STUDENTS’ WITH VISUAL IMPAIRMENTS CONCEPTIONS OF CAUSES OF SEASONAL CHANGE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
The Degree of Doctor of Philosophy in the Graduate
School of The Ohio State University

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* * * * *

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ABSTRACT

The purpose of this qualitative study was to understand and describe the misconceptions that may exist among students with visual impairments and instructional techniques that may help them learn scientific concepts of seasonal change. Teachers’ perceptions of student learning were also examined. Data were obtained from students 1 week prior to and 2 weeks after instruction. Students in a comparison group received traditional instruction concerning seasonal change that included textbooks, 3-D models, and lectures. Students in an inquiry-based group received instruction that included student generated models, graphs of temperature data, and 3-D models.

Students who participated in the traditional instruction all exhibited alternative conceptions before instruction. Reasons for seasons included the Earth’s rotation on its axis, a change in distance between the Earth and the Sun, and the Earth’s tilt moving back and forth as it orbited the Sun. After instruction, students in this group all continued to exhibit alternative understandings of seasons. Only one student in this group held a scientific fragment (e.g., Earth orbiting the Sun) within his alternative explanation. The comparison group teacher believed that his students had a scientific understanding of the cause of seasons after completion of the curriculum which did not reflect students’ actual documented learning.
Students who were members of the inquiry-based group also had alternative conceptions before instruction. Reasons for seasons included the Earth’s tilt moving back and forth as it orbited the Sun, a change in the amount of moisture levels in the atmosphere, and the rotation of the Earth on its axis. One student was able to explain that the Earth orbited the Sun, but could not explain how this motion caused seasons. After instruction, students in this group all had scientific understandings of seasons or scientific fragments, and none held alternative understandings. The inquiry-based group teacher believed that her students had a scientific understanding of the causes of seasons upon completion of the curriculum which was reflective of students’ documented learning.
Dedicated to my loving husband, parents, and grandparents
- I made it Papa, I am a Buckeye!
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CHAPTER 1
INTRODUCTION

“A conscious effort must be made, all the time and everywhere and everybody, to acquaint a blind person with those aspects of the environment that cannot be heard, smelled, or easily grasped by hands and fingers. And even those things that can be observed must be pointed out”
Dr. Geerat J. Vermeij, a renowned blind scientist

Astronomy has fascinated people for many years. Early astronomers gazed up at the heavens to observe the various constellations and planets. These same astronomers also studied the sun and reasons for seasonal change in various locations on our planet.

Fascination with astronomy has been carried into written works as well. Children’s literature has provided poetry and stories about the changes that occur during the seasons (Cousins, 2002; Gibbons, 1988; Helferich, 2007). In an effort to address children’s’ questions about astronomical phenomena, literature has also taken on the task of trying to explain why the seasons change (Branley, 1974; Gibbons, 1985).

Despite the available resources to teach students about the causes for seasonal change, research indicates that many misconceptions still exist among members of general society. Empirical research has shown that school aged children, university students, and school teachers have difficulty in fully understanding many astronomical
concepts including seasons. Although understanding tends to improve with age, students and teachers alike still struggle with these important concepts (Atwood & Atwood 1996; Bakas & Mikropoulos, 2003; Bisard, Aron, Fracek, & Nelson 1994; Kikas, 2003, 2004; Roald & Mikalsen 2001; Trumper, 2001a, 2001b, 2006; Zelik & Bisard 2000). Although several studies exist surrounding this issue, research regarding the understanding of students’ with visual impairments understanding of seasonal change does not exist in the research literature. The National Science Education Standards recognizes the problem that students have in learning the scientific reason for seasonal change.

By grades 5-8, students have a clear notion about gravity, the shape of the earth, and the relative positions of the earth, sun, and moon. Nevertheless, more than half of the students will not be able to use these models to explain the phases of the moon, and correct explanations for the seasons will be even more difficult to achieve. (National Research Council [NRC], 1996, p.159).

The Benchmarks for Science Literacy (American Association for the Advancement of Science [AAAS], 1993) introduces concepts of seasonal change during grades 6-8 and indicates the complexity of the topic by stating that:

The cause of the seasons is a subtle combination of global and orbital geometry and of the effects of radiation at different angles. Students can learn part of the story at this grade level, but a complete picture cannot be expected until later (AAAS, 1993, p. 68).

Misconceptions may inhibit student learning in many ways. In an effort to construct scientific knowledge, Duit (1995) reports that students have great difficulty in learning scientific concepts and may only learn partial scientifically accurate viewpoints. The absence of scientifically accurate viewpoints among students may be a reflection of students trying to mix intuitive and scientific views together when developing their own
understanding. According to Duit, students tend to have a strong resistance to adopting new ideas when the students view the old ideas as successful; the students do not feel any need to accept new ideas or to change old beliefs.

Conceptual change provides a theoretical framework that focuses on constructing knowledge in specific areas and describes learning as a reorganization process of existing knowledge (Vosniadou, 2007a; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). The belief systems of students can directly affect their ability to undergo conceptual change (Vosniadou, 2007b; Stathopoulou & Vosniadou, 2007). “Personal epistemology forms initially a narrow but relatively coherent set of beliefs regarding the nature of knowledge and the process of knowing, which is based on the limited range of children’s initial experience and information they receive…” (Stathopoulou & Vosniadou, 2007). As the child has more experiences, the set of beliefs possessed may begin to change, or may become resistant to change. The child begins to connect his/her belief system to different contexts for different uses in different contexts.

Purpose of this study

The purpose of this qualitative study was to understand and to describe the misconceptions that may exist among students with visual impairments and instructional techniques that may help them learn scientific concepts. Teachers’ perceptions of student learning were also examined. Specifically, the study focused on the conceptual understanding of students with visual impairments about seasonal change. Data were obtained from students 1 week prior to and 2 weeks after instruction. The setting of the study included a residential school for the blind in the southeastern United States and a
residential school for the blind in the Midwest. The students in the southeastern residential school received traditional instruction concerning seasonal change that included textbooks, 3-D models, and lectures. Students in the Midwestern residential school received instruction that was inquiry-based to learn seasonal change concepts. The instructional strategies utilized by the inquiry-based group included utilizing student generated models, graphs of temperature data, surveys of fellow students, friends, and family, as well as 3-D models as described in more detail in chapter three.

Rationale for the Study

The need for research-based practices in science education has been addressed by Congress in three pieces of legislation. Congress first addressed the need for educational research in the Goals 2000 legislation. Science education was not specifically mentioned; however, the need for educational research was explicitly expressed. Congress followed the Goals 2000 with the reauthorization of the Elementary and Secondary Education Act in 2001 known as the No Child Left Behind Act (NCLB) in which science educational standards, as well as the need to have better teaching practices within science, were reflected. Following NCLB, Congress passed the Education Science Reform Act which focused primarily on educational research within science education.

The 103rd Congress mandated that educational research needed to be conducted in order to know which methods and processes of learning were best for children in America’s schools. In the Goals 2000 legislation, the following statement was included regarding the need for research:

The Congress finds as follows with respect to improving education in the United States:
A majority of public schools in the United States are failing to prepare students to achieve the National Education Goals. The Federal Government should support an extensive program of educational research, development, dissemination, replication and assistance to identify and support the best responses for the challenges ahead. A significant investment in attaining a deeper understanding of the processes of learning and schooling and developing new ideas holds the best hope of making a substantial difference to the lives of every student in the United States. The Office of Educational Research and Improvement within the Department of Education should be at the center of this campaign in order to coordinate such efforts. (P.L. 103-227)

According to the Department of Education, student achievement scores in scientific literacy are far below the international standards and are not adequate for “…full participation as productive citizens in the 21st Century…” (U.S. Department of Education, 2003). The Department of Education stresses that in order to develop new strategies to keep America safe and prosperous, as well as technologically competitive, attention needs to be shifted back to science education as had been done in the era following the launch of Sputnik. Therefore, mandates were written within NCLB in order to address those concerns. According to the law:

"(a) Purpose.--The purpose of this part is to improve the academic achievement of students in the areas of mathematics and science by encouraging State educational agencies, institutions of higher education, local educational agencies, elementary schools, and secondary schools to participate in programs that--"

"(1) improve and upgrade the status and stature of mathematics and science teaching by encouraging institutions of higher education to assume greater responsibility for improving mathematics and science teacher education through the establishment of a comprehensive, integrated system of recruiting, training, and advising mathematics and science teachers;"

"(2) focus on the education of mathematics and science teachers as a career-long process that continuously stimulates teachers' intellectual growth and upgrades teachers' knowledge and skills"

"(3) bring mathematics and science teachers in elementary schools and secondary schools together with scientists, mathematicians, and engineers to increase the subject matter knowledge of mathematics and science teachers and improve such teachers' teaching skills through the use of sophisticated laboratory equipment and
work space, computing facilities, libraries, and other resources that institutions of
higher education are better able to provide than the elementary schools and
secondary schools;
"(4) develop more rigorous mathematics and science curricula that are aligned
with challenging State and local academic content standards and with the
standards expected for postsecondary study in engineering, mathematics, and
science; and
"(5) improve and expand training of mathematics and science teachers, including
training such teachers in the effective integration of technology into curricula and
instruction.” (P.L. 107-110)

Following NCLB, the Education Science Reform Act of 2002 (P.L. 107-279)
authorized for the creation of a council to research science educational practices. Within
this legislation, the definition for scientifically based research is:

(18) Scientifically based research standards.—
(A) The term "scientifically based research standards" means research
standards that--
(i) apply rigorous, systematic, and objective methodology to obtain reliable and
valid knowledge relevant to education activities and programs; and
(ii) present findings and make claims that are appropriate to and supported by the
methods that have been employed.
(B) The term includes, appropriate to the research being conducted--
(i) employing systematic, empirical methods that draw on observation or
experiment;
(ii) involving data analyses that are adequate to support the general findings;
(iii) relying on measurements or observational methods that provide reliable data;
(iv) making claims of causal relationships only in random assignment experiments
or other designs (to the extent such designs substantially eliminate plausible
competing explanations for the obtained results);
(v) ensuring that studies and methods are presented in sufficient detail and clarity
to allow for replication or, at a minimum, to offer the opportunity to build
systematically on the findings of the research;
(vi) obtaining acceptance by a peer-reviewed journal or approval by a panel of
independent experts through a comparably rigorous, objective, and scientific
review; and
(vii) using research designs and methods appropriate to the research question
posed.
According to the U.S. Department of Education, too many schools have experimented with lessons and materials that were proven to be ineffective (U.S. Department of Education, 2003). Therefore, schools must now use teaching methods that have been researched and have been found to be scientifically based; defined by the Department of Education as providing reliable evidence that a program or practice results in improved student achievement.

Several problems exist in providing teachers of students with visual impairments (TVI) research-based practices that have been proven for students with visual impairments. Visual impairment is labeled as a low incidence disability. The U.S. Department of Education (2004) reported that in 2002 there were 26,030 students with visual impairments in the country. Therefore, obtaining large sample sizes and utilizing traditional quantitative methodologies can be very difficult when researching such small population. Much research within this disability field needs to be conducted in order to find research based methodologies for best practice as required by federal guidelines.

Many manuals exist to explain how to teach students with visual impairments in the area of science (Dion, Hoffman & Matter, 2000; Hadary & Cohen, 1978; Koenig & Holbrook, 2001; Kumar, Ramassamy, & Stefanich, 2001; Willoubhy & Duffy, 1989). However, very little research has been conducted to determine the effectiveness of these curriculum materials. The few research studies that have been conducted concerned adaptations made to specific curricula (Erwin, Perkins, Ayala, Fine, & Rubin, 2001; Linn & Their, 1975; Long, 1973; Struve, Their, Hadary, & Linn, 1975; Waskoskie, 1980).
Within the field of visual impairments, a lack of research presents a barrier to ensuring that researched-based teaching methods are provided for TVIs to use with their students with visual impairments.

Teachers must teach specific standards and benchmarks as outlined in NCLB 2000. In addition, the *National Science Education Standards* recommends that teachers should to teach the astronomical phenomena of seasonal change in grades 6-8. Specifically, Content Standard D states that a student must develop the understanding that:

> The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day. (NRC, 1996, p.161)

The *Benchmarks for Science Literacy* state in Standard B: The Earth, that students must understand the following concept:

> Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in heating of the earth's surface produces the planet's seasons and weather patterns. (AAAA, 1993, p.69)

Learning the concepts related to causes for seasons become a challenge for students. Learning about seasons requires a “complex chain of reasoning” in order to make the leap from observations, such as weather conditions and temperature, to a model that explains this astronomical phenomena (Newman, Morrison, & Torzs, 1993). Students must be able to move from concrete models of the Earth and Sun to being able
to account for the Earth’s tilt translating into differences in the Sun’s rays causing changes in temperature and amount of daylight.

Most sighted students have difficulty understanding this topic as required, but students with visual impairments have a more challenging time understanding scientific phenomena. Frequently students with visual impairments students are left out of critical experiences in the classroom (Beck-Winchatz & Riccobono, in press). In astronomy, the problem is compounded by the reliance of curriculum utilizing visual representations and observations. Typically astronomy has not been accessible to the visually impaired. A recent study conducted by Wild, Paul, and Kurz (2007) reported that students with visual impairments learned astronomy through the use of memorization, internet, audio-descriptions, and tactile diagrams or manipulatives. Only a small percentage, 3.67 percent, actually participated in authentic observations or interactions with astronomers from the community. According to Ikospentaki, Vosniadou, and Irini (2006) students with visual impairments are less likely than sighted children to develop scientifically accurate models of the Earth and relationships of the Earth with the Sun than sighted children.

Not only are there standards for teaching causes of seasonal change, standards for teaching methodologies also exist to inform teachers about preferred strategies. The National Science Education Standards recommend that teachers utilize inquiry-based methodologies in order to teach science. There are nine recommended science process skills for middle school students that help to engage them in inquiry-based learning. These skills are: observing, measuring, classifying, inferring, hypothesizing, participation
in controlled investigations, predicting, explaining, and communicating (Carin, Bass, & Contant, 2005).

However, the ways in which these standards are implemented in the classroom reflect the belief system of the teacher. “To understand teaching from teachers’ perspectives we have to understand the beliefs with which they define their work” (Nespor, 1987, p. 323). Therefore, teacher beliefs must be examined in order to fully understand educator’s thoughts on curriculum standards and pedagogical practices.

Research has shown that science content educators’ beliefs affect the way in which the science curriculum is taught (Levitt, 2001; Roehrig & Kurse, 2005; Tobin & Gallagher, 1987; Tsai, 2002). Specifically, the beliefs a science content educator holds about the nature of science and the teaching and learning of science will determine to a great extent the type of science education a child receives. In a traditional sense, there is heavy emphasis on rote memorization and textbook reading. A teacher who utilizes inquiry based learning approaches provides the students the opportunity to guide their own learning through questions and hands-on explorations (Levitt, 2001; Roehrig & Kruse, 2005; Tsai, 2002). Therefore, it is important to understand the instruction used by the science educator as well as the views of the teacher concerning the instruction and student learning in the classroom.

The field of visual impairments lacks science education teaching supported by research which reflects the NSES standard of inquiry-based teaching and science processes skills. Research in the general field of disabilities seems to indicate that inquiry-based methodologies are beneficial for students. However, no specific mentions
of students with visual impairments were made within the research findings. Research reports in this area tend to focus on students who have disabilities that are of higher incidences than visual impairments.

Mastropieri (2005), reports that students with disabilities benefit from an inquiry-based instructional method in the science curriculum. Inquiry-based instruction techniques are activity-based and can facilitate the efforts of regular education teachers as well as specialists in making appropriate modifications based upon the needs of the student. Student inquiries are made through the use of teacher or student guided questions throughout the lesson. Students are encouraged to develop their own scientific meanings of concepts in real-world situations; reflective of the conceptual change theory methodologies. Inquiry-based instruction has shown to increase student efficacy and decrease student behavior problems since they are focused on interesting learning experiences (Mastropieri, 2005). Mastropieri does not state which students’ disabilities are included in his research findings.

Wild et al. (2007), reported that science teachers utilized inquiry-based methodologies in 61.11% of the classrooms which contained visually impaired students. The study did not analyze whether or not the students with visual impairments were able to participate in the inquiry-based approaches utilized in the classroom. The effectiveness of inquiry-based methodologies has not been reported for students with visual impairments.

In utilizing teaching methodology presented at the 2007 National Federation of the Blind’s Youth Slam, a science camp was specifically designed for blind students and
blind mentors. Students with visual impairments utilized models and experiences in understanding the distance of the Earth from the Sun, the tilt of the Earth, and the rotation of the Earth. In order to gain understanding and provide explanations for seasonal change, inquiry based methodologies were implemented. However, these methodologies have not been empirically tested with students with visual impairments for effectiveness of the instruction.

Empirical research has shown that misconceptions exist among members of general society in regards to causes for seasonal change. However, this research has never examined any misconceptions that may be held by students with visual impairments. In an effort to address these misconceptions, the National Research Council recommends that students in grades 6-8 should be taught about causes for seasonal change while utilizing an inquiry-based approach. Inquiry-based approaches have been found effective for students’ ability to construct scientifically accurate conceptual understanding. However, this approach has not been studied with middle school students who have visual impairments.

The United States Congress has required that science curriculum should be taught based upon standards for educational progress, plus teaching methodologies from authentic, effectual research. No such research exists in the field of visual impairments. Many manuals and recommendations from practicing professionals in the field have been published, but these methodologies are not based on empirical research.

The purpose of this qualitative study was to understand and describe the misconceptions that may exist among students with visual impairments and instructional
techniques that may help them learn scientific concepts. Teachers’ perceptions of student learning were also examined. Specifically, the study focused on the conceptual understanding of students with visual impairments about seasonal change. These components were studied in order to begin to address compliance with mandated researched based best practice policy set forth by the federal government.

Research Questions

The following research questions guided the design of the study and the analysis of the data:

1. What are the representative types of conceptual understandings held by middle school students with visual impairments about the causes of seasonal change?
2. What are the conceptual understandings of middle school students with visual impairments about the cause of seasons before instruction?
3. What are the conceptual understandings of middle school students with visual impairments about the cause of seasons after instruction?
4. What are the conceptual understandings held by middle school students with visual impairments about the cause of seasons before and after instruction within both the comparison and inquiry-based group?
5. How do the conceptual understandings held by middle school students with visual impairments differ between groups from pre-instruction to post-instruction?
6. How do middle school science teachers’ perceptions of students with visual impairments learning compare to students’ documented learning of the causes of seasons?

Significance of the Study

The National Science Education Standards recommends teaching utilizing an inquiry-based approach. The research indicates that inquiry-based methods are effective for students with disabilities (Lynch Taymans, Watson, Ochsendorf, Pyke, & Szesze, 2007; Mastropieri, 2005). However, within each of these studies, students with visual
impairments were not specifically included in the student disability groups that were analyzed. Only one study to determine the effectiveness of inquiry-based methods has been conducted with students with visual impairments (Erwin et al., 2001). Also, missing from these studies was an analysis of teacher’s perceptions of the learning which occurred in their classrooms compared to the actual learning.

Furthermore, the Standards also require that students be taught the reason for seasonal change in the middle school years. However, after an extensive search in the literature, no research was found addressing how students with visual impairments were being taught seasonal change or what misconceptions students with visual impairments had on the topic. Teachers need these research based methodologies required by the mandates of standards-based teaching practices set forth by Congress.

This study addressed both the lack of research in the field of visual impairments and science education while identifying and describing the types of conceptual understandings middle school students as well as identification and description of conceptual understandings of middle school students with visual impairments about seasonal change. This study answered an additional question: How do middle school science teachers’ perceptions of students with visual impairments learning compare to students’ documented learning of the causes of seasons?

Definition of Terms

**Alternative conception** – conceptual understanding that does not agree with scientifically accepted norms (Atwood & Atwood, 1996).
Comparison group - middle school students with visual impairments who are taught causes for seasonal change utilizing textbooks, lectures, and models.

Inquiry – “inquiry is a step beyond "science as a process," in which students learn skills, such as observation, inference, and experimentation. The new vision includes the "processes of science" and requires that students combine processes and scientific conceptual understanding as they use scientific reasoning and critical thinking to develop their understanding of science.” (NRC, 1996, p. 105)

Inquiry Education – Curriculum that is taught in order to allow students to utilize the inquiry-process skills of observing, measuring, classifying, inferring, hypothesizing, controlled investigation, predicting, explaining and communicating (Carin, Bass, & Contant, 2005). Student misconceptions are acknowledged while opportunities are provided in order for the student to construct scientific conceptual understanding in a meaningful way.

Inquiry group – middle school students with visual impairments who are taught causes for seasonal change utilizing an inquiry-based teaching methodology.

Low incidence disability – a disability or impairment that affects a small portion of the population. Visual impairment is considered to be a low incidence disability.
Mental model – construct of the learning that serves to explain phenomena in response to the task at hand; can be both scientifically accurate or misconception (Schnotz & Preub, 1999)

Seasonal change – The astronomical phenomena that causes variances in temperature, sunlight, and life due to the tilt of the Earth’s axis in relation to the orbit around the sun (Jones & Edberg, 1990; Ridpath 1987). This tilt in relation to the orbit results in the Sun’s change in altitude above the horizon during the year. Thus, different places on the Earth receive differing amounts of sunlight throughout the year. The effects of the varying amounts of sunlight result in variance of temperature and daylight as the Sun’s position in the sky varies during each season (Jones & Edberg, 1990).

