group completed the task within 15 minutes. On the learning test, students were asked to select the best answer for each of the 10 multiple-choice questions and to complete the 2 short-answer questions. Both groups completed the task within 20 minutes.

Instruction

Classroom routines were similar during each of the 2 1/2-week instructional sessions. These routines generally included (a) an introduction to the topic, (b) in-class and at-home reading and writing assignments, (c) whole-class discussion, (d) teacher demonstrations, and (e) individual and small group laboratory experiments.
Concept circle diagram group. For this group, the teacher followed an instructional format that included three sequences, each for 2 1/2 weeks. These sequences were (a) direct explanation, (b) guided practice, and (c) independent practice (adapted from Pearson & Gallagher, 1983). These sequences focused on the use of concept circle diagrams: (a) introduction to the strategy, (b) review and guidance in its use, and (c) monitored progress of its application, respectively.

The concept circle diagram group studied the first topic on refraction and reflection within a direct explanation sequence. In the first week, the teacher introduced the notion of concepts and the use of concept circle diagrams for identifying and learning science. Using overhead transparencies, she provided (a) the definition of concept as "a pattern or regularity in objects or events," and (b) examples (e.g., the concept of city) and non-examples (e.g., the instance of Baton Rouge). Then she introduced the use of concept circle diagrams as a way of graphically representing the students' understanding.

With additional transparencies, the teacher explained the three parts of a concept circle diagram and modeled the basic technique of diagram construction. This began with explanations of the different size circles found in a typical diagram and
the relationships among them, followed by illustrations of familiar concepts. For example, a superordinate concept insects was indicated by the largest concept circle, while subordinate concepts such as social insects and bees were indicated by successively smaller circles. In addition, she presented the rules for coloring: (a) using contrasting colors to indicate different concepts (e.g., bees colored red; wasps colored green), and (b) coloring the largest circle only if all possible subordinate concepts are included (e.g., the large circle insects was left uncolored as there are subordinate concepts other than social insects and bees that could have been included).

Having introduced the concept circle diagram technique with familiar concepts, the teacher introduced and discussed the first topic, namely refraction and reflection. The students were given the expository materials to read both in and out of class and then asked to construct their own diagrams in class, choosing any concept from the readings that they wished to represent. The superordinate and subordinate concepts generally chosen were (a) sources of light: man-made and natural, and (b) light and objects: transparent, translucent, and opaque. While the students attempted to construct their diagrams, the
teacher worked with individual students on guiding and improving their construction technique.

In addition to the readings and concept circle diagram construction activities, the teacher performed various demonstrations on reflection and refraction. For example, she held different objects up to a flashlight in order to indicate transparent (e.g., glass), translucent (e.g., wax paper), and opaque (e.g., wood) qualities. In addition, the students performed a laboratory activity using flashlights and dark surfaces in order to study the angle of incidence.

Instruction for the second topic followed a similar routine of introduction, in-class and at-home reading and writing tasks, class discussion, teacher demonstration, and laboratory activities, with a guided practice focus for the strategy. In particular, the students reviewed and used the concept circle diagram technique, as well as added the convention of telescoping from one diagram to another. The students again were able to choose a concept to represent by diagraming; generally, these included (a) lenses and eyesight problems, (b) lenses and parts of the eye, and (c) sources of light, a continuation from the previous topic. As the students practiced developing the three components of a diagram, they also included telescoping, for example, elaborating on the
subordinate concept, parts of the eye, to include retina, pupil, and iris.

In addition, the teacher illustrated the topic of lenses and light by comparing a camera with the human eye to examine the role lenses play in each. During the students' laboratory periods, they used flashlights and plane, concave, and convex mirrors to study the different images produced by each.

The last topic on the electromagnetic spectrum again followed a similar instructional routine. However, the students' construction of concept circle diagrams was accomplished without direct explanation or guidance by the teacher. That is, the teacher assigned concept circle diagrams as part of the normal class procedure, while the students were free to choose a concept and means of representation (i.e., with/without telescoping). During this sequence, the teacher guided the students' use of flashlights and prisms to observe the color spectrum.

The researcher, aided by the reading instructor, gathered descriptive information throughout the 8-week unit to study these instructional and assessment activities within the larger classroom context. This information included: (a) field notes on classroom observations, (b) informal interviews with the teacher and six selected students, (c) teacher-developed
materials such as expository texts, topic tests, and lab activities, and (d) student-generated artifacts such as concept circle diagrams and study guides.

Generally, the researcher attended class twice a week for the entire 105-minute period. While an observer of classroom activities throughout the three instructional sequences, she participated during the first sequence, answering questions and providing feedback to individual students as they attempted to construct their first diagram construction. Further, she conducted informal interviews with the teacher and the six students following the 8-week instructional unit. The reading instructor was an observer only, taking field notes throughout the first two sequences.

Traditional instruction group. The traditional instruction group studied the same three topics, generally using the same classroom routine described above: (a) topic introduction, (b) in-class and at-home assignments, (c) discussion, (d) teacher demonstrations, and (e) individual and small group laboratory experiments. However, instead of using the concept circle diagram templates and practicing the construction of diagrams, they utilized the study guides as a group, and they completed each item as the lessons progressed. In addition, at the end of each topic, the students reviewed the subject matter by
participating in a classroom game show. Thus, while
time-on-task was similar for the two groups, the
traditional group used more familiar activities and
strategies for learning science concepts.

Posttesting

The same procedures and tests were used for
posttesting following completion of the unit. First,
all students took the concept identification test on
the last instructional day; both groups completed the
task within 15 minutes. Then, the students took the
concept learning test on the following day; both groups
completed the task within 20 minutes.

Scoring

Concept identification. Identification of the
science concepts was accomplished in a two-step
procedure. First, a panel of three experts, composed
of a science education professor, a science education
instructor, and the researcher, was given the science
text passage and asked to identify all the science
concepts presented therein. From their separate lists,
seven concepts were identified by all of the experts
and six concepts were identified by at least two of the
experts. Second, these 13 concepts were verified
against the Dictionary of Scientific and Technical
Terms (Parker, 1989); all were present in the
dictionary's corpus. Thus, the final list used for scoring included the experts' 13 science concepts.