Teacher of the visually impaired (TVI) – A licensed educator who has been specifically trained and qualified to teach specific skills to students with visual impairments (Corn & Koenig, 2000).

Traditional Education – Teaching methodology that “…presents information in essentially final form” (Trundle, Atwood, Christopher, & Sackes, in review). Reliance is placed heavily upon the utilizing of textbooks and rote memorization for student learning.

Types of conceptual understanding – based on Trundle, Atwood, and Christopher (2002) model: groups of meanings provided for explanation of a scientifically accepted
norm; examples include scientific, scientific fragments, alternative fragments, scientific with alternative fragments, and no understanding.

- **Alternative fragments** – include a subset or subsets of alternative conceptions identified from literature on seasonal change

- **Alternative fragments with a scientific fragment** - Conceptual understanding that contains multiple alternative conceptions and only one scientific concept

- **No Understanding** – exhibit no or irrelevant evidence of understanding seasonal change

- **Scientific Fragments** – include a subset, but not all of the concepts identified as scientific understanding of causes of seasons or scientific reasoning of causes of seasons

- **Scientific understanding of causes of seasons** – Based upon the reasons for seasonal change explained above. Learner must identify:

  1.) The Earth is tilted.
  2.) The Earth moves in an orbit around the Sun.
  3.) The tilt in relation to the orbit results in different places on Earth receives varying amounts of sunlight throughout the year
  4.) This variable in the amount of sunlight results in changes of temperature and daylight (AAAS, 1993; Jones & Edberg, 1990; NRC, 1996; Ridpath, 1987).

- **Scientific with alternative fragments** – dominantly includes a subset of scientific conceptions of causes of seasons with at least one fragments of alternative conceptions
**Visual impairment** – An impairment of the vision that causes a real or perceived disadvantage in performing specific tasks (Corn & Koenig, 2000).

**Organization of the Study**

This study is presented in five chapters:

Chapter 1 contains the introduction of the study, the purpose of the study, rationale of the study, research questions, significance of the study, definition of terms, and organization of the study.

Chapter 2 contains a review of literature and research related to the study.

Chapter 3 contains a description of the research methodology and procedures to be utilized in the study.

Chapter 4 contains the presentation and analysis of the data.

Chapter 5 contains a discussion of the findings, conclusions of the study, limitations of the study, and implications and recommendations for future research.
CHAPTER 2
LITERATURE REVIEW

Introduction

The purpose of this qualitative study was to understand and to describe the misconceptions that possibly existed among students with visual impairments and instructional techniques that could enable them to learn scientific concepts. Teachers’ perceptions of student learning were also examined. Specifically, the study focused on the conceptual understanding of students with visual impairments about seasonal change. Chapter 2, a review of selected and relevant research is divided into eight sections: constructivism, conceptual change research, teacher beliefs, inquiry-based education, teaching methods utilized to teach students with visual impairments about science, scientifically based research methodologies utilized to teach students with visual impairments about science, seasonal change research, and limitations of the research followed by a summary. The seasonal change literature is divided into sections based upon the age of the participants in the study.

Constructivism – Foundation of Conceptual Change

Constructivism is an epistemology that explains how learners make sense of the world around them by examining the interactions between objects and subjects through a series of activities (Somekh & Lewin, 2005). Therefore, knowledge is a human construct
(Duit, Widodo, & Wodzinski, 2007). The objects or phenomena by which the person interacts are “real”, but the observations and the interpretations are affected by the subjective nature of the learner. Knowledge is a result of the learner constructing meaning by connecting existing knowledge, experiences, and conceptualizations (Martin, 2000). The learner is viewed as struggling to impose meaning on their experiences and the world around them (Bell, 1993).

Research involving constructivist epistemologies has shown that learners possess “…skills and attitudes important for learning such as critical thinking, self regulation, cognitive flexibility, the ability to communicate ideas, and to learn from collaboration” (Vosniadou, 2007b, p. 100). In addition to these skills, learners that are aware of their own beliefs possess a deeper understanding of the world around them (Stathopoulou & Vosniadou, 2007). However, if the learners have relied upon rote memorization and superficial experiences that lack a purpose, they are unable to gain a deeper understanding of the world around them.

The role of the constructivist teacher is to induce cognitive disequilibrium (Martin, 2000). The teacher should create an environment in the classroom that encourages students to question beliefs and to ask questions about their world. Students should be encouraged to make predictions about problems in their classroom based upon their prior experiences. When this prediction does not work, students should be encouraged to question their prior beliefs. The teacher should utilize the students’ understandings to help them to reconstruct their beliefs in a valid and meaningful way.
The present study utilized constructivist theoretical perspectives to guide the intervention methodology. Specifically, conceptual change theory which reflects constructivist epistemology was the guiding theoretical framework for creating the intervention methodologies as well as the testing methodologies.

**Conceptual Change Theory**

Conceptual change theory reflects a constructivist epistemology. The theory provides a framework that focuses on constructing knowledge in specific area and describes learning as a reorganization process of existing knowledge to make sense of new knowledge (Vosniadou, 2007a; Vosniadou et al., 2001). Construction of knowledge starts at a young age and is based upon experiences of and interpretations made by the child in everyday situations. This early knowledge can lead to deeply held beliefs about the way the world works. These early beliefs can even continue to be held by adults. By the time a student enters elementary school, the student arrives with many initial concepts about the physical world that may include misconceptions and nonscientific understandings. Students may have a series of very well-defined mental models they use in order to explain various phenomena (Murphy, Alexander, Greene, & Edwards, 2007). Construction of new knowledge is a slow process and involves awareness on the part of the student. The child tends to rely on past representations of knowledge in order to bridge the gap to the newly constructed knowledge (Vosniadou et al., 2001).

The belief systems of students can directly affect their ability to undergo conceptual change (Stathopoulou & Vosniadou, 2007; Vosniadou, 2007b). “Personal epistemology forms initially a narrow but relatively coherent set of beliefs regarding the
nature of knowledge and the process of knowing, which is based on the limited range of children’s initial experience and information they receive…” (Stathopoulou & Vosniadou, 2007). As the child has more experiences, the set of beliefs possessed may begin to change or may become resistant to change. The child begins to connect his/her belief systems to different contexts for different uses in different contexts. Brewer (2008) proposes that students develop naïve theories to form mental representations involving theories and a cognitive interaction in order to provide explanations for phenomena accruing in the natural world. Once a student develops these theories, then a naïve model can develop for which a students create a mental representation that involves not only physical and spatial properties but also a casual and mechanical explanation. It is uncertain what naïve representations of astronomical phenomena students with visual impairments will have of a representation traditional taught and exhibited through visual images. This study examined students’ with visual impairments theories and models of astronomical phenomena in order to learn about their theories and models created both before and after instruction.

Students who have a belief that knowledge is complex, uncertain, and constantly evolving are more willing to provide space to allow for new paradigms and theories to be understood (Vosniadou, 2007b). Students’ beliefs about learning goals, study strategies, and self-regulation all effect their epistemological beliefs. Mason and Gava (2007) found a direct link between students’ epistemological beliefs and the amount of conceptual change students allow to occur. Therefore, this study examined the beliefs of students
before instruction in order to gain understanding of the knowledge the students possess and their ability to undergo conceptual change.

Stella Vosniadou (2001) writes about the link between persuasion and conceptual change to address misconceptions in children. Research has shown that a change in the person’s attitude will often lead to overcoming misconceptions. This change can be accomplished through persuasion. However, conceptual change has been linked to change in the content and structure of the beliefs of a person.

Pintrich (1999), states that motivational beliefs may also become both a constraint and a resource in conceptual change. Pintrich offers five propositions regarding the effect of motivational beliefs. The first proposition is that the “adoption of a mastery goal orientation should facilitate conceptual change” (p. 35). As students develop mastery goal orientation, they are more likely to process information at a much deeper level and therefore increase the probability of conceptual change. The more extrinsic the set of goals are for a student, the less of a chance the student will have deeper levels of understanding. Therefore, extrinsic goals could serve to constrain conceptual change through a limitation of deeper understandings of the materials presented to the student. Teachers need to engage students in authentic activities that could facilitate mastery goal orientation. The second proposition states that “adoption of more “constructivist” epistemological beliefs should facilitate conceptual change (p. 37). This proposition reflects the research of Vosniadou and her colleagues presented above. However, Pintrich adds that the change in epistemological beliefs adds to deeper levels of cognition as well as conceptual change. The third proposition of Pintrich’s states that “Embracing higher
levels of personal importance, value, and interest should facilitate conceptual change” (p. 40). Personal importance and value beliefs of the student are self-generated and interact with learning by increasing the level of attention, persistence, and activation of the knowledge; thus resulting in higher levels of conceptual change. However, if a classroom does not include these motivational features of personal importance, value, and interest on the part of the student, conceptual change opportunities will diminish as the student is not interested enough to focus on the new knowledge. The fourth proposition, “Adoption of higher levels of self-efficacy for learning should facilitate conceptual change” is based upon the self-efficacy research of Bandura (p. 42). Self-efficacy is a construct that describes a students’ level of confidence in the ability to do a new task. Therefore, if the student is confident that learning can occur, a conceptual change may be more likely to occur. The higher levels of confidence the student possesses can translate into a capacity to change their ideas and utilize cognitive tools to integrate and synthesize new ideas. The last proposition states that “Adoption of a belief in personal control of learning should facilitate conceptual change” (p. 44). The levels of beliefs students possess concerning their learning could have an effect on the level of accommodation of new information. If the learner does not view themselves as being in control over their learning, they might be less willing to resolve discrepancies between their prior knowledge and the new information presented in the classroom. Therefore, a student’s ability to engage in conceptual change may be hindered in the process.

Conceptual change within the classroom needs to reflect not only the ability of the teacher to attend to the epistemological beliefs and motivational beliefs of the student, but
also to the way in which curriculum is presented. According to Vosniadou (2001), three specific factors can influence a child’s ability to change misconceptions and develop a scientific understanding. The first factor involves comprehensibility, clarity, and credibility of arguments found in the textbooks of children can help make persuasive arguments and lead to conceptual change (Vosniadou, 2001). Secondly, young children’s beliefs also need to be addressed so that they can make a connection to change. And third, research has also shown that the more motivated students are to learn, the more likely students will change their misconceptions.

Vosniadou and her colleagues contended that a teacher must realize that there are stages to learning each concept (Vosniadou et al., 2001). Progressing through previous stages influences the success of learning new concepts in the next stage of scientific understanding. In helping students to construct a scientific understanding, there are things that a teacher can do in order to help students. First, the teacher should help the students to construct their own meanings of scientific concepts and help the students to become aware that they are doing so; motivation is a key factor in conceptual change. Second, the learning should be based in real-world situations to help students make a connection to the concept being studied. Third, teachers need to know how their children learn science. Teachers must interact with their students and learn the cultural and social factors contributing to their students misconceptions. Last, teachers must encourage students to work together, to help each other reorganize their thoughts, and to engage in activities with others that will help to formulate scientific ideas (Vosniadou et al., 2001).
Duit (2003) asserts that research on conceptual change has been difficult to conduct in the classroom. Previous research has been focused on pre-arranged scenarios presenting limitations within the research approaches. These limitations include the differences between cognitive development and the understanding of scientific principles and concepts. The research needs to take into consideration the environmental effects of where the research is conducted as well as the cultural and social influences of the environment. Researchers also need to be aware of the motivational factors influencing the student. The philosophies of the learner should be analyzed when researching conceptual change because the philosophies may have an effect on the student’s ability to understand models.

Research utilizing conceptual change may contribute to the educational practices of teacher’s more than traditional forms of instruction (Duit, 2003). Therefore, research utilizing conceptual change theory will be beneficial for TVIs to influence their teaching of astronomical phenomena to students with visual impairments more so than traditional forms of instruction as reported by Wild et al. (2007).

Teacher Beliefs

“To understand teaching from teachers’ perspectives we have to understand the beliefs with which they define their work” (Nespor, 1987, p. 323). Therefore, teacher beliefs must be examined in order to fully understand the willingness of a teacher to collaborate as well as to understand educator’s thoughts on curriculum standards, pedagogical practices, inclusion, and assessment. Pajaras (1992) reported that teacher beliefs are personal and unaffected by persuasion. The beliefs can be formed through
chance encounters, an intense experience, and a series of events. Beliefs include ideas about the person and about what others are like. Presumptions are entities that exist beyond the control or knowledge of the individual and are believed by the individual because they are present.

Beliefs have a strong effect on teachers (Pajaras, 1992). Teachers often teach materials and courses that reflect the values with which the teacher holds concerning the content area (Nespor, 1987). This in turn reflects the energy expended on an activity as well as the manner in which the teacher will expend their energy in the classroom.

Beliefs do not require a group consensus (Pajaras, 1992). The teacher does not need to have validity or appropriateness associated with beliefs held. Beliefs do not require internal consistency either. The inconsistent nature of the internal belief system reflects the disputable and inflexible nature of the beliefs.

Beliefs of teachers ultimately affect their views of education. According to Levitt (2001, p. 2), “Educational beliefs include beliefs about students and the learning process, about teachers and teaching, about the nature of knowledge, about the roles of schools in society, and about the curriculum.” Teachers hold beliefs about their own work and subject matter in which they teach. Research has shown that science content educators’ beliefs affect the way in which the science curriculum is taught (Levitt, 2001; Roehrig & Kurse, 2005; Tobin & Gallagher, 1987; Tsai, 2002). Specifically, the beliefs a science content educator holds about the nature of science and the teaching and learning of science will determine to a great extent the type of science education a child receives, whether in a traditional sense with a heavy emphasis on rote memorization and textbook
reading or whether a teacher utilizes inquiry based learning approaches entailing hands-on experiences for the students (Levitt, 2001; Roehrig & Kruse, 2005; Tsai, 2002).

Therefore, the beliefs held by TVIs have an impact on the way in which they view their students’ access to science curriculum. These beliefs also influence the ways in which they present the curriculum to their students, the amount of time and energy expended on lessons, as well as assess student learning. This study accessed the perceptions of the comparison group teacher and the inquiry-based teacher in order to access their perceptions of student learning and teaching methodologies utilized in their classrooms. These perceptions were compared to documented student learning science content related to the cause for seasons.

Inquiry-Based Education

Inquiry-based education in science allows a student to engage in scientific activities much like a scientist. Students utilize thinking processes similar to how a scientist would begin to examine the natural world. The National Research Council defines inquiry as:

Inquiry refers to diverse ways in which scientists study the natural world and propose explanations based on the evidence…It refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (NRC, 1996, p.2)

Inquiry education refers to not only science content, but also a way in which to learn and understand science.

Understandings of science inquiry represent how and why scientific knowledge changes in response to new evidence, logical analysis and modified explanations debated within a community of scientists. (NRC, 2000, p. 21)
According to Carin et al. (2005) there are process skills for conducting inquiry-based investigations. There are 9 skills emphasized for use in middle school classrooms. They are: observing, measuring, classifying, inferring, hypothesizing, controlled investigation, predicting, explaining and communicating. They are outlined in Table 2.1. Observing is the process of gathering information using all of your appropriate senses. For example, a student may look outside and gather information about the weather or smell plants growing. As students develop observation skills, they tend to focus on similarities and differences while paying attention to details as well (Carin, et al., 2005).
<table>
<thead>
<tr>
<th>Process of Science</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observing</td>
<td>Gather information using all appropriate senses and instruments that extend the senses.</td>
</tr>
<tr>
<td>Measuring</td>
<td>Quantify variable using a variety of instruments and standard and nonstandard units.</td>
</tr>
<tr>
<td>Classifying</td>
<td>Group objects or organisms according to one or more common properties.</td>
</tr>
<tr>
<td>Inferring</td>
<td>Draw a tentative conclusion about observations based on prior knowledge.</td>
</tr>
<tr>
<td>Hypothesizing</td>
<td>Make a statement about a possible relationship in the natural world that might be found through investigation.</td>
</tr>
<tr>
<td>Controlled</td>
<td>Investigate by deliberately manipulating one variable at a time and observing the effect on a responding variable, while holding all other variables constant.</td>
</tr>
<tr>
<td>Investigation</td>
<td></td>
</tr>
<tr>
<td>Predicting</td>
<td>Make a forecast of a possible outcome of an investigation based on known patterns in data.</td>
</tr>
<tr>
<td>Explaining</td>
<td>Logically link evidence and scientific knowledge to make sense of puzzling events.</td>
</tr>
<tr>
<td>Communicating</td>
<td>Record and present the results of investigations to others in multiple ways.</td>
</tr>
</tbody>
</table>

Table 2.1: Process Skills of Inquiry Learning for Middle School Students (from Carin et al., (2005))

Measuring is the next process skill for completing a scientific investigation. Measuring often refers to quantifying an observation. This can be done utilizing thermometers, rulers, balances, timers, measuring cups, cylinders, or any other type of measuring device the student wishes to explore. Accurate measurements lead to an
enhanced description already produced by the child and can help the student to create a quality prediction or hypothesis; another process skill. (Carin, et al., 2005)

Classification is another important science process skill that helps to organize information. There are two classification systems typically utilized in the elementary and middle school science classrooms. The first is binary classification where students are asked to divide objects into two groups based upon similar properties. However students may also engage in multistage classification systems where objects are sorted based upon similar properties multiple times until a hierarchy of sets and subsets are formed. Classification of objects helps students to gain an understanding about the properties and functions of objects in their environment (Carin, et al., 2005).

Once multiple observations about objects are made, an inference can be completed by the student. An inference is an interpretation made by the student based upon prior knowledge and experiences. Students should be asked to make explicit their inferences based upon observations, measurements, concepts and assumptions (Carin, et al., 2005).

Hypothesizing naturally follows the inference process. The hypothesis is the statement that the student communicates about a possible relationship that might occur between the natural world and the investigations he is about to undertake. Students should communicate this statement in either a written or verbal form.

Once the predications are made, a controlled investigation can follow. These investigations can be driven by the student’s curiosity and ingenuity, or can be planned by the teacher depending on the ability level of the student. The controlled investigation
is conducted by deliberately manipulating one variable at a time and observing the effect on other variable in the experiment while holding them constant (Carin, et al., 2005). For example, a student may examine the effects of light on plant growth. The student may use the same plant, amount of water, soil, pots, and place them all in the same environmental space. However, the student would manipulate the amount of light each plant receives by covering and uncovering plants at a variety of time interval. Each plant would be exposed to light at different time intervals.

While working in the controlled investigation, a prediction can be made by the student. The student is encouraged to look at the data and make a guess of the outcome based upon patterns in the data. This allows students to learn about the importance of using evidence to support their predictions. The evidence, or data, should be represented in a variety of ways such as through graphs, recorded calculations, pictures, etc (Carin, et al., 2005).

Upon completion of the investigation, explanations can be made. In order to practice this skill, students should be encouraged to logically link the evidence collected in the investigation to scientific phenomena. For example, utilizing the plant investigation described above, students should be encouraged to explain why plants do not grow as vivaciously in the winter as in the summer. Students can also explain the particular amounts of sunlight required to grow their plants.

Finally, students need to communicate their learning. This can be done in multiple ways. Students may take an assessment, create a poster, complete a presentation, etc. Teachers should take into account the ability level of the student.
Research utilizing inquiry-based instruction has been found to be beneficial to students with disabilities. Lynch et al. (2007) found that inquiry-based instructional techniques were beneficial for students with disabilities. Similarly, Mastropieri (2005) found that students with disabilities benefit from an inquiry-based instructional method in the science curriculum. Inquiry-based instruction techniques can facilitate the efforts of regular education teachers as well as specialists in making appropriate modifications based upon the needs of the student. Less behavior problems tend to result from the use of this teaching process.

Wild et al. (2007), reported that science teachers utilized inquiry-based methodologies in 61.11% of the classrooms which contained visually impaired students. The study did not analyze if the students with visual impairments were able to participate in the inquiry-based approaches utilized in the classroom. The effectiveness of inquiry-based methodologies has not been reported for students with visual impairments. This study will examine the science process skills utilized in an inquiry-based classroom as well as the effectiveness of this methodology for students with visual impairments.

Methods Used to Teach Students with Visual Impairments

Teachers of students with visual impairments (TVI) have a responsibility to work with the general education teachers to make common core subjects, such as science, accessible to their students in the most meaningful ways possible. Scientific knowledge is important for all students because

Interaction with scientific phenomena provides the way for the child to attain systematic reasoning powers, and makes it possible for him to gain mastery and understanding of his environment since many of the phenomena and materials
with which science deals are part of the real world in which the child lives. (Hadary, 1978).

Science can provide the visually impaired student that same knowledge and understanding. According to Geerat J. Vermeij, a renowned blind marine biologist, “A conscious effort must be made, all the time and everywhere and everybody, to acquaint a blind person with those aspects of the environment that cannot be heard, smelled, or easily grasped by hands and fingers. And even those things that can be observed must be pointed out.” (Vermeij, 2004). Teachers can acquaint and make the world of science more accessible to visually impaired students through collaboration, adaptations in the classroom and laboratory, as well as by providing extra-curricular opportunities in the field.

Many manuals exist to explain how to teach students with visual impairments in the area of science (Dion et al., 2000; Hadary & Cohen, 1978; Koenig & Holbrook, 2000; Kumar et al., 2001; Willoubhy & Duffy, 1989). However, very little research has been conducted to determine the effectiveness of these suggestions for modification and teaching methodology. With little researched methodologies reported and no researched methodologies found in the area of causes for seasons for students with visual impairments, these manuals and suggestions will be utilized in the treatment design for this present study.

One technique that will be utilized in the treatment is that of demonstration. Adaptations and modifications for this component of science include allowing the student to sit in a lab station near the demonstration, giving the student a clear verbal explanation
by a lab partner or by the teacher, giving a written description of the demonstration prior
to class, exploring a model or diagram of the item demonstrated, and allowing the
demonstration to be used prior to class (Ross & Robinson, 2000).

Models and graphics will be utilized as well. Models will be explained in detail
and constructed by all students. Graphics will be adapted for the specific needs of the
student. Adaptations the teacher can make include outlining graphics in puff paint or
thick fabric paint, using sheets of heavy metal foil in which lines and symbols can be
impressed from the back, using a raised-line drawing board, and making an enlarged
graphic. Books full of tactile pictures are available as well on different scientific subject

The use of measuring devices will be utilized in the present study. Measuring
devices can also be adapted for the students with visual impairments (Ross & Robinson,
2000). Braille yardsticks and rulers are available as well as containers adapted for
measuring liquid volume, adapted time keeping devices, and weighing systems with large
print, tactile, and voice output.

Lab partners are often used when completing tasks and will be utilized in the
present study. Visually impaired students should be paired up with vision students (Ross
& Robinson, 2000). Both students should share in the responsibility of recording data
properly. This type of cooperative learning helps not only in the facilitation of the
assignment but also in the social interactions of the visually impaired students and the
vision students.
Understanding our world is of vital importance to all children. Many modifications can be made for visually impaired students to ensure that the same quality of scientific education is available to them. Through modification, the use of technology, and utilization of specialty programs, visually impaired students are insured a more successful learning environment in the scientific classroom.

**Scientifically Based Research Methodologies Utilized to Teach Science to Students with Visual Impairments**

As discussed in the previous section, many manuals exist to explain how to teach students with visual impairments in the area of science (Dion et al., 2000; Hadary & Cohen, 1978; Koenig & Holbrook, 2000; Kumar et al., 2001; Willoubhy & Duffy, 1989). However, very little research into the effectiveness of these suggestions has been conducted. Much of the research that has been conducted concerns the effective adaptations that have been made to specific curricula, not to the methodology or approaches. However, at least one study exists for students with visual impairments in all levels of school; one for students in early childhood, one for middle childhood, two in secondary education, and one at the college level. (Erwin et al., 2001; Linn, 1972; Linn & Peterson, 1973; Linn & Their, 1975; Long, 1973; Struve et al., 1975; Gough, 1978; Waskoskie, 1980). Each of the curriculum studied had limitation in populations, areas of science, lack of exposure to science by their population, and use of established curricula.

**Science Curriculum Improvement Study**

The first curriculum study that was conducted for students with visual impairments was inspired by the events occurring during the space race of the late 1950’s
when America had a renewed interest in science and technology. In 1959 a group of scientists, psychologists, and educators met at Wood Hole, Massachusetts to discuss the issue of improving science education in the schools (Long, 1973). As a result of this meeting a new curriculum for elementary and science education was adopted and named the Science Curriculum Improvement Study (SCIS).

This curriculum adopted two important new trends: the emphasis on scientific inquiry and use of a variety of equipment outside of textbook use (Long, 1973). Materials used in the curriculum were concrete, and they allowed all children the opportunity for tactile explorations. Manipulative skills such as pouring and filtering became a part of the curriculum as well (Linn & Their, 1975). This curriculum became the basis for the first science education research for students with visual impairments.

Linn and Peterson (1973) began studying the SCIS curriculum to test the effectiveness of the curriculum on children with visual impairments. They found that the Material Objects section of the curriculum was valuable to children with visual impairments. This section allowed the children to manipulate concrete materials in order to begin to understand properties related to floating and sinking. The visually impaired children were able to increase their awareness related to the properties of objects.

Following up on research conducted using the SCIS curriculum, a staff consisting of researchers from UC Berkeley received a grant from the U.S. Department of Education in order to adapt the curriculum for students with visual impairments (Linn, 1972). Specific adaptations were made. The new curriculum was called Adapting Science Materials for the Blind (ASMB) (Linn, 1972; Linn & Their, 1975; Long, 1973; Struve et
The adaptive curriculum allowed students to be exposed to the same curriculum as their sighted peers utilizing specifically adapted materials. Examples of the materials include circuits that used motors instead of light bulbs to indicate a closed circuit; brailled puzzles; plastic boards with large print numbers and plastic bubbles that could be depressed (Long, 1973; Struve et al., 1975). The adapted materials in the ASMB were to be used in classes with students who were both sighted and visually impaired. Both the SCIS and the ASMB could be used simultaneously. The activities in the ASMB were replaced with alternative assignments for the students with visual impairments.

Two of the physical science units of the ASMB were analyzed; Interaction and Systems and Subsystems and Variables (Long, 1973; Struve et al., 1975). Lessons were taught to 14 students with visual impairments from the Washington D.C. area. These students ranged in age from 9 to 19 and were in grades 3-7. The students were from a low socio-economic status. None of the students had additional impairments. All of the students attended public schools in the surrounding urban areas. The students were brought to American University once a week for an hour to be taught the ASMB curriculum by student teachers under the direction of a university supervisor. A control group of 16 students from San Francisco Bay, who exhibited the same characteristics as their counterparts in Washington, D.C. was also analyzed. These students were from 12 different schools and were mostly taught using traditional textbook methods (Long, 1973; Struve et al., 1975).

Pre-treatment and post-instruction assessments were given concerning material from both units. The pre-instruction assessments showed that both sets of students
performed similarly; below average (Long, 1973; Struve et al., 1975). However, during the post-instruction assessments, the experimental group performed statistically significantly better utilizing the curriculum (Long, 1973; Struve et al., 1975).

The results suggest that the curriculum improved the science concept development and science skills of the students, who were exposed to the lesson methodology of the ASMB (Long, 1973; Struve et al., 1975). Further testing of the curriculum in residential schools and resource classrooms showed similar results (Linn & Their, 1975). However, when the curriculum was taught to students with multiple impairments, the results were not as positive (Linn & Their, 1975). Therefore, it could be concluded that the skills taught in the ASMB could be beneficial to students with visual impairments that were of high to average cognitive intelligence and had no other impairments.

The Lack of Action

Following all of the research that was conducted out of the SCIS and ASMB curriculums, research within the area of science education for the visually impaired was practically non-existent. From the late 1970’s to the early 2000’s, only 2 other studies were conducted. These studies were non-published doctoral theses (Gough, 1978; Waskoskie, 1980). The results of these doctoral research studies are summarized in the following sections.

Studying the Science-Related Problem Solving Processes

Gough, (1978) a student at Indiana University, studied the problem-solving abilities of high school students with visual impairments in their abilities to answer
science questions on a standardized test as well as series of problems in a science lab. Nine students with visual impairments aged 15-18 at the Indiana School for the Blind were tested during the 1975-1976 academic school year. Four students were enrolled in level I high school biology, four in Biology II, and one student who had completed Biology I comprised the group. These students were given a multiple-choice biology test containing items found in the “Testing and Evaluation in the Biological Sciences” standardized tests. The students were encouraged to express to researchers how they answered the questions. Thoughts from the students were recorded for analysis. Field notes were also used during the analysis. It was found that the students used the process of successful elimination during their tests (Gough, 1978).

A second component of this research was conducted with the same students engaging in environmental science activities. Students engaged in modified activities to determine hoop incidence, hoop transect, soil compaction, soil absorbency, and degree of slope (Gough, 1978). Hoop incidence involved throwing a hoop with a line attached for easy recovering on the ground to determine the number of leafy plants that existed inside of the hoop. This was done 10 times, and an average was taken to determine the number of plants in a 60’x65’ plot. Hoop transect involved selecting a line along the sample space in which 5 to 10 hoops were placed. The students then examined the number of plants, dead materials, twigs, leaves, nonliving plants, soil moisture, hardness of the soil, and soil particle size in each hoop. In order to determine soil absorbency, students pressed a 46 ounce juice can, in which the ends were removed, into the ground and filling it with water. Students then counted the number of seconds it took the soil to absorb the water.
The last measurement was of soil compaction. This was measured by pressing a dowel rod with a pointed end into the soil. On the top of the dowel was a spool attached with rubber strips. Students recorded the number of units down the dowel the spool had to be pushed in order to cause the dowel to penetrate the soil. During all experiments, the instructors assisted the students with making accurate measurements (Gough, 1978).

Once the students finished the experiments, they were given a set of essay questions concerning the experimental procedures and concepts examined during the experimentation. The response process of the students was again recorded using field notes and tape recordings for analysis. It was found that the students used analysis, hypothesis, and inference generation in order to answer the essay questions (Gough, 1978). The results were never duplicated. Gough did not test the students following experiments in a physical science lab or other biological labs to determine if the students would use the same approaches in their answering techniques.

Audio-Tutorial-Self-Instruct Laboratory Curriculum

William Waskoskie, at the University of Pittsburgh, developed 5 self-instruct lab exercises for 3 blind college students and 3 blind volunteers from the Indiana Branch of the Association for the Blind in Indiana, Pennsylvania (Waskoskie, 1980). He studied whether or not an audio-tutorial-self instruct laboratory curriculum was beneficial for students studying material presented in a first-year biology course. The exercises presented incorporated audio-tutorials that utilized models, verbal descriptions, and fresh or preserved materials concerning circulation, organism behavior, frog anatomy, taxonomy, and plant adaptations. Each of the five lessons were presented in a different
sequence to find which sequence of presentation using a model, verbal description, or fresh/preserved materials were best for the students (Waskoskie, 1980).

The use of field notes and student interviews were utilized to analyze the data along with pre-instruction and post-instruction assessments. Waskoskie found that the method of material presentation did not allow the participants additional benefits. There was a difference between verbal presentation and using specimens, but no difference between verbal presentations and model usage. Use of a t-test analysis on the assessment results showed that the lab conveyed the proper biological concept learning. Waskoskie (1980) implies that models and specimens are not significantly different from verbal descriptions in conveying biological concepts. However, a significant improvement was made using a combination of verbal interpretations and tactual experiences using models and specimens. Feedback from the members in the group supported the need for concrete experiences in the laboratory. Many of the participants indicated that they did not receive lab experiences in their residential schools (Waskoskie, 1980).

Waskoskie does not indicate if there were differentiation in the improvement between the participants who had lab experience and those whose lab experiences were limited. The information concerning the volunteers was limited. Their experiences or lack there of in preparation for a collegiate level science course could have significantly effected the outcome of the study.

Neither of these theses was ever published and both of them were never duplicated to determine if the results were accurate.
The Playtime Is Science Curriculum

It was not until 2001 that another study emerged in the area of science education for students with visual impairments, and it was the first study that focused on analyzing an adapted curriculum for the visually impaired in early childhood. The Playtime Is Science curriculum was adapted from a national Science Foundation Program for Persons with Disabilities. The goal of the curriculum is to incorporate science and scientific thinking into the daily routine of children with disabilities. Within the program are physical science lessons. The lessons analyzed allowed students to participate in problem solving, gross motor skills, cooperative learning skills, buoyancy, and cohesion. These skills were exhibited in lessons that involved building with junk, sinking and floating, and bubbles utilizing inquiry based activities. The curriculum was modified to teach students with visual impairments (Erwin et al., 2001).

Qualitative analysis through observations and interviews of 5 boys and 4 girls who were multiracial and visually impaired were utilized in order to determine the effectiveness of the curriculum. The students were in two classrooms with sighted peers; one fourth grade and one first grade (Erwin et al., 2001).

Overall, this curriculum seemed to benefit both the teachers and all of the students in the classroom. Through use of the curriculum, students exhibited enthusiasm, persistence, the desire to perform as a scientist by using the language and concepts learned in sharing their results, risk taking, making meaningful connections, and engaging in positive peer interactions. Teachers responded to this program as well. They seemed to encourage their students to share and give their opinions, engage the students
with visual impairments with the other members of the classroom, and helping students to make the meaningful connections by sharing their personal life stories with the students (Erwin et al., 2001).

None of the studies in the field of visual impairments conducted in science education addresses astronomical phenomena. No inquiry-based studies exist for school-age children with visual impairments. Only one study, which was conducted with early childhood students, examined inquiry-based learning for students with visual impairments (Erwin et al., 2001). Therefore, the present study began to address both science instruction about astronomical phenomena and the effectiveness of inquiry-based learning with children with visual impairments.

Seasonal Change Research

Seasonal change is due to the tilt of the Earth’s axis in relation to the orbit around the sun (Jones & Edberg, 1990; Ridpath 1987). This tilt results in the Sun’s change in altitude above the horizon during the year. Thus, different places on the Earth receive differing amounts of sunlight throughout the year. In the northern hemisphere, summer begins at the summer solstice. The solstice occurs as the sun reaches its highest point in the northern hemisphere occurring at north positive twenty-three and one-half degrees. During this season, the Sun will reach a higher position in the sky at noon then in the winter; beginning during the winter solstice. The winter solstice occurs as the sun reaches its greatest declination point of negative twenty-three and one-half degrees. The overall effect is that the days are longer in June than in the winter due to the length of time the
sun is in the sky. Temperatures seem warmer in the summer due to the sun’s higher placement in the sky as well.

Spring begins during the vernal equinox; around the 21\textsuperscript{st} of March in the Northern Hemisphere. This is the time of year when the sun crosses the celestial equator and begins to move north (Ridpath, 1987). Therefore, the days begin to get longer and the temperatures begin to increase as the sun reaches a higher position in the sky.

Autumn begins during the autumnal equinox; around the 23\textsuperscript{rd} of September in the Northern Hemisphere. Once again the sun crosses the celestial equator; however the sun begins moving south. Thus, as the sun moves further south, shorter days and cooler temperatures will result.

Research indicates that the biggest misconception in society related to the causes of the seasons is due to a varying distance of the Earth from the Sun (Bisard et al., 1994). The Earth does vary slightly in the distance from the Sun. However, in the Northern Hemisphere, the Earth is slightly closer to the Sun during the winter season and slightly further in distance during the summer season. Therefore, this misconception does not account for the main causes for seasonal change.

Research concerning misconceptions among visually impaired children, specifically astronomical concepts, has never been studied. In order to understand the nature of misconceptions in children, research concerning sighted individuals and hearing impaired children will be analyzed and used as framework for conducting future research with visually impaired children.
Empirical research has shown that school-aged children, university students, and school teachers exhibit difficulty in fully understanding astronomical concepts. Although understanding tends to improve with age, students and teachers alike still struggle with these basic concepts. Bisard et al. (1994) surveyed a variety of different aged levels of people. In total, 708 people were surveyed, which included 180 middle school students, 157 senior high students, 236 college freshman and sophomore introductory astronomy students, 56 college junior and senior astronomy students in an advanced astronomy course, 52 physical and earth science teachers in a refresher astronomy course, and 27 general education teachers in a refresher astronomy course. The results showed that general education teachers exhibited the same rate of misconceptions about the reason for the seasons as the middle school students. College freshman and sophomores reflected the same rate of misconceptions as their counterparts in senior high. The college junior and senior astronomy students along with the physical and earth science teachers had the lowest rates of misconceptions surrounding seasonal change and exhibited about the same rate of occurrence of misconceptions. All groups had low correct response rates (ranging from 11-26%) on questions involving the position of the sun in the sky at specific times of the day and year.

According to Trumper (2006), astronomy is presented as facts and explanations for astronomical phenomena are usually missing in instruction or take the form of simple statements of causes without giving the student the opportunity to make casual connections to previous learning. The presentation of astronomical phenomena, according to Trumper (2006), does not take into account: “(a) the interrelationships that
exist among the different concepts; (b) that the acquisition of some concepts may be a prerequisite for the acquisition of others; and (c) that the students may have already formed their own conceptions.” (p. 881). Therefore, misconceptions exist among all age groups which have been documented in empirical research.

The following sections will examine empirical research of school-aged children, students with hearing impairments, university students, and school teachers. Understanding the current misconceptions surrounding seasonal change that exists among sighted members of society will provide valuable insights into future research and methodologies which may address misconceptions concerning seasonal change in children with visual impairments.

School Aged Children Research

Trumper surveyed 448 rural Israeli junior high students; “154 students aged 13 in grade 7, 152 students aged 14 in grade 8, and 142 students aged 15 in grade 9” (Trumper, 2001b, p.1115) concerning their knowledge of astronomical concepts using a questionnaire. The students evaluated had completed at least 75% of the questionnaire. Concepts covered within the questionnaire include the day-night cycle, moon phases, dimensions and distances, seasonal changes, location of the sun, spatial distances of objects from the Earth, the revolution of the moon, time zone occurrences, causes for solar eclipses, and concepts about the universe. Overall, only 36.4% of the students gave a correct response to questions asked about the various astronomical concepts. The percentages increased with age. The boys in the study scored significantly better than the girls.
In regards to the data on seasons, 46% of the students answered questions correctly “…indicating the reason for the different seasons is the tilt of the Earth’s axis relative to the plane of its orbit as it revolves around the sun” (Trumper, 2001b, p.1117). Forty-five percent of the students indicated that the varying distance between the Earth and the Sun caused the difference in seasons. Thirty-six percent of the students were able to correctly identify the reason for differences in temperature during the seasons. Overall, only 20% of the students correctly identified the tilt of the Earth’s axis and used that same reasoning to explain the differences in temperature during the seasons. Twenty-eight percent of the students were able to identify changes in amount of daylight between hemispheres. Given all three questions about the seasons; the reasons for them, the changes in temperature, and the changes in amount of daylight, only 6% of the students accurately answered all three questions.

Trumper (2001a) continued his research by giving the same questionnaire to 378 senior high students in Israel; “153 in grade 10, 116 in grade 11, and 109 in grade 12” (Trumper, 2001a, 101). As in his previous research, only students who had completed at least 75% of their questionnaire were evaluated.

Overall the students answered 43.6% of the questions correctly (Trumper, 2001a). However, when asked questions about the concept of seasons, 62% of the students gave a scientifically accurate answer indicating that the causes of the season are due to the tilt of the Earth’s axis as it revolves around the Sun. Forty-seven percent of the students used that same answer to explain the difference in temperature in the seasons. Of the students who were able to scientifically identify the reason for the seasons, 13% described the
differences in temperature due to the Earth being closer to the sun, and 24% thought the Earth’s rotational axis was flipping back and forth as the Earth revolved around the Sun. When asked about the differences in seasons across different hemispheres, only 34% were able to identify the Southern Hemisphere as having longer daylight in the winter. Overall, 13% of the students were able to identify all three seasonal concepts: causes, temperature change, and differences between the hemispheres. Trumper (2001a) found that the older students had a better understanding of astronomical concepts than their younger counterparts.

Bakas and Mikropoulos (2003) gave 102 secondary Greek students aged 11-13 a questionnaire with 9 multiple choice questions quizzing the students about their knowledge of astronomical concepts. Questions were asked of the students concerning movement of celestial bodies, sizes of celestial bodies, day and night, as well as the causes of the seasons. The questionnaires were distributed after the students had completed a related unit in Geography class.

When asked about the differences in temperature, 58.8% attributed the difference to the “change of the angle created by the rays of the Sun and the surface of the Earth” (p. 958). Eighteen students, or 17.6%, indicated that the change in temperature corresponded to a change in the distance between the Sun and the Earth, while 16.7% believed that the temperatures are warmer in the summer due to the Sun staying in the sky longer. Seventy-nine percent of the students were scientifically able to account for temperature changes in the North and South Pole.
To help the students overcome these misconceptions, the students participated in a computer simulated Virtual Reality Simulation. The students were able to interact with simulated environments using hypothetical scenarios, both realistic and non-realistic.

After use of the virtual environment, 27 students from the original study were asked questions concerning the seasons. Eighty-five percent of the students were able to explain the causes of the seasons as the change in angle of the Sun’s rays to the Earth. Two of the students attributed distances between the Earth and the Sun as the cause of the seasons, and 2 of the students could not answer the question.

*Teaching Approaches for School-Aged Students*

Hsu (2008) studied 87 northern Taiwanese students who were second-year senior high school students at a public school. All of the students were nonscience majors in the school. Fourteen of the students in the study had no conception of the causes for seasons. Thirty-one of the students mixed the cause for seasons with other scientific phenomenon they had been studying. For example, 19 of the students described the tides and ocean flow, 27 students described the planetary wind systems and air pressure, while another student described the Sun covering the clouds. Other common misconceptions involved the change in the Sun, the duration of the sunshine and radiation on the Earth, as well as the Earth facing toward or away from the Sun. Three responses given by students described the Earth’s tilt. Students stated that the tilt allowed some locations to be closer to the Sun and others to be further from the Sun. Four students stated that the tilt of the Earth caused changes on Earth in regard to distance from the Sun and the amount of sunlight that could hit the Earth. Only one student was able to give a completely accurate
scientific explanation for seasons while 25 student responses indicated at least a partial
scientific explanation for causes of seasons. By far, the majority of the students had
either no understanding of seasons or exhibited misconceptions.