The pretests and posttests then were scored by the researcher. For a correct response, a student had to circle a concept identified by the experts. Partial credit was given for a response that contained incomplete phrases or extra terms. Each correct response received 2 points, partial responses 1 point, and incorrect responses a zero.

Concept learning. Each question on the pretest and posttest, including multiple-choice and short-answer, was scored by the researcher as correct or incorrect. Each correct response received 1 point, while each incorrect response received a zero.

Concept circle diagrams. A panel of three experts, including the science education instructor, the reading education instructor, and the researcher, met seven times over a two-month period following data collection in order to evaluate the six students' concept circle diagrams. First, the researcher trained the two instructors on the three scoring procedures. Then, for each of the five sets of diagrams completed, the experts individually reviewed all diagrams and met as a panel to discuss their evaluations. Finally, during the seventh meeting, the panel reviewed the
evolution of each student's diagrams across the five sets.

For mastery of technique, the diagrams were evaluated according to a modification of Wandersee's (1987) assessment checklist, including seven questions applicable to the rules for diagram construction (see Figure 4). Specifically, the evaluator views a diagram and checks Yes indicating that the rule has been followed or No indicating that the student requires further practice. For set 1, diagrams were evaluated only on six questions; coloring was not applicable for that set. For sets 2-5, diagrams were evaluated on all seven questions. Percentage of agreement among the three experts across all diagrams was .95. Instances of disagreement concerned the correct use of title and explanatory sentence during evaluation of sets 1 and 2, as well as coloring during set 2; differences were resolved through discussion.

For graphic complexity, the diagrams were evaluated for concept relationships according to three components (Wandersee, 1987). These included (a) arrangement of circles illustrating multiple relationships, (b) coloring illustrating exclusive/inclusive relationship, and (c) use of telescoping illustrating additional relationships for a selected subordinate concept (see Figure 5). In
### Mastery of Technique

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the title fit the diagram?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Are the concepts displayed in the proper way to show exclusive/inclusive relationships or hierarchy?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Does the explanatory sentence fit the diagram?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Has the student used color to clarify the meaning of the diagram?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Are the concepts the student elected to display important to the learning goals?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Are the concept relationships appropriately shown in the diagram?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Has the student followed circle construction rules?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Mastery of Technique Checklist
**Graphic Complexity**

<table>
<thead>
<tr>
<th>Question</th>
<th>Simple</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the diagram illustrate multiple concept relationships?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Does the coloring illustrate exclusive/inclusive relationships?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Does the telescoping illustrate additional relationships for a selected subordinate concept?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 5. Graphic Complexity Checklist*
contrast to Wandersee’s pre-determined mastery of technique checklist, these three emerged as the data were read.

In assessing graphic complexity, the evaluator views the diagram and indicates a Complex score if the diagram graphically depicts relationships or a Simple score if the diagram does not include these components. Set 1 diagrams were evaluated only on circle arrangement, set 2 diagrams were evaluated only on arrangement and coloring, while sets 3–5 diagrams were evaluated on arrangement, coloring, and telescoping. Percentage of agreement among the experts was .96 on all diagrams. The few instances of disagreement focused on inclusive relationships during evaluations of sets 3 and 4; differences were resolved through discussion.

For assessing conceptual sophistication, the diagrams were evaluated according to the student’s source of concepts as presented in the diagram’s (a) title, (b) graphic, and (c) explanation (see Figure 6). Similar to graphic complexity, these checklist questions also emerged from the data. In assessing conceptual sophistication, the evaluator views the diagram and indicates an Explicit score if the concept was extracted directly from the text materials (lens as concave/convex) or an Implicit score if the concept was the student’s interpretation of the text materials.
Conceptual Sophistication

<table>
<thead>
<tr>
<th>Question</th>
<th>Explicit</th>
<th>Implicit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the source for the title?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. What is the source for the graphic?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. What is the source for the explanation?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6.** Conceptual Sophistication Checklist
(lens as correction for near- or far-sightedness). Percentage of agreement among the experts across all diagrams was .90. Instances of disagreement involved title and explanation during evaluations of sets 1 and 2; differences were resolved through discussion.
CHAPTER 4
RESULTS

To examine the potential use of concept circle diagrams for classroom learning, two research questions were posed: (a) Do concept circle diagrams enhance the identification and learning of science concepts more than traditional learning methods? and (b) Do concept circle diagrams evolve in quality within and across three instructional sequences? Data analysis for research question 1 included inferential statistics to examine differences between treatment groups (Borg & Gall, 1968). Data analysis for research question 2 included descriptive statistics for three evaluation measures, as well as a descriptive analysis to search for patterns within and across students (Miles & Huberman, 1984).

Research Question 1

Based on a quasi-experimental, non-randomized pretest/posttest design, separate analyses of covariance examined differences between the concept circle diagram group (CCD) and the traditional instruction group (TRAD) on concept identification and concept learning tasks. For each analysis, the dependent variable was the posttest score, while the covariate was the pretest score. For the purposes of
this study, only the 39 students who had completed both pretests and posttests were included in the final data analyses (CCD = 18; TRAD = 21).

Concept Identification

A one-way ANCOVA was performed on the concept identification task to assess differences between experimental groups. No statistically significant difference was found, $F(1, 77) = 0.60$, $p<.4451$. Based on adjusted means, the concept circle diagram group ($M = 7.10$, $sd = 3.94$) performed similarly to the traditional instruction group ($M = 8.06$, $sd = 3.58$).

Concept Learning

A two-way ANCOVA was performed on the concept learning task, using a 2 group (CCD/TRAD) x 2 level (literal/inferential) factorial design. A statistically significant main effect was found for the group factor, $F(1, 77) = 5.27$, $p<.0274$. Using adjusted means, the concept circle diagram group ($M = 8.12$, $sd = 1.52$) outperformed the traditional instruction group ($M = 6.61$, $sd = 1.69$). In addition, a statistically significant main effect was found for the level factor, $F(1, 77) = 62.97$, $p<.001$. Again using adjusted means, correct responses on the literal-level questions ($M = 4.72$, $sd = 1.28$) were greater than on the inferential-level questions ($M = 2.65$, $sd = 1.29$). However, the interaction between the two factors was
not statistically significant, $F(1, 77) = 0.04, p<.84$. (See Table 1 for adjusted means and standard deviations.)

Research Question 2

For research question 2, descriptive analyses were used to evaluate five sets of concept circle diagrams that were constructed by the six selected students in that treatment group. Diagram sets 1 and 2 were constructed during the direct explanation sequence, sets 3 and 4 were constructed during the guided practice sequence, while set 5 was constructed during the independent practice sequence.

Analyses first included descriptive statistics for three evaluation measures—mastery of technique, graphic complexity, and conceptual sophistication. Tables 2-4 present percentages of checklist scores for each measure, organized by the three achievement levels, three instructional sequences, and five diagram sets. As noted earlier, the evaluations varied according to diagram set, as not all checklist items were applicable to all sets.

As seen in Table 2, the high achieving students were the most consistent in mastery of technique across all diagrams constructed. The drop from 100% to 79% on the last set paralleled the rise in conceptual sophistication for one student; that is, she chose an
Table 1

**Adjusted Means and Standard Deviations of Concept Learning Scores by Group and Level of Question**

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Literal</th>
<th>Inferential</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCD</td>
<td>18</td>
<td>5.12 (0.92)</td>
<td>3.00 (1.19)</td>
</tr>
<tr>
<td>TRAD</td>
<td>21</td>
<td>4.31 (1.42)</td>
<td>2.30 (1.31)</td>
</tr>
</tbody>
</table>

*Note.* Literal=six points possible; inferential=six points possible.
Table 2

Percentages of Mastery of Technique Checklist Scores by Student Achievement Level, Instructional Sequence, and Concept Circle Diagram Set

<table>
<thead>
<tr>
<th>Level</th>
<th>Direct Explanation</th>
<th>Guided Practice</th>
<th>Independent Practice</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Set 1</td>
<td>Set 2</td>
<td>Set 3</td>
<td>Set 4</td>
</tr>
<tr>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Average</td>
<td>75</td>
<td>86</td>
<td>100</td>
<td>71</td>
</tr>
<tr>
<td>Low</td>
<td>75</td>
<td>93</td>
<td>57</td>
<td>86</td>
</tr>
</tbody>
</table>

Set 1: Percentage=Number of Yes scores received/6 Yes scores possible. (Statement 4: coloring not applicable here.)

Sets 2-5: Percentage=Number of Yes scores received/7 Yes scores possible.
implicit concept to diagram but did not accurately describe it in her title and explanation. In contrast, the average achieving students improved in mastery of technique from set 1 to 3, but dropped on set 4 due to the students' use of propositions, rather than concepts, as labels for subordinate circles. However, on set 5, both students achieved 100% accuracy in their technique.

Finally, while the low achieving students appeared to fluctuate in their scores, there was a consistent pattern. That is, the lower scores on sets 1 and 3 indicated an introduction to a new set of rules within the two instructional sequences. In set 1, the students learned the new technique and improved with practice on set 2; in set 3, the students learned how to telescope and again improved with practice on set 4. The slight drop on set 5 was due to one student's failure to label the major concept.

As seen in Table 3, scores were generally similar across the achievement groups on graphic complexity. On set 1, only one statement was applicable for scoring; none of the students showed relationships among the subordinate concepts within the major circles. On set 2, two statements were used for scoring; while all students colored their diagrams correctly, they did not arrange their circles accurately.
Table 3

Percentages of Graphic Complexity Checklist Scores by Student Achievement Level, Instructional Sequence, and Concept Circle Diagram Set

<table>
<thead>
<tr>
<th>Level</th>
<th>Direct Explanation</th>
<th>Guided Practice</th>
<th>Independent Practice</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Set 1</td>
<td>Set 2</td>
<td>Set 3</td>
<td>Set 4</td>
</tr>
<tr>
<td>High</td>
<td>00</td>
<td>50</td>
<td>67</td>
<td>67</td>
</tr>
<tr>
<td>Average</td>
<td>00</td>
<td>50</td>
<td>67</td>
<td>67</td>
</tr>
<tr>
<td>Low</td>
<td>00</td>
<td>50</td>
<td>17</td>
<td>50</td>
</tr>
</tbody>
</table>

Set 1: Percentage=Complex score received on Statement 1: arrangement of circles. (Statement 2: inclusive/exclusive coloring and statement 3: telescoping not applicable here.)

Set 2: Percentage=Number of Complex scores received/2 Complex scores possible. (Statement 3: telescoping not applicable here.)

Sets 3-5: Percentage=Number of Complex scores received/3 Complex scores possible.
On set 3, all three checklist statements were considered for scoring. Although the high and average achievers were accurate on coloring and telescoping, the low achievers only were correct on telescoping. On set 4, the high and average achievers performed similarly to set 3, while one low achiever was accurate on both telescoping and coloring. On set 5, one high and one average achieving student continued to telescope and color, while their counterparts only colored; the low achieving students only colored their diagrams.

As seen in Table 4, scores generally were low for the students' conceptual sophistication. The high achieving students fluctuated in their scores across sets 1 through 4. This was due to one student's consistent selection of explicit concepts, rather than implicit concepts, for diagram construction. However, on set 5 both students chose implicit concepts, although the second student used an explicit label for the graphic that lowered her overall score.

The average achieving students also showed inconsistent scores across the five sets. This was due to one student who consistently chose explicit concepts, while the second student chose implicit concepts until set 5; on that diagram, he selected an explicit concept, title, and explanation. The low
Table 4

Percentages of Conceptual Sophistication Checklist Scores by Student Achievement Level, Instructional Sequence, and Concept Circle Diagram Set

<table>
<thead>
<tr>
<th>Level</th>
<th>Direct Explanation</th>
<th>Guided Practice</th>
<th>Independent Practice</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Set 1</td>
<td>Set 2</td>
<td>Set 3</td>
<td>Set 4</td>
</tr>
<tr>
<td>High</td>
<td>17</td>
<td>33</td>
<td>00</td>
<td>17</td>
</tr>
<tr>
<td>Average</td>
<td>67</td>
<td>33</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Low</td>
<td>17</td>
<td>00</td>
<td>00</td>
<td>00</td>
</tr>
</tbody>
</table>

Sets 1-5: Percentage = Number of Implicit scores received/3 Implicit scores possible.
achieving students showed the most consistent pattern on sets 1 through 5 as neither student selected implicit concepts; the single exception was on set 1 where a student used an implicit label.