In an effort to help students to overcome their misconceptions, students were
divided into two groups, each receiving a different treatment. One group of 44 students
was exposed to a teacher-guided instruction of the causes of seasons. Another group of
43 students were allowed to take student-centered approaches to learning.

Hsu found that the student-center group improved their scientific understanding of
the seasons much better than the teacher-guided instructed students. However, some
students in the student-centered approach acquired more alternative conceptions without
the teacher’s guidance. The researcher hypothesized that there may have been a few
weaker learners in this bunch and would need the assistance of a teacher in order to guide
their learning.

Students with Hearing Impairments

Research has also been conducted to compare the misconceptions of astronomical
concepts between deaf students and hearing students. Roald & Mikalsen (2001) examined
the differences in astronomical concept knowledge between students who were deaf and
students who were hearing. The students were asked to explain, draw, or choose models
to demonstrate their knowledge of day and night, summer and winter, and the phases of
the moon during an interview with researchers. The methodology was the same as used
by Vosniadou and Brewer in their 1992 study. A total of 26 hearing impaired students
and 13 hearing students participated in this study. Eighteen deaf students in primary
school between the ages of 6 and 12 were studied along with 8 deaf secondary school students from the National Resource Centres for Deaf Education. These students attending the school are from various regions around Norway. Thirteen hearing students from two schools in Bergen, Norway were also studied.

Overall, 8 deaf students and 5 hearing students gave a partial explanation for the astronomical concepts related to seasonal change. Eighteen deaf and 8 hearing students were able to give full explanations to describe seasonal changes. Within their explanations, 21 deaf and 12 hearing students had coherent explanations in their descriptions of seasonal change while 5 deaf and 1 hearing students did not have full inner coherence in their descriptions (Roald & Mikalsen, 2001).

Twenty-two of the participants were able to identify the Earth as a sphere. Those students were specifically asked what caused the seasons. Three deaf students identified that the tilt of the Earth caused different seasons. Six deaf students and 5 hearing students thought that the distance from the Sun was the cause of the seasons. Wobbling of the Earth’s axis during a change in seasons was named by 2 deaf and 1 hearing students. Three hearing students and 1 deaf student felt that the sun itself demonstrated different qualities in the summer and winter. One hearing student said that winter was caused by a shadow of the moon and 1 deaf student felt that winter was caused by clouds.

Two-thirds of the students did not understand the physical concepts of the seasons. However, they demonstrated explanations they felt to be accurate which indicates that the students had observed and reasoned about the world around them.
Misconceptions Among University Students

Kikas (2003) studied 132 first year university students in Estonia who were studying in the fields of humanities and social science, applied science, and science. She gave each of the students two tasks. The first task was to evaluate responses given by other students regarding scientific phenomena. The students were to evaluate the responses based upon scientific validity. The students were to rank the responses using a likert scale 1-4 with 4 being the most scientifically accurate answer. The second task involved a problem to solve concerning differences in temperature through the various seasons.

When the students were given problems specifically related to seasonal changes on Earth, one-tenth of the students described the change in seasons due to the distance theory; the earth is farther away from the sun in winter and closer in summer. To describe the differences in temperature, the students had difficulty in their explanations since this is a topic that is not covered within the planetary system unit. Of the remaining students, the ones who were able to evaluate the responses accurately were also able to give scientific explanations to the problem solving task.

Zelik and Bisard (2000) found similar results. When 213 introductory astronomy students at both the University of New Mexico and Central Michigan University were surveyed, 32% of the students stated that the reason for seasonal change was due to the Earth being closer to the sun in the summer.
Future teachers enrolled at a major Midwestern university exhibited many misconceptions as well. Atwood and Atwood (1996) sampled 49 senior level students in a professional block of coursework. Overall, 85% of the students provided misconceptions to the researchers through interview responses utilizing models. They found that 19 students felt that the reason for the seasons was due to the distance from the earth to the sun, 3 felt that the sun revolved around the earth and caused the reason for the seasons, 7 felt that the tilt changed as the earth revolved around the sun, and 4 felt that the pole of the hemisphere having summer is directly pointed toward the sun. In written responses, 24 of the students attributed seasonal changes are caused by the change in distance from the earth to the sun.

In an additional study to assess university students’ misconceptions surrounding seasonal change, Trumper (2006) gave 138 university students a written questionnaire and interviewed the students twice to assess their knowledge and misconceptions surrounding seasonal change. Of the total population, 83 students were taught utilizing a traditional lecture-based methodology which also included computer animations, simulations, and demonstrations. The remaining 55 students were taught utilizing a constructivist approach. This methodology consisted of assessing students’ existing conceptual understanding concerning seasonal change and provides experiences that would target students’ misconceptions to help them accept scientific views. The 55 students were asked to track the sun’s path in the sky, track the sun’s shadows, record the daily temperatures, and track the sunrise and sunset times. Experiments concerning light changing due to angles were also conducted.
During the pre-instruction, both the students who were taught utilizing traditional lecture-based methodologies and those who were taught utilizing a constructivist approach exhibited similar rates of misconception occurrences. However, during the post-instruction, students who had received instruction utilizing constructivist methodologies did statistically significantly better in both the interviews and the post-instruction.

**Misconceptions Among Teachers**

It is important to understand the misconceptions of the teachers concerning astronomical phenomena as well, since they will be given the duty of helping the children they teach to overcome inaccurate scientific understandings. Kikas (2004) studied five groups of teachers. Thirty of the teachers were from the area of science, mainly chemistry and physics, 28 were biology teachers, 57 were primary teachers, 32 were pre-service teachers, and 51 were humanities teachers.

Each group of teachers was asked to evaluate responses given by students on a questionnaire as to their scientific accuracy using a likert-type scale: 1 was does not correspond with scientific explanations to 4, which was completely scientifically accurate. The second portion of the experiment involved choosing the correct explanation for a task they were presented. For evaluation of the responses regarding the seasons, the question asked was “In Estonia it is warm in summer and cold in winter; the temperature is medium during autumn and spring. For the climate to be similar throughout the seasons, what would need to be different about the Earth” (Kikas, 2004, 437).

Overall, the differences in teaching experience and location of their schools did not account for the differences in their scores (Kikas, 2004). One hundred percent of the
biology teachers and 91% of the primary teachers evaluated the scientifically accurate response given by students regarding seasonal changes as mainly, or completely, scientifically correct. Misconceptions were labeled as scientifically accurate by 56% of the biology, 67% of the science teachers, and 56% of the primary teachers. Eighty-one percent of the trainee teachers labeled both the scientific explanation as valid, and 72% labeled the misconceptions as scientifically valid as well. Within the science teacher and biology teacher group, less than 30% of the teachers labeled both the scientifically valid and misconception answers as scientifically valid. The humanities teachers showed similar results as the trainee teachers; however, their individual percentages were not explicitly given. For evaluation of the task problems, “…more than half of the primary, trainee, and humanities teachers were able to choose the correct answer” (p. 442). However, 37% of the trainee teachers, 16% of the primary teachers and 15% of the humanities teachers showed misconceptions in their understanding of the physical reasons for seasonal changes. Some of the teachers, 8 primary and 5 trainee teachers, stated that the reason for changes in the seasons was due to the change in distance for the Earth to the Sun. The percentage of correct responses for the science and biology teachers was explicitly given.

Overall, the primary school teachers and the trainee teachers showed they did not understand the physical reasons for seasonal change. The length of the sentences and words seemed to effect the teacher’s evaluations. Teachers tended to evaluate the student answers with longer explanations and more use of scientific terminology as scientifically accurate regardless of content.
In an effort to understand what information is available to teachers to help them in their understanding and teaching methodologies, Atwood and Atwood (1996) found that elementary science textbooks do not always provide teachers the information concerning seasonal change. This is viewed, by the researchers, as a lack of scientific literacy for an adult and could result in serious problems for teachers who were expected to help their students understand scientific phenomena.

According to the research, students exhibit a common misconception related to causes of the seasons. Students report that seasons are due to the varying distance of the Earth from the Sun (Atwood & Atwood, 1996; Bakas and Mikropoulos, 2003; Kikas, 2003; Roald & Mikalsen, 2001; Trumper, 2001a, 2001b, 2006; Zelik & Bisard, 2000). However, utilizing constructivist-teaching methodologies as well as the use of virtual environments appear to help students to construct scientifically accurate conceptual understanding of the causes of seasonal change (Bakas & Mikropoulos, 2003; Hsu, 2008; Trumper, 2006).

Teachers exhibit misconceptions that are similar to their students when identifying the causes for seasonal change (Atwood & Atwood, 1996; Kikas, 2004). Furthermore, teachers are unable to identify the misconceptions of their students on assessments given in the classroom (Kikas, 2004). Research suggests that the type of teacher training a teacher receives may help to lesson the types of misconceptions a teacher has regarding causes for seasonal change (Kikas, 2004). This training is important because once a teacher enters the classroom; the scientifically accurate information may
not be available to them in the textbooks utilized by their school district (Atwood & Atwood, 1996).

**Researcher Recommendations**

Trumper’s data (2001a, 2001b, 2006) shows a need for teachers to address misconceptions their students may have at all levels of instruction. Zelik, Schau, and Mattern (1998) suggest that at the beginning of class, an initial check for the knowledge level of the class should be conducted. The teachers need to work with the students to understand what their students believe and how those beliefs become part of the student’s interpretations of scientific phenomena. By engaging the students in activities that will help them to make connections with new concepts being presented, teachers will have a better opportunity of helping their students to overcome misconceptions they may have.

The results from Bakas and Mikropoulos (2003) show that the use of the virtual environment helped the students to overcome their misconceptions that still existed after using traditional teaching methods. The authors believe that the use of virtual environments can help children to better understand the abstract phenomena of astrological concepts.

Hsu suggests that teaching seasons utilizing a student-centered approach allows students to overcome their own misconceptions. The author also cautions that a teacher must know their students and ensure that they can handle this form of learning as some students in the study actually gained more alternative conceptions by working on their own without participating in teacher-guided instruction.
Roald and Mikalsen’s research (2001) on deaf children indicate a knowledge lag between deaf students and hearing students. This could be attributed to their lack of exposure to information. Within Norway, astronomical concepts are to be taught in all grades, so the lack of scientific accuracy of the student’s answers is troublesome for the authors. More research needs to be conducted in determining the best way to teach children with hearing impairments scientific concepts.

Zelik and Bisard (2000) show that misconceptions of teachers can exist and can reflect those of students in junior and senior high school. Therefore, teachers need to be aware of scientifically accurate concepts and be able to convey that content in a meaningful way to their students while being aware of their own bias. Atwood and Atwood (2006) suggest that preservice teachers’ conceptions should be targeted during coursework by providing instruction to teachers that targets alternative conceptions frequently held. Teachers also need to be taught concepts in methodology classes that are not found in textbooks, but teachers are responsible for teaching.

Future Research

Research concerning misconceptions of astronomical phenomena in children with visual impairment has not been conducted. Roald and Mikalsen (2001) indicated that children with hearing impairments tend to have a knowledge lag. This too can be a problem in children with visual impairments. These students tend not to be exposed to information as soon as their sighted peers. Will the students with visual impairments exhibit the same patterns of misconceptions as their sighted counterparts in the Trumper (2001a, 2001b), Roald and Mikalsen (2001), Bakas and Mikropoulos (2003), or Bisard,
Aron, Fracek, and Nelson (1994) research? More research needs to be conducted in order to determine the misconceptions of children with visual impairments. This present study will begin to answer this question.

Limitations of Research

School-aged students, college students, and teachers alike demonstrate misconceptions in understanding astronomical concepts. By analyzing sighted peers, one can begin to understand the trends that should be present among students with visual impairments if the students have equal access to the curriculum. However, after an exhaustive search of the literature, no studies were found to help in beginning to understand the misconceptions that exist among students with visual impairments in understanding astronomical concepts. Research needs to be conducted in order to identify the misconceptions in astronomical phenomena among students with visual impairments and their teachers.

Gaps Within the Literature

In reviewing the findings of each of the research studies on science education for the visually impaired, it is evident that students with visual impairments need concrete objects in which to manipulate within the environment in order to increase their knowledge of scientific concepts (Erwin et al., 2001; Linn, 1972; Linn & Peterson, 1973; Linn & Their, 1975; Long, 1973; Struve et al., 1975; Gough, 1978; Waskoskie, 1980). Combining verbal interpretation and tactual experiences using models and specimens also seem to be effective in increasing scientific understanding of biological concepts (Waskoskie, 1980). Inquiry-based methodologies appear to be beneficial to students with
visual impairments in early childhood settings (Erwin et al., 2001). However, many of these recommendations are based upon initial study results. This present study utilized many of the strategies suggested by previous research.

Gough (1978) suggests that students with visual impairments use analysis, hypothesis, and inference generation in order to answer essay questions and uses the process of successful elimination during standardized tests. This study was never replicated, and the tests used in the study are outdated and unrepresentative of the current tests that are federally mandated.

Each of the research studies presented concerning teaching children with visual impairments are based upon a specific curriculum: either modifications of an existing curriculum or creation of the researcher’s own curriculum used in the study. Three of the four research studies were conducted over 20 years ago. Many of the curriculum standards and content have changed in recent years due to the high stakes testing and advances in the field of science.

The research has not been found to have been duplicated to test for reliability in the findings, with the exception of the ASMB curriculum. The only science curriculum areas studied were in physical science, environmental science, and biology.

Theories of teaching and learning should also be studied in regards to teaching science to students with visual impairments. For example, Lynch et al. (2007) found that the use of conceptual change theory is beneficial to students with disabilities. However, students with visual impairments were not included in the study. Would this theory of
teaching and learning lend to scientific understanding and knowledge development in children with visual impairments?

Teacher beliefs reflect how a teacher will teach in the classroom (Nespor, 1987). Those beliefs dictate the amount of time and energy a teacher will place on the content and curriculum being taught. Teachers may perceive that a student is learning when learning may not have occurred. However, research does not indicate how the perceptions of student learning by teachers for the visually impaired will compare to the documented student learning. Will teacher perceptions of their students’ with visual impairments learning be accurate?

Chapter Summary

Conceptual change theory can become a powerful tool to aid in changing the misconceptions that students have in the scientific classroom (Duit, 2003). However, the research needs to be more applicable to everyday classroom experiences. This present study will utilize conceptual change theory into the teaching methodologies utilized in a residential classroom setting.

Teacher Beliefs have a strong effect on teachers’ classroom practices (Pajaras, 1992). However, research needs to be conducted to examine the beliefs of the science content teacher in how students with visual impairments are instructed and how the teacher perceives the students are learning in his classroom. The present study examined the perceptions of the participant teacher’s perceptions of students with visual impairments learning compare to students’ documented learning of the causes of seasons.
School-aged students, college students, and teachers alike demonstrate misconceptions in understanding astronomical concepts. By analyzing sighted peers, one can begin to understand the trends that should be present among students with visual impairments if the students have equal access to the curriculum. However, the need for researching the misconceptions of students with visual impairments is great. Student participants in the present study will be asked pre-instruction and post-instruction interview questions in order to examine the types of misconceptions they have about the causes of seasons.

Many manuals exist to explain how to teach students with visual impairments in the area of science (Dion et al., 2000; Hadary & Cohen, 1978; Koenig & Holbrook, 2000; Kumar et al., 2001; Willoubhy & Duffy, 1989). However, very little research has been conducted to determine the effectiveness of these recommended curriculum materials (Erwin et al., 2001; Linn & Their, 1975; Long, 1973; Struve et al., 1975; Waskoskie, 1980). This present study will address the effectiveness of curriculum for causes of seasons.

With the lack of scientific educational research in the field of visual impairments, the need for research is great. Research in the field is limited by the number of participants, validity, and adherence to current standards. Current research is needed in order to adhere to the mandates of the No Child Left Behind which requires that teachers work with all children, and they should be aware of what techniques work best for the children they teach. The field of visual impairments has much research to do in order to make sure that students with visual impairments are receiving the best scientific
education possible. This study examined the effectiveness of a teaching methodology utilized to help students construct knowledge of causes of seasons in order to begin to move the field toward adhering to the mandates of No Child Left Behind and the Educational Science Reform Act.
CHAPTER 3

METHODOLOGY

Introduction

The purpose of this qualitative study was to understand and to describe the misconceptions that possibly existed among students with visual impairments and instructional techniques that may help them learn scientific concepts. Teachers’ perceptions of student learning were also examined. Specifically, the study focused on the conceptual understanding of students with visual impairments about seasonal change.

Data were obtained from students 1 week prior to and 2 weeks after instruction. This study was designed to address not only mandates in the legislation outlined by the United States Congress, but also to begin to generate a research-based astronomy curriculum that would benefit students with visual impairments. This chapter will outline the procedures and methods to be used in this study, and divided into six sections: a description of participants, setting, methods, data collection, data analysis, and trustworthiness.

Participants

Students

Two groups of students participated in this study. The participants were asked a set of nine interview questions as part of a pre-instruction and post-instruction
assessment. Students received instruction that was either taught utilizing traditional methods or inquiry-based methods. All students in the class were participants in the instruction. However, only the students who agreed to participate in the study and had parental consent were interviewed.

The first group of students asked to become members of a comparison group was 7th graders who had various levels of visual impairment and levels of academic achievement. These students received traditional instruction. The students in this group were given a pre-instruction and post-instruction assessment. See table 3.1 for participant demographic information.

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<td>13</td>
<td>F</td>
<td>Caucasian</td>
<td>Braille</td>
<td>Independent</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>M</td>
<td>Caucasian</td>
<td>Braille</td>
<td>Independent</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 3.1 Demographics of Student Participants

Three students out of a class size of 4 had parental consent to be interviewed. Of those students, 2 were male and 1 was a female. The female was 15 years old. One male
was 13 and the other male was fifteen years old. Two students were Caucasian, and the third student was African American. One student utilized Braille as a reading medium, one student utilized large print, and one student utilized regular print. All students were independent travelers, and, of those students, only one utilized a cane. One female and one male participated in the pre-instruction. The third student did not return his permission slip to the researcher until after instruction had begun and therefore was unable to participate in the pre-instruction interview. However, all students participated in the written statements and post-instruction. See table 3.2 for the type and number of participants in each portion of the study.

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Pre-Interviews</th>
<th>No. of Written Statements</th>
<th>No. of Post Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparison (n=3)</td>
<td>2*</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Inquiry-Based (n=4)</td>
<td>2*</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 3.2: Type and Number of Participants in Each Portion of Study  
* Note: Not all students participated in the pre-interview

The second group of students received inquiry-based instruction. Students in grades 7-8, with various levels of visual impairment and levels of academic achievement, were asked to participate in this study. However, only students in 7th grade agreed to participate in the study. See table 3.1 for participant demographic information. The students in this group were given a pre-instruction and post-instruction assessment with the exact questions as their peers in the comparison group.
Four students out of a class size of 7 had parental consent to be interviewed. Of those students, 2 were female and 2 were male. The female participants were ages 13 and 15, while the male participants were ages 15 and 13 years old. All of the students were Caucasian. Three students utilized Braille as a reading medium while the fourth student utilized large print. All were independent travelers; 3 of the students utilized a cane. One female and one male participated in the pre-instruction. Students 6 and 7 did not participate in the pre-instruction because they turned in their paperwork after instruction had begun. All students participated in the written statement and post-instruction. See table 3.2 above for the type and number of participants in each portion of the study.

Teachers

The inquiry group received specific modified instruction from their classroom teacher at a state school for the blind. The educator was certified to teach science in the state where the school was located. However, the instructor was not a certified educator of the visually impaired but was pursuing her licensure to become certified.

The comparison group received instruction from a science educator at a state school for the blind. The educator was certified to teach science in the state where the school was located, but was not a certified educator of the blind. The teacher was also pursuing a licensure to become a certified teacher of the visually impaired.

Participant Observer

The researcher was the participant observer in the classroom during all instruction. All lesson plans were adapted by the researcher. Therefore, the researcher was available to the inquiry teacher to help clarify the lesson plans provided to her. The
researcher was also the participant observer in the comparison group classroom during all instruction. Field notes were taken to document what happened in the classroom and student reactions to the methodologies presented in order to gain a better understanding of student interview answers (Norris & Walker, 2005; Stark & Torrance, 2005). The researcher made note of the classroom, the contents contained within such as bulletin boards, class posters, textbooks, etc., and also recorded student teacher interactions in those notes. Thoughts and interpretations were also included to be used later as a guide for analyzing the results (Altrichter & Holly, 2005). The instruction of both the inquiry-based classroom and the comparison classroom was video-taped by the researcher in order to make additional notations in the field notes. The researcher conducted all interviews of students and teachers. Audio-tapes and video-tapes of the interactions were also made. The researcher analyzed the data collected. The researcher also checked for inter-rater reliability between experts.