Additional analyses included a descriptive analysis to search for patterns within and across the students on their diagrams as well as through informal interviews. The following presentation is organized around the three instructional sequences and the five sets of concept circle diagrams constructed by the high, average, and low achieving students. The final section presents the evolution of each student’s work across the three sequences.

**Direct Explanation**

Two different sets of diagrams were constructed by the students under this sequence. For set 1, the students constructed diagrams on the concepts of their choice using all the rules from the mastery of technique checklist except for coloring. Figure 7 presents an average achieving student’s first diagram (her final diagram appears in Figure 11). For set 2, they were to include the rules for coloring and they could use the same diagram as set 1.

**Set 1.** According to the diagram evaluations, the high achievers varied in their diagram construction. While Sharon’s major concept, light sources, was
Figure 7. Set 1 diagram constructed by Rachel, an average achieving student.
explicit, her subordinate concepts, *sun, bulbs,* and *lamps,* were original choices. In addition, she wrote three sentences in her explanation which resulted in a thorough and concise description. Based upon her implicit concepts and explanation, her diagram was conceptually sophisticated. In comparison, Nickie's one diagram entitled *kinds of opaque objects* was a simple diagram with explicit concepts from the text. Both of these high achieving students mastered the technique for constructing diagrams.

The two average achieving students also differed in their diagram construction. Rachel's title was *how the spectrum can be seen,* however, because her title and explanation did not match her diagram, she failed to master the technique. On the other hand, Paul completed three separate diagrams on *illuminating objects, movements of light,* and *different artificial light sources.* All were correctly constructed, thus indicating complete mastery of the technique. Further, both students demonstrated conceptual sophistication as they combined the concepts from different pages of text to write their titles and explanations.

Finally, the two low achieving students differed in their construction of diagrams. Mandy constructed a simple yet correct diagram on the major concept *light,* with two subordinated concepts of *manmade light.*
and natural light. Her title, concepts, and explanation were explicit and illustrated no conceptual sophistication. In contrast, Doug constructed a diagram entitled objects that reflects off light that was not correct. That is, his major concept, object, was not content specific, while his explanatory sentence did not match his diagram. In addition, two of his subordinate concepts were explicit, demonstrating no conceptual sophistication; however, his third choice for a subordinate concept, transparent paper, was implicit. Thus, Mandy had mastered the technique, but Doug had not.

In reviewing set 1 diagrams, three observations were made by the research team. First, nearly all students were able to master the technique of constructing diagrams. However, as seen in Table 3, none of the eight diagrams from this first set was graphically complex. Finally, the researchers’ attention was drawn to the use of labels for major concepts which were not content specific; while this was noted only in Doug’s diagram for set 1, they found additional instances in later sets.

Set 2. Both high achieving students chose to reconstruct the same diagrams chosen for set 1 with some changes. That is, Sharon’s title moved from explicit to implicit, thereby increasing her conceptual
sophistication score. Nickie substituted one explicit subordinate concept, brick, for another, TV, which did not change her score. In addition, both students colored their diagrams correctly, improving their graphic complexity scores. Finally, the two students continued to demonstrate mastery of technique.

The two average achieving students differed in their diagram constructions. Rachel chose the same title as her first diagram; however, she used propositions in her subordinate circles rather than her original single labels, thereby lowering her score on mastery of technique. In addition, she colored her diagram correctly, as indicated in her graphic complexity score; further, she retained her implicit title and explanation, again demonstrating conceptual sophistication. Paul constructed two diagrams: artificial light sources, carried from set 1, and some types of light, a new diagram. The first diagram still showed mastery of technique as well as conceptual sophistication; in addition, he demonstrated graphic complexity through his use of coloring. The second diagram also was correctly constructed, as well as used coloring; however, his title, graphic, and explanation were explicit.

Finally, the low achieving students varied in their diagram constructions. Mandy chose a new concept
for this set, transparent objects. She continued to demonstrate mastery of technique, while her new use of coloring was accurate. In contrast, Doug retained the same major concept as used in his first diagram. While he again did not show mastery of technique, he did demonstrate graphic complexity through his use of coloring; however, his graphic changed to explicit, thereby lowering his conceptual sophistication score. Finally, both Mandy and Doug labelled their major concepts without being content specific.

In reviewing set 2 diagrams, the same three observations were made by the research team. First, nearly all students again demonstrated mastery of technique in their diagram constructions. However, all indicated graphic complexity in their correct use of coloring. Finally, the two low achieving students used labels which were not content specific.

**Guided Practice**

There were two sets of diagrams constructed under this sequence. The technique of telescoping was introduced with Set 3 and also used with Set 4. In order to be counted as a completed assignment, the students had to also color their diagrams. The students were free to choose their own concepts including any from the first sequence. As examples, Figure 8, 9, and 10 present Set 3 diagrams for Sharon,
Figure 8. Set 3 diagram constructed by Sharon, a high achieving student.
Figure 9. Set 3 diagram constructed by Paul, an average achieving student.
Figure 10. Set 3 diagram constructed by Mandy, a low achieving student.
a high achieving student, Paul, an average achieving student, and Mandy, a low achieving student.

Set 3. The high achieving students constructed one diagram each. Sharon chose the title of different types of light for her diagram and telescoped from reflected light. Nickie chose the explicit concept of light and telescoped from manmade light giving examples for this one subordinate concept. Both of these students' diagrams illustrated mastery of the technique and graphic complexity, but no conceptual sophistication.