The researcher has a varied background as a middle school science educator, a participant in graduate studies, and has conducted research projects. This experience has allowed the researcher to develop the ability to interview middle school students. The researcher has also completed a series of three courses devoted to qualitative research. Through these courses, the researcher learned proper techniques in designing, conducting, and reporting qualitative research. The researcher has also added experience in analyzing field notes, conducting interviews, analyzing qualitative survey answers, document analysis, interview transcription, and final report writings. These skills have allowed the researcher to confidently prepare a qualitative research proposal.
Setting

School Setting

The data collection, as well as the inquiry-based instruction for the inquiry group was conducted at a state school for the blind in the Midwestern United States. One hundred twenty-three students from across the state that have been identified as legally blind are served at this school (Ohio Department of Education [ODE], 2008). Of these students, 52.3% are male and 47.7% are female (Mazzoli & Staff, 2006). Less than 10% are identified as being economically disadvantaged. In 2006, the graduation rate was 100% while the attendance rate was ninety-four percent. The state does not currently require students to show achievement in science at this grade level. However, achievement data were collected in both mathematics and reading for the current group of 7th graders when they were in their 6th grade year. Those students were 77.7% proficient in reading and 74.0% proficient in mathematics (ODE, 2008).

The collection and instruction for the comparison group was conducted at a residential state school for the blind in the Southeastern United States. One hundred sixty-two students from across the state that have been identified as legally blind were served at this school (Tennessee School for the Blind [TSB], 2008). Of those students, 57.4% are male and 42.6% are female. Eighty-three of the students were identified as being economically disadvantaged. In 2006, the graduation rate was 73.3% while the attendance rate was ninety-three percent. According to the state department of education’s website (2008) the 2007 6th grade students, the current group of 7th graders, were 75% proficient in science, while 12.5% were below proficient, and 12.5% of the
students were advanced in their proficiency test scores. For the subject of mathematics, 12.5% were below proficient, 75% were proficient, while 12.5% were advanced in their proficiency scores. Similar results were found for reading: 12.5% were below proficient, 75% were proficient, and 12.5% were advanced in achieved an advanced score.

Classroom Setting

The inquiry classroom was located on the second floor of the school. The door was located at the back of the classroom. Upon entering, students stopped and placed their canes into a round black receptacle that sat beside the trashcan. To the left of the trashcan were a row of bookshelves which house Braille, large print books, and regular print books. Beside the bookshelves was a sink that also serves as an eyewash station. Shelves above the sink house laboratory supplies. In the front of the room are a series of cabinets and filing cabinets again used for storage of equipment and supplies. To the right of the cabinets was a door that led out to the classroom’s greenhouse. To the right of the door were a series of windows. A chemical hood was located below the first window. Below the second and third set of windows bookshelves housed Braille books and biological equipment such as taxodermical models for the students to explore. Underneath the last set of windows were computers. The back wall contained a chalkboard and bulletin board. On them were posters with science related themes. Below the chalkboard and bulletin boards was another set of computers. Towards the front of the room, sitting in front of the series of cabinets and filing cabinets, were the teacher’s desk and a lab table containing models. Inside the parameter of the room were 6 which accommodated 2 students per table.
The comparison classroom was located on the second floor of the school. Upon entering the door, the students stopped and put their canes into a round black plastic receptacle. Beside this container sits the trashcan which is next to a closet door. Inside that closet were chemicals, additional models, teacher files, and laboratory equipment. Next to the closet were bulletin boards and a chalkboard. One bulletin board ran the length of two side bulletin boards between a chalkboard. The top bulletin board top contained pictures of ecology and people doing research. The bulletin board beside the closet door contains information regarding important events and a school calendar. The bulletin board furthest away from the door contained a tactile and Braille version of the periodic table in a large print version. In front of the bulletin boards/chalkboard was a lab desk with a sink. On top of this desk were models and books. The wall opposite the doorway contained 5 windows. A heater and bookshelves full of Braille books and equipment lined the wall under the windows. The wall that was parallel with the bulletin boards contained bookshelves and a deer mount. On the book shelves were stored Braille books, tactile models, a television, and anatomical models. An exit door was located adjacent to the book shelves. The wall that was parallel with the windows contained both bookshelves full of Braille and large print books and lockers. In the middle of the room lab tables, student desks, supply tables, and the teacher’s workstation could be seen. There were four lab tables located in the back of the room. These desks contained lab equipment, Braille books, models, microscopes, and an eyewash station. Student desks were located at the front of the room just inside the door. There were 7 student desks. Behind the student desks was a small table that sat a Closed Circuit Television,
Braillewriters, and current used Braille books. The teacher’s desk was located in front of the wall of windows facing the student desks. A workstation with a computer and paperwork was located adjacent to the teacher’s desk along with 2 additional student desks.

Methods

The purpose of this study is to understand and describe student understanding of scientific concepts in the natural setting of a classroom. Therefore a qualitative methodology was utilized (Norris & Walker, 2005). Qualitative research provided multiple data samples to enhance the understanding of how people make meaning and interpret their worlds while moderating the researcher’s personal interpretations and cultural meanings into the analysis of the data (Golbart & Hustler, 2005).

Data Collection

The data for the project was collected using student interviews, teacher interviews, classroom observations, and document analysis.

Written Response

Participants were asked to respond to the general question “What causes the seasons for different locations on the Earth that experience winter, spring, summer, and fall?” (Atwood & Atwood, 1996). The students were told that the response to this question would be used by the teacher for future instruction in the classroom and that the response would not affect their grades.
Student Interviews

Interviews were conducted following the written responses. A semi-structured interview methodology was utilized. These interviews centered around nine questions all based upon key concepts identified in the National Science Education Standards (NRC, 1996) as well as previous research (Bakas & Mikropoulos, 2003; Bisard et al., 1994; Roald & Mikalsen, 2001; Trumper, 2001a, 2001b, 2006). Each student was asked the same series of questions both before and after the treatment (See Appendix A). The focus of the interviews was on the student responses and did not impose scientific viewpoints of seasonal change (Barbour & Schostak, 2005).

Pre-treatment interviews were conducted approximately 1 week prior to both groups of participating students involved in any curricular activities or material related to seasonal change. Participants were not informed of the content of the interviews in advance and were unable to discuss the interview content and procedures with other students. All students were able to be interviewed in a single classroom time period. Participant interviews were video-taped and audio-taped for analysis.

Post-treatment interviews were conducted approximately 2 weeks after participants had been involved in curricular activities related to seasonal change. Participant interviews were video-taped and audio-taped for data analysis. As done with the pre-instruction interviews, participants were not informed of the content. Post-instruction interviews were conducted in a single classroom period. The post-instruction interview questions were identical to the pre-instruction interview questions.
Interviews were conducted following a semi-structured interview format (Atwood & Atwood, 1996; Seidman, 2006). Participants were initially asked about the causes for the seasons. Specific content questions followed. Responses given by the participants were followed with researcher responses such as “I see” or “Okay” as well as a repeat of participant answers to serve as a member check of given responses (Barbour & Schostak, 2005; Seidman, 2006). If participant responses were unclear, probing questions from the researcher were asked in order for participants to provide further explanations. However, the researcher avoided asking questions that would sway the answer of the participant. Follow-up questions could include “Explain this to me some more” or “What do you mean?” After the initial questions were asked, students were asked to utilize a tactile globe and a lamp, simulating the Sun and Earth, in order to demonstrate their conceptual understanding of seasonal change. Participants were asked to show the researcher why the seasons changed and to demonstrate the differences between winter and summer in the state where the participant lived. By asking both sets of questions, a member check was conducted (Seidman, 2006) and a check for validity. This also allowed the researcher to check for any contradictory concepts that might exist within participant conceptual understanding or changed responses from previous answers.

Audio-tapes and video-tapes were utilized to record interviews. Field notes were kept as well by the researcher during the interview procedure. These were utilized as both data and reflection (Altrichter & Holly, 2005). Interviews were transcribed for data analysis by the researcher. Themes and patterns that emerged from the data were noted in
order to describe and to present participants’ conceptual understanding of seasonal change (Corbin & Holt, 2005).

*Teacher Interviews*

Both classroom teachers were interviewed in order to probe their thinking about classroom practice and methodology utilized in teaching about seasonal change. Two interviews were conducted: one pre-instruction and one post-instruction. General questions were asked of the classroom teachers such as: How do you present seasonal change to your students?; What methodologies do you utilize?; What can I expect to see in your classroom as students begin this unit? In order to determine how comfortable the inquiry-based classroom teacher was in utilizing this methodology, a series of questions were asked such as: How do the inquiry-based methodologies compare with what you have done?; How comfortable are you with inquiry-based methodologies?; Would you use the inquiry-based methodology in the future?

Following the treatment, a post-instruction interview was conducted with the teachers. This allowed the teachers to reflect on the curriculum taught as well as student learning. General questions were asked such as: Overall, how do you feel the lessons were received by the students?; Overall, do your feel your students learned the topic presented?; Are there any lessons that were not beneficial to the students in your opinion?; Which lessons do you feel were most beneficial?; How do the treatment methodologies compare with what you have done in the past?; What would you change when you teach this topic again in the future? The interview was transcribed and the results analyzed. See Appendix B, entitled *Teacher Interview Questions.*
Classroom Observations

Classroom instruction was video-taped for future data analysis. Observations were noted in the form of field notes to allow the researcher to gather information about each form of instruction the students received. Classroom observations were conducted each day that lessons were taught in both the inquiry group as well as the comparison group. Observational field notes were utilized as an additional data source for the researcher.

Inquiry-Based Instruction

The inquiry group participated in a series of 9 lesson plans that were carried out over approximately a 2 week period. The materials utilized in the lesson plans were provided by the researcher. Lesson plans were inquiry-based and called upon the participants to re-arrange their own current thinking about the reasons for seasonal change following conceptual change theory (Vosniadou, 2007a; Vosniadou et al., 2001). Students were given opportunities to examine their own thinking in an effort to help students develop a more scientifically accurate understanding of seasonal change (Vosniadou, 2001).

Most lesson plans were adapted by the researcher from The Real Reasons for Seasons: Sun-Earth Connections (Gould, Willard, & Pompea, 2004). The lesson plans were adapted utilizing recommendations from the field (Dion et al., 2000; Hadary & Cohen, 1978; Koenig & Holbrook, 2000; Kumar et al., 2001; Willoubhy & Duffy, 1989). Also added were field observations of successful astronomy methodologies utilized with students with visual impairments at the 2007 Summer Youth Slam, the National
Federation for the Blind’s science, technology, and engineering camp specifically for students with visual impairments. Input into lesson plan adaptations were also provided by 2 experts from the field of astronomy for the visually impaired. Benning J. Wentworth II (personal communication, August 2, 2007), TVI, NASA consultant for low incidence disability education, and 2001 Disney’s American Teacher Award Honoree, and Noreen Grice (personal communication, August 2, 2007; personal communication, August 27, 2007) president of You Can Do Astronomy LLC and author of Touch the Sun: A NASA Braille Book and Touch the Universe: A NASA Braille Book of Astronomy both provided input.

Examples of lesson plan adaptations included making pictures taken from space tactually available to the students with visual impairments by utilizing thermoform paper which raised the lines in the diagram and made the image 2-dimensional. Students were also paired with a partner to make models of images together. Images were verbally interpreted by the teacher and the lab partners. Braille paper and Braille graph paper were utilized by the students as well as thermoform images of graphs. In an effort to understand distance, large scale models were created by the students outside of their classroom. Students walked the path the orbit takes around the sun, walked the distance between the Sun and Earth utilizing a scale model, and made comparison of sizes of the Earth and Sun utilizing scale models.

Each lesson plan had a different topic or themes of exploration related to causes of seasons. Students began the curriculum by examining the seasons and characteristics
of each season. Students worked together to develop a list of characteristics and classified each as either a biological, sociological, or meteorological change.

The second lesson allowed students to explore the shape of the Earth and its revolution around the sun by moving around a heat source in an elliptical pattern. Students also examined the night and day cycle by physically rotating their bodies around the Sun and discussing what time of day it would be on their noses. Next, students were asked a series of 3 questions in order to identify their conceptual understanding of the causes of seasons. Specifically, students were asked about the orbit of the Earth around the Sun, the distance between the Earth, Sun and the Moon, and the causes for seasons. Students asked their family and friends these same questions for a homework assignment. Student and family/friends’ responses were tabulated the next day in order to gain an understanding of what their community thought about the causes of seasons.

The third lesson provided the opportunity for students to learn the concepts related to scale models. Students went outdoors to create a scale model of the Earth, Sun, and moon distances. Students then referred back to their survey in order to answer the question related to distances between the Earth, Moon, and Sun.

Orbits were explored next. Students created the orbit of the Earth and Pluto in order to better understand the orbital path of the Earth. Students referred again to the survey to answer the question related to the shape of the Earth’s orbit.

The next lesson students examined different temperatures around the World. Students were given thermoform images of graphical data representing temperatures during each month of the year at 9 locations; all with different latitudes.
This lesson was followed with a similar lesson on length of daylight. Again, students were given thermoform images of graphical data; however this time the data represented the length of daylight at different latitudes on Earth.

The seventh lesson focused on the tilted Earth. Students were given a Styrofoam ball with a string around it to represent the equator. Beads were also pinned in the Styrofoam to represent the North Pole, Alaska, the students’ hometown, and Australia. Students were then placed in a circular pattern around a heat source. The Earth models were all tilted and pointed at a northern location in the classroom. Students were asked guided questions to help them to determine the various seasons on Earth at various spots along the orbital path of the Earth.

Lesson eight examined the Sun’s rays during both summer and winter. First the students took pencils and wiggled them while holding the pencil perpendicular, then while holding the pencils at an oblique angle in order to create different marks on their papers. Students discussed the concentration of light at various angles. A model of three hula hoops was used to review this concept as well as a review of the causes of seasons. Each hula hoop represented a different portion of the Earth: Northern Hemisphere, Southern Hemisphere, and the equator. Students were able to tactually feel the tilt of each portion of the Earth while they moved their hands from east to west across the hoops to simulate the rising and setting of the Sun.

The last lesson reviewed the concepts with the students and asked for them to once again take the survey in order to assess their learning throughout the entire unit. See Appendix D: Lesson Plans for a complete detailed lesson plan for each topic.
Comparison Group Instruction

The comparison group received instruction from their classroom teacher concerning causes of seasonal change without any input from the researcher. This instruction lasted for 2 days and was part of a larger unit on “Earth and Space”. The teacher began by asking students to open their textbooks to the “Earth and Space” chapter in their Glencoe Green Level Science books (National Geographic Society et al., 2003). Students responded by opening their chosen textbooks which reflected their personal reading media whether regular print, large print, and Braille. The teacher then asked the students a variety of questions regarding concepts that would be taught in the chapter such as rotation, revolution, axis, and solar and lunar eclipse. Students responded with the correct definition. Then a lecture regarding these terms ensued which included not only more in-depth information about the terms but also a brief talk regarding day and night. Students were also asked about their conceptual understanding of the moon and the moon phases. Again a lecture followed. To reference the moon phases, students referred to objects they were able to feel and understand, since visually many of the students did not have access to making observation. For example, a crescent roll represented crescent moon, the shape of a smiley face for a crescent moon, or a ball for a full moon. One student even drew crescent shapes on a piece of paper for the teacher.

Once everyone had finished discussing the moon, the teacher read from the teacher’s edition of the textbook about the tilt of Earth, the theories surrounding the formation of the moon, and cause of the tilt of Earth, which included the lack of traditional day and night cycles at various points on the Earth. In an effort to help
students understand the concept of Earth tilt, the teacher utilized a very large tactile globe that was mounted at a 24.5 degree angle on a steel bar representing the axis of Earth. He asked that each student come forward and touch the large globe and feel the tilt. A lecture followed regarding the measurement of a sphere utilizing degree. This concept involved giving the students the meaning of the word and locations of the North and South Pole in degrees.

Similarly, a lecture was given regarding the word solstice. The lecture began with the meaning of the summer and winter solstice followed by an explanation of where each occurred on the globe in terms of latitude direction. Again, the teacher read from the textbook and interpreted the readings for the student. Lectures followed about the words equinox and orbit followed.

The teacher then began to review the textbook with the students by asking them to look at the heading for the first chapter entitled “Earth’s Physical Data” (National Geographic Society et al., 2003). The teacher then reviewed the terms discussed earlier reading from the student text.

The last topic discussed the first day was causes of seasons. The teacher asked the students “Why is it spring in the Northern Hemisphere and fall in the Southern Hemisphere?” One student answered that it was due to the tilt of the earth. A brief lecture followed on tilt of the Earth, similar to the lecture presented earlier in the day.

The following day, the teacher began the class by having the students review the vocabulary words printed in the book’s chapter: “axis, orbit, rotation, solstice, revolution, and equinox” (National Geographic Society et al., 2003, p.480). Each student took a turn
reading the word and giving a meaning. If the student had difficulty with the meaning of
the word, the teacher would tell the student what page to look at in the book for the
answer. The student would then read the passage. The teacher followed with a brief
discussion of the word’s use in science as well as verbal descriptions of pictures in the
book. A model of the Earth, Sun, and Moon’s rotation was placed on the table for the
students to explore tactually during the lectures. During the lecture, the teacher also used
his fist as a Sun and the palm of his other hand to represent the Earth. The lesson ended
when the teacher and students discussed the review questions at the end of the chapter.
Students were required to record their answers using Braille or Bold Line paper and
markers.

Data Analysis

Student Interviews

The first step utilized in the data analysis was to transcribe the audio-tapes and
video-tapes of the interviews. Written responses provided by the students were also
transcribed from preferred student media form such as Braille, Large print, or regular
print. These transcriptions not only serve as a mechanism of preserving the data but
allow for an insight into the data.

Constant Comparative Methodology

Constant comparative analysis was used in order to analyze the data as described
by Trundle, Atwood, and Christopher (2002, 2007a, 2007b), and Bell and Trundle,
(2008). This process allowed for qualitative data to be collected, analyzed, and coded as
an ongoing process to look for gaps, omissions, and inconsistencies in the data (Glasser,
The methodology selected was appropriate due to the nature of the study, which is to understand and to describe a particular phenomenon. Constant comparative analysis has been used with other science content areas such as tides (Ucar, Trundle, & Krissek, 2007), particulate nature of matter (Adadan, Trundle, & Irving, 2008, 2007), and moon phases (Bell & Trundle, 2008; Trundle et al., 2002, 2007a, 2007b). According to Glasser (1965), “the constant comparative method is concerned with generating and plausibly suggesting (not provisionally testing) many properties and hypothesis about a general phenomenon…” (p.438). Constant comparative analysis is essentially a method to describe and to explore a phenomenon.

The constant comparative method may include multiple steps such as: comparison of data within a single interview to a code framework, comparison of interviews within the same group to the coded framework, and comparison of interviews of different groups to the coded framework (Boeije, 2002). Each step will be explained and described how the step will be utilized in the present study in the following sections of this chapter.

Creation of Coding System

Before data analysis began, a coding framework was developed based upon the conceptual understanding presented in the literature and served as a “partial framework” for coding (Glasser & Strauss, 1967, p.45). This framework served as a starting point for the codes which will be used during data analysis. Additional codes, which emerged from the data collected, the field notes, and the transcribed interviews, were added to the coding system. Field notes included ideas about data analysis and coding. These notes
were utilized in the creation of the revised framework which included codes that emerged from the data. See Appendix C: Code Sheet. A partial framework was used because this study looked at a known scientific phenomenon for which an established model exists. The scientific model was used to determine the codes that will serve for describing scientific responses. Previous literature on alternative conceptions about the causes of seasons was used to determine codes for nonscientific responses which the researcher may encounter.