The average achieving students differed in their diagram construction. Rachel chose types of lens as her title and telescoped from the concept concave. Her diagram illustrated mastery of technique and graphic complexity, but was not conceptually sophisticated because of the explicit concepts. Paul constructed a diagram which was double telescoped. He began with the title of kinds of light and telescoped from the subordinate concept natural light. His second diagram was entitled some natural light objects and illustrated the three subordinate concepts of fire, star, and sun. He chose to telescope from the concept fire and titled this third circle some characteristics of fire. The finished diagram showed mastery of technique, graphic complexity, and conceptual sophistication. However,
all three of his largest circles were labelled with concepts which were not content specific.

Both low achieving students had diagrams which were not completed. Mandy had five drafts on the same explicit concepts of concave and convex lens and her diagrams illustrated the degree to which she was thinking about her own knowledge, the relationships of the concepts, and diagram construction. Doug's diagram revealed his confusion between the parts of the eye and convex and concave lens. His explanation also illustrated alternative conceptions about convex and concave lens. Neither of the low achieving students illustrated mastery of technique, graphic complexity, or conceptual sophistication.

In reviewing set 3 diagrams, four observations were made by the research team. First, only the high and average achieving students mastered the technique. An additional observation was that two of the three students who chose new concepts along with the new technique of telescoping were both low achieving students. This probably influenced their lower score in graphic complexity because they may not have had enough time to color their diagrams. A third observation of the team was the decrease in overall conceptual sophistication among all three achievement levels. Finally, one student failed to illustrate his
superordinate concepts with content specific labels, but this time it was an average achieving student.

Set 4. Only Sharon completed a diagram in this set, as Nickie was absent from class the day of the assignment. Sharon’s first diagram was on glass, and she telescoped from opaque using implicit examples which illustrated conceptual sophistication. While her major telescoped label, types, was not content specific, this did not affect her overall score. Her diagram illustrated mastery of technique, graphic complexity, and conceptual sophistication.

Both average achieving students constructed telescoped diagrams. Rachel’s telescoped diagram was titled types of eyesight which showed conceptual sophistication because these concepts were not presented in this manner in the text. Paul constructed his diagram on the concept of light and telescoped from the color of violet. He demonstrated conceptual sophistication from his choice of implicit concepts. However, he incorrectly colored in both major concepts as if they were inclusive when they were not; this lowered his score on graphic complexity.

One low achieving student finished her diagram while the other only partially completed his telescoped diagram. Mandy constructed her one telescoped diagram on artificial and natural light. Her very first
diagram from set 1 had been on these concepts, but she had used the label manmade. Mandy showed mastery of technique, and while her diagram was conceptually simple, it was graphically complex because of the telescoping and her correct coloring. Doug constructed his telescoped diagram on opaque objects. His mistakes included incompletion of the telescoped diagram entitled types of rocks which he did not complete. His choice of concepts for types of rocks included the labels graphic and gravel, revealing some alternative conceptions. Doug again chose labels for the major concept which were not content specific.

Review of set 4 diagrams by the research team resulted in four observations. First, only the high achieving students mastered the technique. Secondly, the low achieving students improved their scores on graphic complexity. Third, the high achieving students had a slight increase in conceptual sophistication. Finally, some students continued to use labels which were not content specific.

**Independent Practice**

During this last sequence the students were again allowed to choose their own topics. They did not have to use the technique of telescoping, but a completed diagram had to be colored. As an example, Figure 11
Figure 11. Set 5 diagram constructed by Rachel, an average achieving student.
presents a diagram by Rachel, an average achieving student.

**Set 5.** Both high achieving students varied again in the construction of their final diagrams. Sharon constructed a diagram which illustrated her mastery of technique and conceptual sophistication. Other than the inclusiveness of the major concept, the diagram was graphically quite simple. In contrast, Nickie chose to telescope her final diagram. Further, she self-corrected her coloring when realizing she had made a mistake. Her diagram was graphically complex and conceptually sophisticated. Her one error was that the title of her telescoped concept, *refracted light*, did not match her diagram label of *refracted objects*.

The two average achieving students constructed two different types of diagrams. Rachel’s last diagram was double telescoped. Her diagram was graphically complex, conceptually sophisticated illustrating the two major concepts of *luminous and illuminated light*, and showed mastery of technique. Paul’s last diagram was graphically simple and his concepts were explicitly from the text. He incorrectly labelled the major concept, *types* when it should have been *mirrors*.

Both low achieving students chose to construct diagrams which were not telescoped. Mandy’s diagram on *colors* illustrated mastery of technique. Doug’s
diagram was on reflected and refracted light. He forgot to label his major concept but otherwise showed mastery of technique. Neither one of these students illustrated conceptual sophistication, but both colored their diagrams correctly and thus were graphically complex in this area.

Three observations were made by the research team as they reviewed the diagrams from the fifth and final set. First, all six students finished their diagrams and scored the highest of all sets on mastery of technique. Next, only two students chose to telescope their diagrams, but all students colored their diagrams. Finally, the high achieving students scored highest in conceptual sophistication, while the average achievers dropped and the low achievers showed none.

Evolution of Individual Participants

Sharon was consistent over time with the construction of her diagrams. From the beginning she exhibited understanding of the techniques and even when new rules were introduced, such as coloring and telescoping, she easily incorporated these into new diagrams. The main feature of Sharon’s diagrams was her thorough and concise explanations.

Nickie consistently chose simple concepts to diagram. Her sentences remained simple while her diagrams improved in clarity over time. Her last
diagram in independent practice was the only one which indicated some conceptual sophistication because of the unique subordinate concepts. She mastered the technique from the beginning.

Rachel consistently chose more difficult concepts to diagram. Her diagrams revealed some alternative conceptions, but each diagram was more progressively complex in graphics and conceptual understanding. Her final work in the independent practice was a double telescope on luminous and illuminated light and beautifully illustrates her progression and mastered understanding of the techniques.

Paul constructed the greatest number of diagrams of all the students. He consistently chose concepts which revealed his understanding of inclusiveness. When the concepts were exclusive, he frequently used the word *some* in his titles and explanations. His diagrams were frequently telescoped, and once he double-telescoped off of one major concept. Due to the consistent graphic complexity and conceptual sophistication of his diagrams, Paul's work often revealed some alternative conceptions. This presentation of a learner's understanding has proven to be one of the strengths of concept circle diagrams.

Mandy chose a variety of simple concepts to diagram. Her work included numerous drafts for several
of her diagrams, showing changes in her attempts to understand and work with the concepts. She correctly used words such as some and just in her titles and explanations. Frequently her sentences were interesting and revealed deeper thoughts. At first her work was poorly colored, but this may have been due to time constraints.

Doug's diagrams consistently revealed alternative conceptions both in mastery of technique and conceptual understanding. Because he was slower to finish than the others, several of his diagrams were not colored. The researcher was aware of the fact that this student had problems understanding inclusiveness. Over time, Doug understood the rules for coloring. His explanations did not always match his diagram. Doug consistently chose labels for his major concepts which were not content specific. His final diagram was conceptually and graphically simple, but there was marked improvement; his only mistake was that he forgot to label the major concept.

Interviews with the six participants revealed that all the students enjoyed constructing the diagrams. All four females said it changed the way they thought about science. When asked what they enjoyed the most, their responses included drawing, coloring, and telescoping. Nickie was the only one who stated that
she tried constructing any diagrams outside of class. Everyone felt that constructing the diagrams was a good way to study science and unlike the way they would have regularly studied. All six students said that if they were given the choice they would continue to use concept circle diagrams.
CHAPTER 5
DISCUSSION, CONCLUSIONS, AND IMPLICATIONS

The present research had two main purposes. First, it sought to examine the use of concept circle diagrams in enhancing fifth graders' identification and learning of science concepts over more traditional methods. In addition, it attempted to examine the evolution in quality of selected students' concept circle diagrams within and across three instructional sequences.

Limitations of the Study

The results of this study are limited in several ways. First, the classroom-based design required the assignment of intact classes, rather than randomization of subjects, to experimental groups. To partially compensate, (a) ability level was accounted for through heterogeneously-grouped classes randomly assigned to treatment conditions, and (b) prior knowledge was accounted for through analyses of covariance, with pretest scores as covariates, when comparing these conditions.

Second, the choice of classroom teacher was deliberate rather than random. As an experienced teacher, she had been trained in the use of concept circle diagrams and had implemented the strategy in her
classroom the previous year. Thus, the selection of this teacher was intended to provide a test of this strategy under optimal conditions. However, all teachers may not be capable of or interested in using this strategy in their instruction.

Third, the design also necessitated researcher decisions regarding content area, length of treatments, instructional and assessment materials, and procedural aspects. Different findings may result given other research decisions. Finally, several participants were not present during the full instructional period, although they were present for the testing sessions and included in the data analyses. Different findings may have been obtained if all participants had attended class each day.

Given these limitations, the results of this study indicate that the use of concept circle diagrams can enhance upper elementary students' science concept learning. In addition, the results suggest that, over time, students' construction of diagrams can evolve in quality. These findings provide initial support for this metacognitive strategy as well as extend previous research on more established strategies, Vee diagrams (Gowin, 1981) and concept mapping (Novak & Gowin, 1984). The following discussion addresses the study's results according to the two research questions, draws
conclusions in terms of classroom instruction, and presents implications for future research in this area.

**Identifying Science Concepts**

As noted in Chapter 2, metacognitive strategies may facilitate students' identification of concepts during their reading. That is, strategies such as concept mapping and concept circle diagrams may enable students to select important concepts as well as to graphically represent their developing understanding (Wandersee, 1987).

However, in the present study, no statistical differences were found between the concept circle diagram and traditional instruction groups on this measure. There may be several reasons for this finding. First, the instrument itself may have been unfamiliar. That is, the text passage used was taken from an actual fifth-grade science textbook to maintain ecological validity. However, these classes were not issued traditional textbooks and so may have been unaccustomed to this format. Additionally, the task itself of circling concepts was one which the students had not been assigned previously.

A second reason may have been the teacher's instructional approach to concept identification. That is, based on observations, the teacher concentrated so intently upon her students' mastering the concept
circle diagram technique that she tended not to provide practice in identifying concepts other than through the diagram.

However, students' ability to identify concepts is an important issue in science learning. In this study, students in both classes tended to circle whole or parts of sentences rather than the science concepts; moreover, this occurred during both the pretest and the posttest. Thus, these students did not attain a clear understanding of the nature of a concept itself. Additional research should be conducted to further examine students' perception and understanding of science concepts, as well as instructional approaches to enhance students' ability to independently recognize important topical concepts.

**Learning Science Concepts**

Metacognitive strategies such as Vee diagrams and concept maps have been shown to facilitate students' meaningful learning from text (Gowin, 1981; Novak, 1984). Building on similar constructivist assumptions, Wandersee (1987) proposed that concept circle diagrams may also promote understanding and learning rather than rote memorization and serve as a vehicle for moving younger/less experienced learners toward mastery of those more sophisticated metacognitive strategies.
In the present study, students using concept circle diagrams learned significantly more science content than students using more traditional methods, as indicated by multiple-choice test results. The adjusted mean of the concept circle diagram group (5.27) shows that they outperformed the traditional group (4.06) on the group factor. This provides some support for the benefits of this metacognitive strategy in enhancing student learning.

There was also a main effect on the level-of-question factor, indicating that both groups performed significantly better on the literal content questions than on the inferential questions. However, as indicated by the lack of significant interactions between the group and the level-of-question factors, the concept circle diagram group did not do statistically better than the traditional instruction group on the inferential questions.

While question asking has long been recognized as a valuable instructional action (Raphael & Gavelek, 1984), most research shows that teachers focus on literal level questions (Gambrell, 1983; Pearson, 1983). In addition, the issue of literal level questions has been researched as it directly relates to science text. Holliday (1991) discussed the impact on student learning of texts overloaded with verbatim
recall questions. These typically appear at the end of chapters and also on tests which accompany these texts.

In the present study, both the teacher's questioning and the text materials' questions tended to be literal. Thus, the influence of the teacher and her assignments, such as answering recall questions, may have influenced the multiple-choice test outcome. However, the concept circle diagram group did outperform the traditional group on the literal-level questions. Such findings indicate that this group did obtain basic science content necessary for further understanding.