The scientific model of seasonal change (Jones & Edberg, 1990; Ridpath 1987) was utilized to establish the criteria for coding scientifically accurate responses of the causes of seasons. Two critical responses are needed in order to indicate that a participant has a scientific understanding of causes of seasons but four critical responses are needed to indicate a scientific reasoning of seasons. If the participants include all critical responses, the interview responses were coded as scientifically accurate. However, if a participant shows a subset of any of the scientific criteria, the code of scientific fragments will be given. These codes are presented in Table 3.3.
<table>
<thead>
<tr>
<th>Code</th>
<th>Definition of Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI_TILT</td>
<td>The Earth is tilted. (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
</tr>
<tr>
<td>SCI_ORB</td>
<td>The Earth moves in an orbit around the Sun. (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
</tr>
<tr>
<td>SCI_LIGHT</td>
<td>The tilt in relation to the orbit results in different places on Earth receiving varying amounts of sunlight throughout the year. (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
</tr>
<tr>
<td>SCI_TEMP</td>
<td>This variable in the amount of sunlight results in changes of temperature and daylight. (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
</tr>
<tr>
<td>ALT_DIS</td>
<td>The distance between the Earth and Sun vary (Atwood &amp; Atwood, 1996; Bakas and Mikropoulos, 2003; Kikas, 2003; Roald &amp; Mikalsen, 2001; Trumper, 2001a, 2001b, 2006; Zelik &amp; Bisard, 2000)</td>
</tr>
<tr>
<td>ALT_WOBBLE</td>
<td>The tilt of the Earth changes during orbit around the Sun (Atwood &amp; Atwood, 1996; Roald &amp; Mikalsen, 2001). The Northern Hemisphere moves from right to left in a motion that is similar to a windshield wiper movement.</td>
</tr>
<tr>
<td>ALT_QUALITY</td>
<td>Sun demonstrates different qualities in the summer and winter (Roald &amp; Mikalsen, 2001)</td>
</tr>
<tr>
<td>ALT_SHADOWS</td>
<td>Shadow of the moon causes winter (Roald &amp; Mikalsen, 2001)</td>
</tr>
<tr>
<td>ALT_CLOUDS</td>
<td>Winter is caused by the clouds (Roald &amp; Mikalsen, 2001)</td>
</tr>
<tr>
<td>ALT_POLE</td>
<td>Pole of the Hemisphere having summer is directly pointed at the Sun (Atwood &amp; Atwood, 1996)</td>
</tr>
<tr>
<td>ALT_ROTATION</td>
<td>The Earth turns on an axis. The geographical position facing the Sun is having summer. The geographical position facing away is having winter (Atwood &amp; Atwood, 1996).</td>
</tr>
<tr>
<td>ALT_MOISTURE</td>
<td>Varying amounts of moisture cause the seasons to change</td>
</tr>
</tbody>
</table>

Table 3.3: Codes and their definitions
Results from previous studies (Atwood & Atwood, 1996; Bakas & Mikropoulos, 2003; Bisard et al., 1994; Roald & Mikalsen, 2001; Trumper, 2001a, 2001b, 2006) were used to establish criteria for probable codes for alternative conceptions that participants may hold. For example, one of the most common conceptions about seasonal change is that the distance between the Earth and Sun varies (Atwood & Atwood, 1996; Bakas and Mikropoulos, 2003; Kikas, 2003; Roald & Mikalsen, 2001; Trumper, 2001a, 2001b, 2006; Zelik & Bisard, 2000). For example, some people believe that summer is caused by the Earth in closer proximity to the Sun. Responses like this example will be coded as Alt_DIS indicating an alternative conception related to the distance between the Earth and Sun. Similar alternative conceptions will be coded using the Alt code followed by a descriptor word or abbreviation describing the type of idea presented in the literature. See table 3.3 for a complete description of codes for alternative conceptions.

**Constant Comparative Analysis and Coding**

The first step in utilizing the constant comparative analysis methodology was to compare the data within a single interview (Boeije, 2003) to the coding scheme created based upon the literature review. According to Charmaz (2005), by making comparisons of data between empirical answers and emergent theory one can learn about the world and increase the clarity of the data analysis. The transcripts of each interview were analyzed in an effort to determine what had been said and how to label the statement with a code. Statements were analyzed and compared to the established coding scheme in order to again establish any new codes that may emerge. New codes that emerged during
data coding and analysis were noted and added to the established coding system. During this step, the researcher analyzed the data by coding interview responses and comparing consistency between the data and the coding framework. The framework was revised to reflect the data.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Aim of Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data from a single interview are compared to the coding scheme</td>
<td>To verify the consistency of answers, to code the transcripts, and to add new codes</td>
</tr>
<tr>
<td>Codes are compared within each interview</td>
<td>To categorize participants based on their conceptual understanding</td>
</tr>
<tr>
<td>Comparisons are made between the participants’ interviews to determine the types of conceptual understanding</td>
<td>To summarize overall conceptual understanding categories with percentages per interview group</td>
</tr>
<tr>
<td>Comparisons are made between the conceptual understandings before and after instruction within each group</td>
<td>To distinguish conceptual change</td>
</tr>
<tr>
<td>Comparisons are made between each group</td>
<td>To distinguish any similarities or differences in conceptual change</td>
</tr>
</tbody>
</table>

Table 3.4: Five levels of comparisons for the analysis of qualitative data (based on Ucar, 2007)

The second step of data analysis required the researcher to compare codes within each interview to determine the consistency of responses throughout the interview. Looking at codes throughout the interview allowed the researcher to categorize the participant’s types of conceptual understanding.
The next step in the process involved comparing interviews between participants (Boeije, 2002). The comparisons summarized the types of conceptual understandings held by the participants within each intervention group. Therefore, the interviews of the inquiry-based group were compared as one group while the interviews of the comparison group were compared as another group. This process allowed the researcher to summarize the overall conceptual understanding categories by percentage within each intervention group (Ucar, 2007).

Following the comparisons within each intervention groups, another comparison was made between the conceptual understandings before and after instruction within each group. This step allowed the researcher to describe the pre and post-instruction understandings and gain insight into the conceptual change achieved by each intervention group (Ucar, 2007).

The final step compared the coded results between the two groups. This also allowed for an understanding and insight into the differences in conceptual change that may have occurred for each group.

Creation of Categorization

Creation of the initial categorization of alternative and scientific conceptions was based upon the Trundle et al. (2007a, 2007b) system in which conceptual understandings were divided into six major categories: scientific understanding of the cause of seasons, scientific fragments, scientific with alternative fragments, alternative fragments with a scientific understanding, alternative, alternative fragments, and no understanding. See Table 3.5 for Categories of conceptual understanding. Each category reflects the types of
conceptual understandings that have been described in previous science content areas involving student conceptual change (Adadan et al., 2007, 2008; Bell and Trundle, 2008; Trundle et al. 2002, 2007a, 2007b; Ucar et al., 2007). Categories created for the current study, as discussed above, have also informed the criteria for identification of each type of conceptual understanding category. These categories served as a starting point for data analysis. However, categories were not restricted to this system. Rather, the categories were revised to be responsive to the data.

Participant overall understanding was categorized as scientific fragments if the responses contained a subset of the scientific conceptions and no alternative conception. Participant responses may also contain alternative fragments which include a subset or subsets of alternative conceptions identified from the literature and were coded as alternative fragments. If a participant’s response contained a subset of scientific understandings and subset of alternative fragments, the code scientific with alternative fragments was given. A participant response that contained alternative fragments with only one scientific understanding, the code alternative fragments with scientific fragment was given. If a participant’s response did not contain information in any category identified, the code no understanding was given.
### Types of Conceptual Understandings

<table>
<thead>
<tr>
<th>Types of Conceptual Understandings</th>
<th>Criteria for Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Understanding of Causes of Seasons (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
<td>Includes four critical elements</td>
</tr>
<tr>
<td></td>
<td>• The Earth is tilted. (SCI_TILT)</td>
</tr>
<tr>
<td></td>
<td>• The Earth moves in an orbit around the sun. (SCI_ORB)</td>
</tr>
<tr>
<td></td>
<td>• The tilt in relation to the orbit results in different places on Earth receiving varying amounts of sunlight throughout the year. (SCI_LIGHT)</td>
</tr>
<tr>
<td></td>
<td>• This variable in the amount of sunlight results in changes of temperature and daylight. (SCI_TEMP)</td>
</tr>
<tr>
<td>Scientific Fragments</td>
<td>Includes a subset, but not all of the concepts identified as scientific understanding of causes of seasons and no alternative ideas are included</td>
</tr>
<tr>
<td>Scientific Fragments with Alternative Fragments</td>
<td>Includes a subset of scientific conceptions of causes of seasons with at least one fragments of alternative conceptions</td>
</tr>
<tr>
<td>Alternative Fragments with a Scientific Fragment</td>
<td>Conceptual understanding that contains multiple alternative conceptions and only one scientific concept</td>
</tr>
<tr>
<td>Alternative</td>
<td>Conceptual understanding that does not agree with the scientifically accepted norms (Atwood &amp; Atwood, 1996)</td>
</tr>
<tr>
<td>Alternative Fragments</td>
<td>Includes a subset or subsets of alternative conceptual understanding</td>
</tr>
<tr>
<td>No Understanding</td>
<td>Exhibit no evidence of understanding of concepts</td>
</tr>
</tbody>
</table>

Table 3.5: Categories of conceptual understandings and criteria for identification
Coding Reliability

In an effort to make the findings more reliable, a research team consisting of the principle researcher and 1 other expert independently viewed the videotapes and transcripts in an effort to classify the emerging data according to the types of conceptions that emerged (Trundle et al., 2007b). The inter-rater reliability was assessed in order to classify the responses of the participants. When discrepancies arose, the team reviewed the participant tapes together, discussed the discrepancies, and reached a consensus on the type of conceptual understanding.

In an effort to decrease coding bias, the groupings of participants were unknown to part of the research team (Trundle, et al., 2002). Only the principle researcher knew the difference between the participants. The analyses were randomized across the 2 groups of participants for both pre-instruction and post-instruction interviews.

The finalized coded data of each group was reported. Pre-instruction and post-instruction codes were compared in an effort to determine the differences in types of conceptual understandings of the students. Frequency counts were made for each group by type of conceptual understanding. Differences in frequencies of each type of conceptual understanding were utilized in order to identify the differences and commonalities of both the inquiry-based groups’ and the comparison groups’ understandings of the causes of seasons.

Trustworthiness

According to Somekh, Burman, Delamont, Meyer, Payne, and Thorpe (2005), the researcher must establish trust in high quality research. This trust must convince the
reader that the findings of the study are credible (Barbour & Schostak 2005). The following strategies will be utilized in order to enhance the trustworthiness of the data: member checking, triangulation, and inter-rater reliability. Descriptions follow of how each strategy was utilized in the study.

**Member Checking**

Member checking was utilized in order to confirm the answers given by the participants to the interview questions. Participants who gave vague or inconsistent answer were probed in order to check if the researcher was able to understand the responses of the participants (Siedman, 2006). The researcher paraphrased the response given by the participant and asked if that was the correct interpretation of the response.

**Triangulation**

According to Barbour and Schostak (2005), triangulation of the data allowed the researcher to cross-check the data for accuracy of facts presented as well as the perspectives of the researcher. The data collected for this study consisted of written responses, interviews, classroom observations, field notes, and student document analysis. The multiple forms of data collected were utilized in the data analysis as a cross-check for accuracy in representation of the findings.

**Inter-Rater Reliability**

The researcher and one other expert evaluated the pre-instruction and post-instruction transcripts of the participants in a randomized fashion. Both experts have experience in analyzing science education qualitative data. The expert was trained in how to utilize the coding sheet. The agreement of the types of conceptual understandings
of the student participants was calculated. If the researchers did not agree on the specific code to associate with the interview response, a discussion followed and a consensus reached. The researchers were in agreement 100% after each student interview was coded.
CHAPTER 4

FINDINGS

Introduction

The purpose of this qualitative study was to understand and to describe the misconceptions that may exist among students with visual impairments and instructional techniques designed to help them learn scientific concepts. Teachers’ perceptions of student learning also were examined. Specifically, the study focused on the conceptual understandings of students with visual impairments about seasonal change. Data were obtained from students 1 week prior to and 2 weeks after instruction. The setting of the study included a residential school for the blind in the southeastern United States and a residential school for the blind in the Midwest. The students in the southeastern residential school received traditional instruction concerning seasonal change that included using textbooks, models, and verbal descriptions of astronomical phenomenon. Students in the Midwestern residential school participated in instruction that was inquiry-based to learn seasonal change concepts. The instructional strategies for the inquiry-based group included student generated models, graphs of temperature data, and 3-D models as previously described in chapter three.
Six research questions guided the research:

1. What are the representative types of conceptual understandings held by middle school students with visual impairments about the causes of seasonal change?

2. What are the conceptual understandings of middle school students with visual impairments about the cause of seasons before instruction?

3. What are the conceptual understandings of middle school students with visual impairments about the cause of seasons after instruction?

4. What are the conceptual understandings held by middle school students with visual impairments about the cause of seasons before and after instruction within both the comparison and inquiry-based group?

5. How do the conceptual understandings held by middle school students with visual impairments differ between groups from pre-instruction to post-instruction?

6. How do middle school science teachers’ perceptions of students with visual impairments learning compare to students’ documented learning of the causes of seasons?

As detailed in chapter three, the inquiry-based students participated in a series of lesson plans adapted by the researcher from The Real Reasons for Seasons: Sun-Earth Connections (Gould et al., 2004). Lesson plans were adapted for students with visual impairments utilizing recommendations from the field (Dion et al., 2000; Hadary & Cohen, 1978; Koenig & Holbrook, 2000; Kumar et. al., 2001; Willoubhy & Duffy, 1989) as well as field observations of successful astronomy methodologies.

The comparison group students participated in a curriculum that relied heavily on textbooks, lectures, and 3-D models.

The video-taped and audio-taped interviews were transcribed so that they could be analyzed and coded using the constant comparison analysis as outlined in chapter...
three. Participant responses were coded. The codes were then categorized according to the type of conceptual understanding: scientific, scientific fragments, alternative fragments with a scientific fragment, alternative, alternative fragments, and no understanding. Comparisons of types of conceptual understandings were made within each group. Finally, the types of conceptual understandings were compared between the inquiry-based group and the comparison group. Frequency counts were then obtained in order to determine the conceptual understandings demonstrated by both groups of participants both before and after instruction.

This chapter will describe the findings for the study. The findings are presented in seven sections: representative types of conceptual understandings, conceptual understandings before instruction, conceptual understandings after instruction, comparison of conceptual understandings before and after instruction within each group, comparison of conceptual understandings between the groups, perceptions of teachers, and summary.

Representative Types of Conceptual Understandings

Creation of the initial categorization of alternative and scientific conceptions was based upon the Trundle, Atwood, and Christopher (2007a, 2007b) system in which conceptual understandings were divided into seven major categories: scientific understanding, scientific fragments, scientific with alternative fragments, alternative fragments with a scientific fragment, alternative, alternative fragments, and no understanding. See Table 3.4 for a description of the categories of conceptual understanding. Each category reflects the types of conceptual understandings that have
been described in previous science content areas involving conceptual change (Adadan et al., 2007, 2008; Bell & Trundle, 2008; Trundle et al., 2002, 2007a, 2007b; Ucar, et al., 2007).

Descriptions of the representative types of conceptual understandings are provided in order to answer the first research question. The purpose of this question is to provide the reader with an example of each type of conceptual understanding found in this study. See Table 3.4 for a listing of the types of conceptual understandings. Results are presented in this section from data from either group. In order to help the reader better understand the results, excerpts from some of the participants’ interview responses, as well as the assigned codes, are also provided as representative examples of each type of conceptual understanding.

1. What are the types of conceptual understandings held by middle school students with visual impairments about the causes of seasonal change?

**Scientific**

In order for a student’s understanding of the cause for seasons to be categorized as scientific, a student had to exhibit conceptual understanding of four critical elements of scientific understanding: 1) The Earth is tilted (SCI-TILT), 2) The Earth moves in an orbit around the Sun (SCI_ORB), 3) The tilt in relation to the orbit results in different places on Earth receiving varying amounts of sunlight throughout the year (SCI_LIGHT), and 4) This variable in the amount of sunlight results in changes of temperature and daylight (SCI_TEMP) (AAAS, 1993; Jones & Edberg, 1990; NRC, 1996; Ridpatch, 1987). An excerpt from a student interview transcript follows and provides an example
of a student who held a scientific understanding. Key concepts from the interview are in bold with the related code.

Student 6, Inquiry-Based Group, Post-instruction Interview

Researcher: Now I want you to tell me verbally what causes the different seasons on Earth.

Student: …the axis being tilted, (SCI_TILT) …the light can reach the Earth at different intensities, so we get more light in certain seasons than we do in other seasons. (SCI_LIGHT)

Researcher: O.K. Anything else?

Student: …temperature change maybe, because that is an indicator of seasons really. Temperature change might be an indicator. (SCI_TEMP)

Researcher: Okay. What does it [Earth] do [in relationship] with the Sun?

Student: It goes around the Sun. (SCI_ORB)

Researcher: O.K. So we will try it with the model. We are going to use a tactile globe that you have in your hands and the lamp to represent the Sun and then I want you to explain to me first what causes seasonal change. Can you get up and show me what causes the different seasons on Earth?

Student: I think…(Student stands up and begins moving the Earth in an orbit around the “Sun” keeping the globe tilted at an angle) (SCI_ORB; SCI_TILT). And the light intensity increases and decreases with the seasons. (SCI_LIGHT)

Scientific Fragments

A participant’s overall understanding was categorized as scientific fragments if the responses contained a subset, not all, of the scientific conceptions of causes of seasons and no alternative ideas were included in his/her answers. Student 4 exhibited scientific fragments during her post-instruction interview. Student 4 demonstrated
understanding that: 1) The Earth is tilted (SCI-TILT), 2) The Earth moves in an orbit around the Sun (SCI_ORB), and 3) Different amount of sunlight results in changes of temperature and daylight (SCI_TEMP). Transcripts of student 4 are presented below. The scientific understandings of both students are highlighted in bold followed by the coding for each.

Student 4, Inquiry-Based Group, Post-instruction Interview

Researcher: I want you tell me verbally what causes the different seasons on Earth.

Student: The Earth rotates around the Sun. (SCI_ORB) And the Sun warms different parts of the Earth (SCI_TEMP)…

Researcher: When you say the Sun warms different parts of the Earth, what happens?

Student: Different parts are warmer than other parts. (SCI_TEMP)

Researcher: Now, using the tactile globe and a lamp to represent the Sun, can you explain to me why the seasons change?

Student: It [Earth] tilts like this (Student tilts the Earth model at approximately a 20 degree angle) (SCI_TILT)...as it goes around (SCI_ORB) (Student moves the globe around the “Sun” in a circular pattern keeping the globe tilted in the original position.)

Alternative Fragments with a Scientific Fragment

Alternative fragments with a scientific fragment conceptual understanding resulted from a student including multiple alternative conceptions and only one scientific conception of causes of seasons. One student held this type of conceptual understanding during the post-instruction interview. For example, student 3 demonstrated conceptual
understanding that the Earth moves in an orbit around the Sun (SCI_ORB). However, this same student exhibited alternative understandings in his answer as well. He stated that the Earth’s rotation on its axis (ALT_ROTATION) was a cause for seasons as well as a difference or change in the tilt of the Earth as it orbits around the Sun (ALT_WOBBLE). The transcript of this interview is found below and coded in bold to demonstrate this type of conceptual understanding.

Student number 3, Comparison Group, Post-instruction Interview

Researcher: What causes the different seasons on Earth?

Student: Well if it [Earth] is like this (Student tilts the northern portion of the globe towards the “sun” at an angle) and this part is the north it would be summer for this entire part of the Earth (student runs hands over the entire northern portion of the globe) But as it is spinning around it will end up like that (Student moves the globe like a windshield wiper to move the Northern Hemisphere away from the Sun and point the Southern Hemisphere toward the “Sun”) (SCI_WOBBLE).

…it will be like this (Student moves the globe to original position) in the summer…and as it goes around (Student rotates the glove so that the portion originally facing the “Sun” is now facing away from the “Sun”)..and then when it goes around to the other side it would be winter (ALT_ROTATION)

Researcher: How long does it take to spin around like that?

Student…365 days for it to go around the Sun (SCI_ORB)

Alternative

The most common type of conceptual understanding among students during pre-instruction interviews was alternative conceptions. Participants who held alternative conceptual understandings held beliefs about seasonal change that did not agree with the
scientifically accepted norms (Atwood & Atwood, 1996, Hsu, 2008). Students with this type of conceptual understanding believed propositions such as the causes of seasons the change in moisture levels in the atmosphere, the rotation of the Earth on its axis, and the wobble of the Earth’s tilt during the orbit around the Sun; a movement similar to a windshield wiper where the Northern Hemisphere is moving from left to right as it orbits the Sun. The alternative conceptual understandings described above represent the codes of rotation, wobble, and moisture.

**Rotation**

A commonly held misconception was that of the Earth’s rotation on its axis causing the seasons. The students with this misconception indicated that the geographic position of the Earth facing the Sun has summer while the part of the Earth that is facing away from the Sun is having winter (Atwood & Atwood, 1996). The change in geographic position that causes seasons is due to the rotation of the Earth on its axis, according to the students with this misconception. Excerpts from participant responses coded as rotation follow. Responses that were coded rotation are in bold with the code (ALT_ROTATION) listed in parenthesis.

**Student 5, Inquiry-Based Group, pre-instruction Interview**

Researcher: What causes the different seasons on Earth?

Student: The Earth it turns while it’s going around the Sun. (Student moves hands in a spinning motion while speaking.)...My hand is the U.S.A. and this here is the Sun (Student makes a fist with his other hand.) **O.K. The U.S.A., this is summer right now. Now it is going around here and it is turning, now it is Fall.** (Student moves “U.S.A” hand a quarter turn clockwise while keeping
the “Sun” in close proximity.) (ALT_ROTATION) [Student continues to make these quarter turn motions with his hand in order to describe all 4 seasons.]

[Similar to the hand motions explained above, the student continues this explanation when given a globe and a lamp representing the Sun until all seasons are explained.] I turn it 25 degrees counterclockwise and now it is Spring (Student moves the vertically positioned globe in a clockwise motion a quarter turn around the “Sun”) I move another 25 degrees counterclockwise and now it is winter(ALT_ROTATION)

Wobble

Another commonly held alternative conception was that of wobble. Participants stated that the tilt of the Earth changes during orbit around the Sun (Atwood & Atwood, 1996; Roald & Mikalsen, 2001). Students stated that the Northern Hemisphere faced toward the Sun during summer and away from the Sun during the winter. This understanding was described and demonstrated with a globe. The students moved the Earth so that that Northern Hemisphere moved from right to left. This motion is similar to that of a windshield wiper; the bottom portion of the wiper is stationary while the top moves back and forth from right to left.