Additional research should be conducted to study the use of concept circle diagrams for improving basic, as well as higher-level, thinking of students. Furthermore, this research could address the teacher's own awareness and use of higher-level questioning and strategies to stimulate more meaningful learning.

Students' Use of Concept Circle Diagrams

Based on the five sets of diagrams constructed by the six purposively selected students during the science unit, their concept circle diagrams did evolve in quality within and across the three sequences. In particular, the high and average achieving students improved in the areas of mastery of technique and graphic complexity.
On the other hand, the low achieving students improved somewhat in mastery of technique but continued to struggle with graphic complexity. During their reading, it appeared that this group may have focused on decoding each word, rather than recognizing and understanding relationships among the concepts. This finding is corroborated by reading research which has found that poorer readers have greater difficulties in recognizing and understanding relationships (Baker, 1989; Paris & Jacobs, 1984).

However, all three groups performed differently on conceptual sophistication. The high achievers increased dramatically during the independent sequence, while the average achievers decreased. Further, the lower achieving students demonstrated no conceptual sophistication across the three sequences. Palincsar and Ransom (1988) reported that one part of children's success in learning is their metacognitive knowledge and strategy use. Their research suggested that readers, particularly low achievers, could be helped to improve their metacognitive knowledge and use of strategies.

Additional research is needed to explore the effect of time and teaching of strategies for all learners, but perhaps specifically for the low achiever. One possibility may be to have low achievers
begin with pictorial images rather than words in the construction of their diagrams. Research is needed to see whether or not such representations allow the learner to "see" relationships that word labels mask.

**Whole Class Use of Concept Circle Diagrams**

Based on researcher and reading instructor class observations and teacher and student interviews, the concept circle diagram class appeared to be actively involved in their interaction with text and the construction of diagrams, as well as in negotiation with the teacher on choices of science concepts and relationships. In particular, they seemed to be enthusiastic about their science learning and interested in the concept circle diagram technique. Such findings reflect Gowin's (1981) beliefs that meaningful learning involves active student participation and that meaning making requires student-teacher interactions.

Over the 8-week unit, this researcher observed the concept circle diagram group during instruction and during the students' construction of four of the five sets of diagrams. She consistently noted that the students', teacher, and peer interactions were on-task; also noteworthy was their interest in learning. These views were also expressed by the reading expert of the research team who visited the class several times; her
enthusiasm focused on the students' involvement and on-task behavior for the entire 105 minutes. These findings also dovetail with research by King (1992) who recommends active strategies, rather than passive ones, in promoting metacognition.

Furthermore, the classroom teacher expressed her surprise on more than one occasion about the number of times that students read and interacted with text as they made choices on concept selection and determined relationships. Osborne and Wittrock (1983) reported that the amount of direct experience with concepts had "tremendous influence" on the knowledge readers brought to and carried away from the science text. The teacher also emphasized that the concept circle diagram group outperformed the traditional group on their unit test (which was different from the researcher's test) and that it was directly related to the strategy. In particular, five of the six students whose diagrams were analyzed made As on the unit test, while one low achiever's score was a C.

**Educational Implications**

Roth (1991) states that not only learners but teachers face a big challenge when conceptual change is the emphasis in a science classroom. One way to help promote conceptual change in the science classroom is to encourage students to develop a new goal for reading
science text—that of sense making. The individual constructing a concept circle diagram not only reads the text but must decide on the general and specific concepts to be included, as well as identify the relationships that connect them. A concept circle diagram is therefore a graphic illustration of an individual's progress in making sense of a particular science text.

One of the strong emphases in the areas of constructivism and conceptual change research in science education is eliciting students' prior knowledge and uncovering any alternative conceptions they hold, as well as asking for students' explanations of natural phenomena (Smith, et al., 1993). Fisher and Lipson (1986) argued that one goal of science instruction is to teach students to recognize and go about correcting their own errors and misunderstandings about the natural world.

Throughout this study, the students commented, first verbally and then in writing, about the cognitive decisions they made in constructing their diagrams. Some included reconsideration of conceptual relationships during coloring, when they realized that they should not have colored the large circle. Other diagrams had notes on the back where students shared their own thoughts about choosing key concepts, or
about concepts they forgot to include. For example, Paul, in his set 3 diagram, originally colored in the large superordinate concept circle, thereby indicating an inclusive relationship. However, upon reflection, he realized that there an exclusive, rather than inclusive relationship, and noted that change on his diagram.

Furthermore, construction of concept circle diagrams were documented as having the potential to aid the teacher in assessing her students' conceptions and prior knowledge. That is, the diagrams could indeed provide a diagnostic tool for the teacher to explore and challenge students' existing views. Via the title, explanatory sentence(s), and graphic, the teacher is, in effect, asking for visual and verbal explanations. After evaluation of students' diagrams, the teacher could point out discrepancies, and encourage continued debate and deliberation by her students.

An important finding of this study was the lack of formative evaluation by the teacher herself. Except for offering her guidance during the first two instructional sequences, the teacher did not individually evaluate and return the diagrams to the students. As a result, additional opportunities for discussion and sharing meaning among the student, the teacher, and the text were not realized. Teaching load
and administrative demands may explain why such opportunities were not seized.

**Future Research Implications**

The potential for the improvement of science instruction that concept circle diagrams offer remains virtually untapped and unexplored. Given constructivism as an underlying theoretical basis, the strategy provides a meaningful alternative to more passive modes of learning that rely heavily on rote memorization of text-based content.

Research is needed on how long-term use of this strategy impacts science learning. Collaborative efforts between science education and reading researchers, and classroom science teachers are to be encouraged. The practice of telescoping from one diagram to the next offers teachers a graphic way of integrating science classwork both within and across units via a strategy that students clearly enjoy.

New modes of assessment are needed to capture the gains students make in moving from rote to meaningful science learning. Traditional multiple-choice items may obscure the fine distinctions and connections that students who use concept circle diagraming are able to make. Interviews about diagrams which students have constructed are a powerful way of probing conceptual understanding. This study underscored the potential
that teacher feedback may have on novice concept circle diagrammers. We need studies that examine the effects of systematic feedback on students' completed diagrams in capturing scientific meaning via concept circle diagram construction.