Student number 4 of the inquiry-based group demonstrated this type of conceptual understanding in both her written statement and her pre-instruction interview. Excerpts from student interviews are shown below with the alternative understanding of wobble in bold and coded as ALT_WOBBLE.

Student 4, Inquiry-Based Group, pre-instruction Interview

Researcher: Can you show me where is summer for us? What would it look like for us?
Student: (Student moves the globe so that the Northern Hemisphere is pointed toward the “Sun”. Movement resembles a windshield wiper; moving the globe to the left.) (ALT_WOBBLE)

Researcher: O.K. Now where is winter?

Student: (Student moves the globe so that the Southern Hemisphere is pointed toward the “Sun” in the windshield wiper movement; moving the globe to the right as described above) (ALT_WOBBLE)

Moisture

Student 6 of the inquiry-based group indicated in her written statement that moisture in the Earth’s atmosphere caused the difference in the seasons. She stated that varying amounts of moisture in the Earth’s atmosphere caused the seasons to change. Below is her written statement. The conceptual understanding of moisture is indicated in bold followed by the label (ALT_MOISTURE).

Student 6, Inquiry-based Group, Written Statement

I think what causes seasons to change is the amount of moisture in the air. (ALT_MOISTURE)

Alternative Fragments

The coding for participants’ responses for this type of conceptual understanding included a subset or subsets of alternative conceptual understandings. Alternative fragments were the second most common type of conceptual understanding across both groups before instruction. Student 1 exhibited this type of conceptual understanding in the pre-instruction interview. She believed that seasons result from the Earth’s rotation on
its axis as well as change in distance between the Earth and Sun as the Earth orbited the Sun. Excerpts from her interview follow by her responses coded in bold.

Student 1, Comparison Group, pre-instruction Interview

Researcher: What causes the different seasons on Earth?

Student: It is summer here (Student points to the locations on the globe facing the “Sun”) and it is winter here (Student points to the side of the globe facing away from the “Sun”) (ALT_ROTATION)

Researcher: What would be winter [for us]?

Student: Uh…when it comes around like that (Student spins the globe 180 degrees so that the portion originally facing the “Sun” is now facing away from the “Sun”) (ALT_ROTATION)

Researcher: What happens between the Sun and the Earth [during different seasons]…What happens do you think?

Student 1: The Earth gets farther and closer to the Sun. It rotates around the Sun. (ALT_DISTANCE)

Conceptual Understandings Before Instruction

Research question 2 examines the types of conceptual understandings held by students before instruction for each group. Specifically:

2. What are the conceptual understandings of middle school students with visual impairments about the cause of seasons before instruction?

Before either type of instruction, middle school students with visual impairments mostly held alternative understandings of seasons. Only one student, a member of the inquiry-based group, held a scientific fragment of the cause of seasons, explaining only that the Earth orbited the Sun.
Pre-Instruction Results: Comparison Group

Prior to instruction, students in the comparison group (n=3) were asked to write about the cause of seasons as well as to participate in a pre-instructional interview.

Results of the types of understandings held by this group of students are presented below in Table 4.1. Students in the comparison group exhibited alternative understandings of the reason for seasons before instruction. No student exhibited any type of scientific understanding before instruction.

<table>
<thead>
<tr>
<th>Type of Conceptual Understanding</th>
<th>Comparison Group</th>
<th>Inquiry-Based Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Scientific Fragments</td>
<td>0</td>
<td>1 (25%)</td>
</tr>
<tr>
<td>Scientific Fragments with Alternate Fragments</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alternative Fragments with a Scientific Fragment</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alternative</td>
<td>2 (67%)</td>
<td>3 (75%)</td>
</tr>
<tr>
<td>Alternative Fragments</td>
<td>1 (33%)</td>
<td>0</td>
</tr>
<tr>
<td>No Understanding</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4.1: Frequencies of Types of Conceptual Understandings Before Instruction

Student 1 stated that the distance between the Earth and Sun as well as the Earth’s rotation on its axis as the cause for seasons. Student 2 demonstrated that he believed that the Earth’s rotation on its axis was also the cause for seasons. Student 3 thought that the Earth changed its tilt during the orbit around the Sun, describing a motion similar to a windshield wiper movement where the Northern Hemisphere moved from right to left depending on the season.
Pre-Instruction Results: Inquiry-Based Group

Prior to the inquiry-based instruction, students in this group (n=4) participated in a written and pre-instructional interview that was identical to their peers in the comparison group. Similar to the comparison group, most students who participated in the inquiry-based instruction also exhibited alternative understandings in the cause of seasons before instruction. See Table 4.1 above. Student 4 indicated that the reason was due to the Earth’s change in tilt as it orbited around the Sun. The Northern Hemisphere, as described by the student, moves from right to left like a windshield wiper as it orbited the Sun (ALT_WOBBLE). Student 5 responded that the causes for seasons were due to the Earth’s rotation on its axis (ALT_ROTATION) while student 6 said the cause for seasons was due to a change in moisture levels in the atmosphere (ALT_MOISTURE). Student 7 was the only student to indicate any type of scientific understanding. He stated that the reason for seasons is due to the orbit of the Earth around the Sun (SCI_ORB). He was able to describe that the Earth moved around the Sun in a circular pattern. This was a scientific fragment.

Conceptual Understandings After Instruction

The third research question was designed to examine the post-instruction interview results of both the comparison group and the inquiry-based group participants. Specifically:

3. What are the conceptual understandings of middle school students with visual impairments about the cause of seasons after instruction?

Middle school students with visual impairments who received traditional instruction regarding seasons continued to hold alternative conceptual
understandings after instruction. However, those who participated in an inquiry-based curriculum held scientific or scientific fragments as their understandings of seasons after instruction.

Post-Instruction Results: Comparison Group

Participants in the comparison group were interviewed approximately two weeks after completion of the traditional instruction unit on causes for seasons. Students with visual impairments who were taught causes for seasons with traditional instruction continued to hold mostly alternative conceptions regarding the causes for seasons after instruction. After instruction, student 1 held an alternative understanding of seasons. Student 2 exhibited an alternative fragment understanding of seasons, while student 3 had alternative fragments with a scientific fragment conceptual understanding. See Table 4.2.

<table>
<thead>
<tr>
<th>Type of Conceptual Understanding</th>
<th>Comparison Group</th>
<th>Inquiry-Based Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific</td>
<td>0</td>
<td>2 (50%)</td>
</tr>
<tr>
<td>Scientific Fragments</td>
<td>0</td>
<td>2 (50%)</td>
</tr>
<tr>
<td>Scientific Fragments with Alternative Fragments</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alternative Fragments with a Scientific Fragment</td>
<td>1 (33.3%)</td>
<td>0</td>
</tr>
<tr>
<td>Alternative</td>
<td>1 (33.3%)</td>
<td>0</td>
</tr>
<tr>
<td>Alternative Fragments</td>
<td>1 (33.3%)</td>
<td>0</td>
</tr>
<tr>
<td>No Understanding</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 4.2: Frequencies of Types of Conceptual Understanding After Instruction
The most common alternative reasoning held by students with visual impairments after being taught utilizing a traditional instruction was that the causes of seasons were due to the Earth’s Rotation on its axis (students 1, 2, and 3) and that the Earth wobbled in its orbit around the Sun; moving like a windshield wiper (student 2 and 3). Only one student (student 3) included a scientific idea within his alternative explanation. He understood that the Earth orbited the Sun and included this scientific fragment within his alternative fragment.

Post-Instruction Results: Inquiry-Based Group

After the inquiry-based instruction, middle school students with visual impairments all exhibited scientific or scientific fragments as their understanding of concepts related to the causes for seasons. See Table 4.2 above. Students 5 and 6 were able to articulate that: 1) The Earth is tilted (SCI_TILT), 2) The Earth moves in an orbit around the Sun (SCI_ORB), 3) The tilt in relation to the orbit results in different places on Earth receiving varying amounts of sunlight throughout the year (SCI_LIGHT), and 4) This variable in the amount of sunlight results in changes of temperature and daylight (SCI_TEMP) (AAAS, 1993; Jones & Edberg, 1990; NRC, 1996; Ridpatch, 1987).

Student 7 showed that he understood that the Earth is tilted (SCI_TILT) and that Earth moves in an orbit around the Sun (SCI_ORB). He also demonstrated that he knew many of the characteristics of seasons such as warmer temperatures in summer and different times for sunrise and sunset, but was unable to articulate the reasons for those change in temperature and sunlight. Student 4 was able to demonstrate conceptual understanding of
all the scientific concepts related to seasonal change except for an understanding that the amount of sunlight varies in different places on Earth throughout the year (SCI_LIGHT).

Comparison of Conceptual Understandings Before and After Instruction in Each Group

Question 4 examined the conceptual understandings before and after instruction.

Specifically:

4. What are the conceptual understandings held by middle school students with visual impairments about the cause of seasons before and after instruction within both the comparison and inquiry-based group?

The purpose of this question is to inform the reader of the change that occurred in each group before and after the instruction.

Middle School students with visual impairments who were members of the comparison group held alternative conceptual understandings both before and after the instruction. Students who participated in the inquiry-based instruction exhibited alternative conceptual understandings before instruction and more scientific understandings after instruction. In other words, the students’ conceptual understandings of the second group changed from alternative to scientific.

Difference from Pre-Instruction to Post-Instruction of Comparison Group

Middle school students with visual impairments who were members of the comparison group exhibited alternative conceptual understandings both before and after the pre-instruction interview. See Table 4.3.
## Table 4.3: Frequencies of Types of Conceptual Understanding Before and After Instruction

<table>
<thead>
<tr>
<th>Type of Conceptual Understanding</th>
<th>Comparison Group Before Instruction</th>
<th>Comparison Group After Instruction</th>
<th>Inquiry-Based Group Before Instruction</th>
<th>Inquiry-Based Group After Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2 (50%)</td>
</tr>
<tr>
<td>Scientific Fragments</td>
<td>0</td>
<td>0</td>
<td>1 (25%)</td>
<td>2 (50%)</td>
</tr>
<tr>
<td>Scientific Fragments with Alternative Fragments</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alternative Fragments with a Scientific Fragment</td>
<td>0</td>
<td>1 (33.3%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alternative</td>
<td>2 (67%)</td>
<td>1 (33.3%)</td>
<td>3 (75%)</td>
<td>0</td>
</tr>
<tr>
<td>Alternative Fragments</td>
<td>1 (33%)</td>
<td>1 (33.3%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No Understanding</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The results tended to show that the type of conceptual understandings of the students did not change very much from the pre-instruction interview to the post-instruction interview following the traditional curriculum. The exception was student 3 who had understood that the Earth orbited the Sun; a scientific fragment of the causes outlined above as the reason for seasons, which was included within his alternative understandings.

### Difference from Pre-Instruction to Post-Instruction of Inquiry-Based Group

Middle school students with visual impairments who participated in the inquiry-based curriculum exhibited mostly alternative conceptual understandings before instruction and more scientific understandings after instruction. In other
words, their conceptual understandings changed from alternative to more scientific. See Table 4.3 above.

Upon completion of the unit, all students in the inquiry group (students 4, 5, 6, and 7) exhibited conceptual understanding that the Earth is tilted (SCI_TILT) and that the Earth orbits the Sun (SCI_ORB). This was the only scientific understanding exhibited by student 7. However, student 4 could also describe the relationship between seasons and temperature (SCI_TEMP). Only students 5 and 6 were able to identify all four scientific explanations for seasons, adding that various locations on Earth receive varying amounts of sunlight causing different hours of daylight and temperature (SCI_LIGHT).

**Overall, middle school students with visual impairments tended to have a more scientifically accurate understanding of seasonal change after participating in inquiry-based instruction.**

Comparison of Conceptual Understandings Between Each Group

Question 5 compares the conceptual understandings of both the inquiry-based group and the comparison group. Specifically, data are provided for the reader that compares the conceptual understandings of both groups. The question asks:

5. How do the conceptual understandings held by middle school students with visual impairments differ between groups from pre-instruction to post-instruction?

The results for the comparison group and inquiry-based group are summarized in Table 4.3 above. **Compared to the traditional instruction, middle school students with visual impairments tended to have a more scientifically accurate understanding of seasonal change after participating in an inquiry-based instruction. Students who**
were taught utilizing a traditional curriculum tended to hold onto their original alternative conceptual understandings. Before instruction, students who were members of the inquiry-based group and the comparison group mostly held alternative understandings about cause for seasons. Only one student, student 7 of the inquiry-based group, exhibited any level of scientific understanding. He was able to include within his response Earth’s orbit of the Sun. **Therefore, students with visual impairments in both groups tended to exhibit an alternative understanding of the cause of seasons before instruction on the topic.** No student that participated in this study had a complete scientific understanding of the cause of seasons before instruction.

After instruction, students in the comparison group were not able to demonstrate a scientifically accurate conceptual understanding of the reasons for seasons upon completion of the traditional instruction. Only one student in this group was able to identify any scientific understanding of the cause for seasons. He stated that the Earth orbits the Sun and he included this scientific fragments within his alternative post-instruction response.

All students in the inquiry-based group could demonstrate conceptual understanding of the Earth orbiting the Sun as well as the Earth is tilted as it orbits the Sun after instruction. **Therefore, the middle school science students with visual impairments in this study were much more likely to hold scientific conceptual understandings after they participated in the inquiry-based instruction.**
Teacher Perceptions of Middle School Students’ with Visual Impairments Learning

In order to assess how middle school science teachers of students with visual impairments perceived their teaching methodologies and student learning, interviews were conducted both before and after instruction for both the comparison group teacher and the inquiry-based teacher. The following research question was asked:

6. How do middle school science teachers’ perceptions of students with visual impairments learning compare to the students’ documented learning of the causes of seasons?

The comparison group teacher’s perceptions of his students learning were not reflective of the students’ documented learning of the causes of seasons.

Conversely, the inquiry-based teacher’s perception of her students’ learning was more reflective of the students’ documented learning of the causes of seasons.

Results: Pre-Instruction Teacher Interview

Middle school science teachers of students with visual impairments were interviewed before and after instruction during the same time intervals as their students. Both classroom teachers were interviewed in order to probe their thinking about classroom practices and instruction about seasonal change. General questions were asked of the classroom teachers such as: How do you present seasonal change to your students?; What methodologies do you utilize?; What can I expect to see in your classroom as students begin this unit? In order to determine how comfortable the inquiry-based classroom teacher was in using this instruction, a series of questions were asked such as: How do the inquiry-based methodologies compare with what you have done?; How
comfortable are you with inquiry-based methodologies? Would you use the inquiry-based instruction in the future?

Comparison Teacher Interview

The comparison teacher began by explaining to the researcher his definition of teaching in a traditional manner. He explained that he would use models, textbooks, and handouts. He explained to the researcher would be seen in his classroom as well. The transcripts of the interview are presented below.

Pre-instruction Interview: Comparison Teacher

Researcher: How do you present seasonal change to your students?

Teacher: Probably in a rather traditional manner. We go through why the Earth has seasonal changes, we look at, we use models, I have a model of the Earth, the moon, and the sun, that uh… they can actually see or feel what the planet Earth is doing in relation to the moon and sun, and how the Earth tilts on its axis as it goes through its annual, uh… movement around the sun, how it spins on its axis as well to create days. (Teacher nods and stops talking)

Researcher: O.K. And you talked a little bit about your methodology that you used with models, do you use any other methodologies in your curriculum?

Teacher: The model that I have which, I don’t have in my room at the moment, is probably my biggest tool that I use. Sometimes I have the kids hold their… their fists as if the fist was the Earth and/or the Sun so that they can feel by using their hands as to how the Earth moves around the Sun and then I do the same thing with the moon and its movement around the Earth.

Researcher: Will you use a textbook, or any handouts, or…

Teacher: Oh yes. And of course I use the textbooks and the uh… the class that we are working with here has very good… uh, diagrams created in the Braille textbook as well, so that the students can read those Braille diagrams as well as the students who are visual.

Researcher: O.K. What can I expect to see in your classroom as students begin this unit?
Teacher: Well the unit is on season, seasons, weather, moon phases, and that sort of thing.

Observations of Comparison Teacher

The comparison teacher’s account of what was to happen during the instruction was accurate. As an observer in his classroom, the researcher concurs that the curriculum he taught was exactly how he described it in his interview. The teacher relied heavily on textbooks during instruction. He read passages to his students about causes for seasons, had students answer the questions provided in the textbook, and had his students look up definitions to key terms in their texts. The comparison teacher used two 3-D models in the class. One model was a tactile globe mounted to a pole at approximately a 20 degree angle. He had students touch the model so that they could see the tilt of the Earth. The other model used in the classroom was of the Earth, Sun, and Moon. The Earth and Moon were on a chain that when spun, the Earth revolved around the Sun while the Moon revolved around the Earth. The students explored this model tactually in order to see the relationships between the Earth, Moon, and Sun in space. The teacher also had students create the revolution of the Earth around the Sun by using their hands to represent the Sun and the Earth. The Sun was represented with a clinched fist. The Earth was represented with a flat palm that would move in circular motion around the clinched fist. For a more detailed description about the comparison group instruction, see chapter three.

What was not described by the teacher was the apparent lack of motivation of his students. The comparison group students did not appear to fully participate in the instruction. Many of the students had their heads down and were reminded by the teacher
to stay awake in their class. Students also needed reminding of what page to look at in the textbook as the teacher was reading or to answer specific questions in the text.

While the account of instruction by the comparison teacher was accurate, he did not describe how students would be reacting to his instructional techniques.

**Inquiry-Based Teacher Interview**

The inquiry-based teacher began her interview describing how she would normally teach seasonal change in her classroom followed by her expectation of the new curriculum she was about to use. She also discussed her comfort levels with using an inquiry-based curriculum. A portion of her interview with the researcher is presented below.

Pre-treatment Interview: Inquiry-Based Teacher

Researcher: How do you usually present seasonal change to your students?

Teacher: Typically by using globes and a light source, generally.

Researcher: Do you rely heavily on a textbook?

Teacher: Uh, yes, I also use a textbook. There is, one of the chapters in my junior high textbook goes over seasonal changes, eclipses, the Moon, Sun, Earth relationship. So I typically use that in addition to some tactile materials and I also have some tactile diagrams that I use.

Researcher: My next question was what methodologies do you utilize? You said the textbook, the tactile diagrams, and the model.

Teacher: Correct.

Researcher: Do the kids interact with the models and the…

Teacher: Yes, yes.
Researcher: What can I expect to see in your classroom as students begin this unit? You have looked over some things.

Teacher: Uh-huh.

Researcher: What are some of your expectations?

Teacher: Well, I think probably my biggest expectation is that, uhm…the kids, some of the kids are going to struggle with the material, the grade level of the material is such that I think it is a little more advanced than some of my students are, even though I know it is geared toward middle school students. I have to heavily modify things and so that is probably one of the things I am going to have to do with this curriculum.

Researcher: O.K.

Teacher: Also it is fairly comprehensive and that looked like it was going to be an issue to me where it looked like I was going to take more time than it would probably typically take in a normal classroom situation in a public school setting.

Researcher: Are there any lessons that you feel were not beneficial to your students as you looked over them in your opinion?

Teacher: No, not at this point, not right now.

Researcher: How do the inquiry-based methodologies compare with what you have done in the past?

Teacher: Um…I have used some of this, uh, typically I have used stuff from, some of the stuff from the GEMS series in the past, so I know that is where you got a good chunk of this curriculum. So…typically I mix that in and I have over the course of the last number of years.

Researcher: O.K. How comfortable are you with inquiry-based methodologies?

Teacher: I am fine with that.

Researcher: And would you use the inquiry-based methodologies in the future?

Teacher: Yeah!
Observations of Inquiry-Based Teacher

The inquiry-based teacher’s interview indicated that she would typically teach using many of the same methodologies as the comparison teacher in her classroom when teaching seasons to her students: models, textbooks, and tactile diagrams. Observations of this traditional teaching methodology were not made in her classroom. However, for this study, she used an inquiry-based approach with her students as described in chapter three. The teacher seemed very comfortable with this teaching methodology as she stated in her interview. Her lessons were very fluid. She seemed very comfortable with allowing the students to guide their own learning and to ask questions as they arose. These questions never seemed to get her off track and she was able to tie the student questions to the materials and topics being taught in the classroom.

She stated that she had some fear that her students may struggle with the material and lessons that were developed by the researcher for her students. However, the teacher never let the students know these fears. She praised her students for their participation and encouraged them to try to answer all questions she asked. As an observer in the classroom, the researcher would never have known the teacher was concerned that her students would struggle.

The inquiry-based teacher stated that she was also concerned about the time the lessons would take to teach in her classrooms. Again, this was never shown in her classroom. Students were never rushed through lessons and if time ran out during a particular instructional period, the lesson was picked up the very next day. She even built in extra time in her teaching schedule to accommodate time that may be needed in
addition to the scheduled time with the researcher. The teacher stated that over the course of the past few years, she has used some of these methods in her teaching. The researcher was unable to observe past teachings, however she appeared to be experienced with the inquiry-based methodologies she was asked to teach. The teacher also indicated that she would continue to do so. The researcher was unable to observe future lessons of the teacher.