We need studies that extend our understanding of the dimensions of (and relationships between) graphic complexity and conceptual sophistication that this study explored. Just as the mathematics education community recognized the potential of Venn diagrams to enhance deductive reasoning and show relationships between mathematical sets, science educators must recognize and research the role that concept circle diagrams can play in teaching exclusive-inclusive relationships among science concepts and in preparing students to work with more complex metacognitive strategies. As the strengths and prime teaching applications of this strategy come into sharper focus through the results of science education research, we can position concept circle diagraming within the science teacher's pedagogical content knowledge. Lee Shulman would be pleased.
REFERENCES


Roth, K. J. (1986). *Conceptual change learning and student processing of science texts* (Research Series No. 167) East Lansing, MI: Michigan State University, Institute for Research on Teaching.


APPENDIX A

Instructional Materials for
the Concept Circle Diagram Group
Concept

a pattern or regularity in events or objects, designated by a label

food  Is this a pattern or a regularity?

sandwich  Is this a pattern or a regularity?

big mac  Is this a pattern or a regularity?
# Patterns

<table>
<thead>
<tr>
<th>Objects</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>hailstone</td>
<td>precipitation</td>
</tr>
<tr>
<td>rock</td>
<td>erosion</td>
</tr>
<tr>
<td>river</td>
<td>flood</td>
</tr>
</tbody>
</table>

Which of the following are events and which are objects?

- bird
- wind
- hurricane
- flower
- photosynthesis
food
sandwich
hamburger
big mac

Which one of these is a concept?
Which one of these is the strongest concept?
Which one of these is the weakest concept?
Which one of these is not a concept?
locomotion

flying

gliding

flying squirrel

Which one of these is a concept?
Which one of these is the strongest concept?
Which one of these is the weakest concept?
Which one of these is not a concept?
## CONCEPT CIRCLES

**My Name:**

**Score:**

<table>
<thead>
<tr>
<th>Title:</th>
<th></th>
<th></th>
</tr>
</thead>
</table>

**Explanation:**

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Thermometers measure temperature. Look at the three kinds of thermometers people use to measure most temperatures. You might have the kind of thermometer shown to the left at home. This kind of thermometer is a glass tube with a small amount of liquid -- mercury or alcohol -- inside.
CONCEPT CIRCLES

My Name: Score:

Title: Kinds of thermometers

Explanation: Three kinds of thermometers used to measure temperature are mercury, electronic and liquid-crystal.
There are about 800,000 known different kinds of insects (species) of which about 9,000 are social insects.

There are about 4,500 known species of ants, 8,000 of termites, 300 of wasps, and 500 of bees. These are all of the social insects.
APPENDIX B

Assessment Materials
Please read the following paragraphs. Circle only the science concepts in each paragraph.

Earthquakes are more common in some areas of the world than in others. During the 1960s, scientists began to keep records of the locations of the world's earthquakes. Each location where an earthquake occurred was marked on a world map similar to the one in Figure 14-9. Scientists noticed that there was a pattern of earthquake locations. Most earthquakes occurred in narrow zones. Those zones were separated by large areas where almost no earthquakes occurred.

In looking at the earthquake patterns on a world map, scientists noticed they seemed to divide Earth's crust into about nine separate sections. These large sections and several smaller sections of Earth's crust and upper mantle became known as plates. Scientists have developed a theory about Earth movements after studying earthquake locations and other data. The plate tectonics (tek TAHN ihks) theory states that the plates of Earth ride on top of mantle material that is partially melted. The plates may be pushed together, pulled apart, or may slide past one another. The place where plates meet is called a plate boundary (BOWN dree). Three different movements describe the way plates can move at a boundary.

Figure 14-9. Scientists studied world earthquake data before developing the theory of plate tectonics.
Circle the correct answer. Please answer all questions. If you wish to explain your answer, write your comments under the question. If you need more space, write on the back of this paper.

1. A lens that is thicker at its edges and thinner in the center is called a ____________ lens.
   a. plane
   b. convex
   c. multiple
   d. concave

2. Light travels in ____________ lines.
   a. broken
   b. perpendicular
   c. straight
   d. curved

3. Incident light rays strike the surface of frosted glass. Most of the rays are ____________.
   a. transmitted
   b. absorbed
   c. reflected
   d. reflected and scattered

4. A prism separates white light into different colors because ____________.
   a. each color is refracted at a different angle
   b. all of the colors bend at the same angle
   c. some of the colors bend at different angles
   d. only red, orange, and yellow bend at the same angle

5. The image of a flower reflected from a concave mirror ____________.
   a. will be not visible
   b. appears upside down
   c. looks just like the original mirror
   d. appears smaller than the flower
6. A(an) ______________ object does not allow any light to pass through it.
   a. transparent  
   b. translucent  
   c. opaque  
   d. none of the above

7. There are four light sources in a room. Which one would be the hardest to find?
   a. red bulb  
   b. infrared lamp  
   c. green bulb  
   d. white light

8. How would you describe this piece of paper?
   a. white and transparent  
   b. white and opaque  
   c. white and translucent  
   d. white and 100% reflective

9. White light includes the following colors.
   a. green, orange, violet  
   b. ultraviolet, red, yellow  
   c. blue, indigo, gray  
   d. yellow, green, infrared

10. A robber enters a dark alley and shines his flashlight at his intended victim. The victim has a mirror in his hand. Which drawing shows how the victim should hold the mirror to make the light shine into the robber's eyes?

   a.  
   b.  
   c.  
   d.  
11. Give an example of natural light.

12. Give an example of artificial light.
VITA

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DOCTORAL EXAMINATION AND DISSERTATION REPORT

Candidate: Connie S. Nobles
Major Field: Education

Title of Dissertation: Concept Circle Diagrams: A Metacognitive Learning Strategy to Enhance meaningful Learning in the Elementary Science Classroom

Approved:

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Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination: [Signatures]