Observations confirmed the fidelity of the instruction implementation. The techniques used in the classroom of the inquiry-based teacher did reflect inquiry-based methodologies. Fears of student comprehension of topics and materials as well as time were not evident in her teaching. What was evident was her ease in teaching seasons using inquiry-based methodologies.

Results: Post-Instruction Teacher Interview

Post-instruction interview questions allowed the teachers to reflect on the curriculum taught as well as student learning. General questions were asked such as: Overall, how do you feel the lessons were received by the students?; Overall, do your feel your students learned the topic presented?; Are there any lessons that were not beneficial to the students in your opinion?; Which lessons do you feel were most beneficial?; How did the treatment methodologies compare with what you have done in the past?; What would you change when you teach this topic again in the future?

Comparison Teacher

The comparison group teacher’s post-instruction interview was very brief. He did not elaborate on many of his answers even though he was given the opportunity. He
indicated in his interview that he felt that the students had learned a lot about seasons from his instruction. He felt that most of them knew the scientific reasons for seasons and had learned it quite well. The teacher felt that all of his lessons were beneficial to his students. He stated that he might do a little preliminary study of the Earth, oceans, and plate tectonics before teaching about seasons next time. See a portion of the transcript of interview below.

Post-Instruction Interview: Comparison Teacher

Researcher: Overall how do you feel that the lessons were received by your students?

Teacher: Very well, and I think they learned a lot about the seasons. Most of them knew the rudiments.

Researcher: Good, and our next questions was overall do you feel your students learned this topic you presented?

Teacher: I believe they learned it quite well.

Researcher: And, are there any lessons that were not beneficial in your opinion?

Teacher: No.

Researcher: Which lessons do you feel were most beneficial?

Teacher: (Pause)...I think all were about equal in there effectiveness to further the kids’ understandings about seasons.

Researcher: And what would change when you teach this topic in the future if anything?

Teacher: I might do a little preliminary study of uh…the Earth, the oceans, and the tectonic plate movements before we got into seasons.
Comparison Teacher’s Perceptions vs. Documented Student Learning

The comparison teachers’ perception of his students’ learning was not reflective of the actual learning of his students. The comparison group teacher indicated that he believed his students had learned the material. However, all of the students in the comparison group still had alternative ideas about causes for seasons after instruction. All three of his students included the rotation of the Earth on its axis as a cause of seasons within their explanation which is an alternative understanding. In addition, students 2 and 3 also believed that the Earth’s tilt moved back and forth during its orbit. This was an additional alternative fragment within their explanation. Only one student, student 3 was able to demonstrate any type of conceptual understanding of seasons. He understood the Earth orbited the Sun. However, this scientific fragment was in addition to the alternative fragments he held. See above for comparison group student understandings.

Inquiry-Based Teacher

The post-instruction interview of the inquiry-based group teacher indicated that she felt that the students had learned a lot from the interview. She indicated that the students enjoyed the lessons and were active participants in each component of the unit. Her fear about time needed for the unit had changed. She indicated that the time frame worked for her classroom schedule. Fears about the lessons being too difficult also changed. She indicated that the modifications made the curriculum accessible to her students. The inquiry-based teacher felt that a few lessons still needed to be changed a
little more, but for the most part, all of the lessons were beneficial to her students; specifically lesson 7 on Earth models. There were some difficulties with the lamp used to represent the Sun. The lamp would only tilt at one angle, and the heat was not great enough for all students to feel. A new heat/light source that could be mounted to the ceiling or a physical bar over the desks should be used in the future. Therefore, the lesson was difficult for some students to access, but the concepts appeared to be learned by all of the students. Some reservations were expressed regarding student learning. The teacher felt there might still be some confusion about concepts, but stated that she could see growth in her students. She expressed to the researcher that she would not change anything when this topic was taught in the future. As a follow-up to a question about teaching in the future, she indicated that she had conducted a research project of her own and had taught the exact same unit to her 8th grade students. She stated that the students learned a lot from the unit and showed tremendous growth. The teacher utilized the same Sun-Earth Survey from the lessons to measure their learning. The 8th grade class was able to identify all of the causes of seasons by the end of the unit. In addition, this teacher also taught the lesson regarding orbits with her high school class that was learning about orbits of the planets in our solar system. Again, she saw similar results. Currently this teacher is writing an article for other science teachers about her positive experiences with this instruction. Portions of the transcript from her interview are presented below.
Post-Instruction Interview: Inquiry-Based Teacher

Researcher: Overall how do you feel the lessons were received by the students?

Teacher: I think they really enjoyed them. I think they participated, you got full participation from most of the kids and I think that they…it brought concrete examples to some abstract concepts, so I think that was good for them…and I think they seemed to really enjoy them so…

Researcher: Do you feel your students learned the topic?

Teacher: I think for the most part. I think there is still a little confusion there, but for the most part I think that when you look at the results of the survey compared to the beginning there was definite growth.

Researcher: Do you feel there were any lessons that were not beneficial?

Teacher: No, I don’t think there were any that were not beneficial with the modifications we made, they were all very…we were able to get through the material in a time frame that made sense and I thought that all of the lessons hit the major points that you needed to hit so…

Researcher: In a follow-up, Is there any lessons, or which lesson do you feel was the best out of all of those topics, was the most beneficial to the students?

Teacher: The one I thought was, but there was still a little confusion and I somehow we need to clarify that a little bit or maybe tweak it or change it a little bit was the lesson where you had the models of the Earth on the axis. I think that that would probably could have been the best lesson, but there were little snafus and things that didn’t work out quite right but ultimately that is probably, that one and also looking at the temperature graphs. I thought that was really, really helpful and day and night.

Researcher: And all the students seemed to talk about that.

Teacher: They did. Yeah, they really liked those. And I actually the one…and I think this was beneficial…the one where we went out and looked at the distances…um relative distances. I thought the lessons were pretty well done and everything flowed really well and No! I don’t think I would change it.
Inquiry-Based Teacher’s Perceptions vs. Documented Student Learning

The inquiry-based teacher expressed concerns that her students may exhibit some confusion regarding concepts related to reasons for seasons. She also said in her interview that “…for the most part I think that when you look at the results of the survey compared to the beginning there was definite growth.” This growth is evident in the results of the interviews from her students. During the student pre-instruction interview of the inquiry-based group, 3 of the 4 students exhibited alternative conceptions regarding the causes for seasons as described above. Only one student had any scientific understanding of the causes of seasons, and that was indicated in his written statements where he described the Earth orbiting the Sun. However, by the post-instruction interview, all 4 students had changed their conceptual understanding of reasons for seasons. Students 5 and 6 could demonstrate conceptual understanding for all of the reasons for seasons. Student 5 also realized his mistakes in the pre-interview and spent most of his interview describing these mistakes to the researcher. At one point when the researcher tried to redirect his thoughts from his new understanding that the rotation of the Earth on its axis was not the cause of seasons, but the cause of day and night, he said “First I am going to show you this…” and continued to tell the researcher his new conceptual understanding of day and night. Student 6 seemed to have a similar experience in becoming aware of her new and deeper conceptual understanding. She indicated that the reason for seasons was due to changes in levels of moisture in the atmosphere. After instruction, she appeared to be more aware of her new understandings. She was meticulous in the way in which she presented her new understandings of the
seasons. She would stop herself if she felt her representations of the Earth and Sun were not scientifically accurate. For example, when the researcher was probing the student about the rotation of the Earth, the student stopped and said “…oh gee…I am trying to make it look realistic.” She then took a deep breath and went on to explain that the Earth rotates on its axis slowly while revolving around the Sun while carefully spinning the globe as she moved it around the Sun in a circular pattern. Her new understandings were communicated eloquently.

Student 4 could name 3 of the 4 scientific causes for seasons while student 7 could name 2 of the scientific causes for seasons. None of the students in the inquiry-based teacher’s participant group held any alternative conceptual understandings about causes of seasons.

The inquiry-based teacher’s perception of student learning reflected the actual student learning. Students were able to discuss and demonstrate a scientific understanding of seasons. According to the data, the student participants did not perceive confusion regarding concepts related to reasons for seasons; however, not all students in her class were participants in this study. Therefore, it is not known if confusion exists for these students.

Summary of Teacher Perceptions

The comparison group teacher accurately described the instructional techniques that he would use in the classroom; use of textbooks, 3-D models, and lectures. These techniques were observed by the researcher. However, the researcher also observed an
apparent lack of student motivation in the classroom that the comparison teacher did not comment on in his pre-instruction or post-instruction interview.

In the post-instruction interview, the comparison teacher commented on his perceptions of student learning. The comparison teachers’ perception of his students’ learning was not reflective of the actual learning of his students. The comparison group teacher indicated that he believed his students had learned the material. However, all of the students in the comparison group still had alternative ideas about causes for seasons after instruction.

The inquiry-based teacher described her teaching techniques used in her classroom in the past as well as her fears with new curriculum. Her traditional techniques of teaching were never observed by the researcher. The fears she spoke of were never apparent in her classroom during the current study. Her teaching was fluid and allowed students ample time to explore the materials used in her teaching.

The post-instruction interview of the inquiry-based teacher talked about her perceptions of student learning. Her perception of student learning reflected the actual student learning. Students were able to discuss and demonstrate a scientific understanding of seasons.

Chapter Summary

Middle school students with visual impairments tended to have an alternative understanding of seasons before either type of instruction. One student, a member of the inquiry-based group, could identify the scientific fragment that the Earth orbits the Sun. All other students held alternative ideas about the causes of seasons. They
identified that the Earth’s tilt moved back and forth during the orbit, the Earth’s rotation on its axis caused the seasons, as well as the Earth’s moisture levels all led to different seasons.

Upon completion of the curriculum, students who were members of the comparison group continued to hold alternative conceptual understandings. No participant of this instruction could identify all of the scientific reasons for seasons. All three of the students still held alternative understandings after instruction was given. Only one student, student 3, was able to identify that the Earth orbited the Sun, a scientific reason for season that he also included within his alternative understanding. Their teacher felt that the students had learned the material and would successfully answer the interview questions regarding seasons. Students were not able to demonstrate a scientifically accurate conceptual understanding of the reason for seasons as their teacher had perceived.

Compared to the traditional instruction, middle school students with visual impairments tended to have a more scientifically accurate understanding of seasonal change after participating in an inquiry-based instruction. Two students, students 5 and 6 were able to identify all 4 reasons for seasons, while students 4 and 7 were still able to demonstrate scientifically accurate reasons for seasons but lacked all four reasons in their responses. No student in the inquiry group held an alternative understanding after completion of the curriculum.

The comparison group teacher indicated in his interview that he felt that the students had learned a lot about seasons from his instruction. He felt that most of them
knew the scientific reasons for seasons and had learned it quite well and would be able to demonstrate scientific conceptual understanding about causes of seasons. However, these perceptions of his students’ learning were not reflective of the actual learning of his students. The comparison group teacher indicated that he believed his students had learned the material. However, all of the students in the comparison group still had alternative ideas about causes for seasons after instruction.

The inquiry-based teacher perceived that her students may have trouble with the curriculum; however, in the post-instruction interview she felt that the lessons were ultimately beneficial to her students and will be used in the future. The inquiry-based teacher’s perceptions of the lessons were documented in the students’ ability to show at least some scientific understanding of seasons and no alternative understandings.
CHAPTER 5

CONCLUSIONS

Introduction

The purpose of this qualitative study was to understand and describe the misconceptions that may exist among students with visual impairments and instructional techniques that may help them learn scientific concepts. Teachers’ perceptions of student learning were also examined. Specifically, the study focused on the conceptual understandings of students with visual impairments about seasonal change. Data were obtained from students 1 week prior to and 2 weeks after instruction. The setting of the study included a residential school for the blind in the southeastern United States and a residential school for the blind in the Midwest. The students in the southeastern residential school received traditional instruction concerning seasonal change that included textbooks, 3-D models, and lectures. Students in the Midwestern residential school received instruction that was inquiry-based and focused on seasonal change concepts. The instructional strategies for the inquiry-based group included student generated models; graphs of temperature data; surveys of fellow students, friends, and family; as well as 3-D models. The instruction for both groups was described in more detail in chapter three.
This chapter discusses the findings in chapter 4 and situates these findings within the context of the previous literature in regards to seasons, inquiry-based education, and teacher perceptions. This chapter has 5 sections of discussion: seasonal change, inquiry-based learning, teachers’ perceptions, limitations of the study, and implications and recommendations for the future research.

Seasonal Change

The *National Education Standards* (NRC, 1996) and *Benchmarks for Science Literacy* (AAAS, 1993) both recognize that students in the middle school grades should have an understanding of the causes of seasons. Empirical research has shown that school aged children, university students, and school teachers have difficulty in fully understanding many astronomical concepts including seasons. Although understanding tends to improve with age, students and teachers alike still struggle with these important concepts (Atwood & Atwood, 1996; Bakas & Mikropoulos, 2003; Bisard et al., 1994; Hsu, 2008; Kikas, 2003, 2004; Roald & Mikalsen 2001; Trumper, 2001a, 2001b, 2006; Zelik & Bisard 2000). Research regarding the understanding that middle school students with visual impairments have about seasonal change does not exist in the literature. By analyzing sighted peers, one can begin to understand the trends that should be present among students with visual impairments if the students have equal access to the curriculum. However, researchers have not previously explored what conceptual understandings these students may have in regards to seasons since this topic is traditionally taught utilizing methods that rely on visual interpretations of the phenomena.
Further impacting this study was the lack of scientific educational research being conducted for students with visual impairments. Many manuals exist to explain how to teach students with visual impairments in the area of science (Dion, et al., 2000; Hadary & Cohen, 1978; Koenig & Holbrook, 2000; Kumar et al., 2001; Willoubhy & Duffy, 1989). However, very little research has been conducted to determine the effectiveness of these curriculum materials (Erwin, et al., 2001; Linn & Their, 1975; Long, 1973; Struve et al., 1975; Waskoskie, 1980).

By focusing on a segment of the population that traditionally does not have many scientific research studies in the literature, the present study makes a significant contribution to the field of visual impairments. A focus on students’ with visual impairments conceptual understandings of causes of seasons will further contribute to the understanding of society’s conceptions of the causes of seasons.

_Students’ with Visual Impairments Understandings of Seasons_

Both the comparison group and the inquiry-based group had alternative understandings prior to instruction intervention of the causes for seasons which have been shown in the previous research. Many of the students believed that the Earth’s rotation on its axis caused the seasons. Students reported that the geographical positioning of the Earth caused seasons: the portion of the Earth facing the Sun had summer while the portion facing away from the Sun had winter. These findings were similar to misconceptions pre-service teachers possessed as reported by both Atwood and Atwood (2006) as well as Taiwanese middle school students as reported by Hsu (2008). Another alternative understanding held by the students in this study was that the Earth’s tilt
changed in a back and forth motion as it orbits around the Sun, moving from right to left. This motion is similar to a windshield wiper. This same misconception was reported by Atwood and Atwood (1996) in their study with pre-service teachers as well as by Roald & Mikalsen (2001) in their study with hearing impaired students. One of the students stated that the Earth changed its distance from the Sun, thus causing the seasons, with summer happening when the Earth is closer to the Sun. This misconception was documented in the literature as the most common misconception held by the general population (Atwood & Atwood 1996; Bakas & Mikropoulos, 2003; Bisard et al., 1994; Hsu, 2008; Kikas, 2003, 2004; Roald & Mikalsen 2001; Trumper, 2001a, 2001b, 2006; Zelik & Bisard 2000). The current study provides evidence that this was not common for students with visual impairments as only one student identified distance as the cause for seasons. Keeping in mind that the reason most people report that distance plays a role in seasons may be due to problems with drawings in textbooks of orbital paths, it is not surprising that students with visual impairments who are not exposed to these types of drawings and representations would not exhibit this common misconception. One of the students in the current study stated that moisture in the air was the reason for seasons. This misconception was not documented in previous studies on seasons.

Following the instructional intervention with traditional instructional strategies, the comparison group still had alternative understandings about the causes for seasons. All three of these students included the rotation of the Earth on its axis as a cause of seasons within their explanations. In addition, students 2 and 3 also believed that the Earth’s tilt changed in its orbit, moving back and forth like a windshield wiper, and
included this fragment within their explanation. Holding onto misconceptions even after instructional intervention has been documented in the literature (Bakas & Mikropoulos, 2003; Hsu, 2008; Trumper, 2006). Only one student, student 3 was able to demonstrate any type of scientific understanding of seasons. He understood the Earth orbited the Sun. However, this scientific fragment was in addition to the alternative fragments he held.

The inquiry-based group did not hold onto their alternative conceptions after instruction. Students in this group all had at least some scientifically accurate reasons for seasons after they participated in inquiry-based instruction. All students were able to identify that the Earth orbited around the Sun and that the Earth was tilted. In addition to these understandings, student 4 was able to understand the reasons temperature changes on Earth. Students 5 and 6 could identify all of the above reasons as well as demonstrate an understanding of the changes in light. Therefore, the inquiry-based curriculum appeared to be beneficial to these students in helping them to construct new meanings for the causes of seasons similar to previous studies utilizing both constructivist teaching methodologies and virtual environments (Bakas & Mikropoulos, 2003; Hsu, 2008; Trumper, 2006). No study in the literature review demonstrated scientific understandings by all participants upon completion of an inquiry-based curriculum on seasons (Bakas & Mikropoulos, 2003; Hsu, 2008; Trumper, 2006) and none of the other studies included children with visual impairments.

Inquiry-Based Learning

Students in the inquiry-based group participated in a series of lessons to help them construct scientifically accurate meanings for the causes of seasons. The lesson plans
reflected inquiry-based process skills as well as meeting the standards laid forth in the National Science Education Content Standards (NRC, 1996).

As previously discussed, the students who were members of this intervention were more likely to construct scientific conceptual understanding than their peers in comparison group who participated in traditional teaching methodologies. This was similar to the results in the literature regarding participation of students with disabilities in inquiry-based instruction. Both Mastropieri (2005) and Lynch et al. (2007) found that inquiry-based instructional techniques were beneficial for students with disabilities. Missing from the reporting of these results were specific indicators that students with visual impairments would benefit from these techniques.

Inquiry-based learning utilizes constructivist epistemologies. Research involving constructivist epistemologies has shown that learners possess “…skills and attitudes important for learning such as critical thinking, self regulation, cognitive flexibility, the ability to communicate ideas, and to learn from collaboration” (Vosniadou, 2007b, p. 100). In addition to these skills, learners who are aware of their own beliefs tend to possess a deeper understanding of the world around them and ability to communicate that understanding (Stathopoulou & Vosniadou, 2007). However, if the learners have relied on rote memorization and superficial experiences that lack a purpose, they are unable to gain a deeper understanding of the world around them. This may explain the results of the comparison group’s lack of scientific understandings of seasons upon completion of their traditional curriculum.
Additionally, students may have been aware of their learning and beliefs. For example, student 5 appeared to become aware of his learning regarding the day and night cycle. He initially described the turning of the Earth on its axis, which actually causes the day and night cycle, as the reasons for seasons. In the post-instruction interview, he described not only all four scientifically accurate reasons for seasons, but he continuously told the researcher about his learning of day and night throughout the interview. At one point when the researcher tried to redirect his thoughts back to seasons, he said “First I am going to show you this…” and continued to tell the researcher his new conceptual understanding of day and night. This student appeared to be aware of the changes he had made in his beliefs and wanted to ensure that the researcher was aware of his new conceptual understanding.

This change reflects the research of Stathopoulou & Vosniadou (2007). Through participation in constructivist instruction, the student appeared to become aware that his previous beliefs about the rotation of the Earth on its axis causing seasons was incorrect. During instruction, the student participated in a lesson concerning the day and night cycle in which he rotated his body around a heat source to stimulate different times of the day. After completion of this lesson, the student was able to verbalize that the rotation of the Earth on its axis was not a cause of seasons. After participating in the inquiry-based instruction, it appeared that he possessed a deeper understanding of the day and night cycle as well as the causes of seasons and was able to communicate those conceptual understandings to the researcher based upon his post-instruction interview. See chapter 4 for transcripts from this interview.
Student 6 seemed to have a similar experience in becoming aware of her new and deeper conceptual understanding. She indicated that the reason for seasons was due to changes in levels of moisture in the atmosphere. After instruction, she appeared to be more aware of her new understandings. She was meticulous in the way in which she presented her new understandings of the seasons. She would stop herself if she felt her representations of the Earth and Sun were not scientifically accurate. For example, when the researcher was probing the student about the rotation of the Earth, the student stopped and said “…oh gee… I am trying to make it look realistic.” She then took a deep breath and went on to explain that the Earth rotates on its axis slowly while revolving around the Sun while carefully spinning the globe as she moved it around the Sun in a circular pattern. Her new understandings were communicated eloquently.

Students in the comparison group did not appear to gain this deeper level of understanding. The instruction relied heavily upon rote memorization without authentic experiences in their curriculum, as described in chapter three. No students in this group were able to change their alternative conceptions of the reason for seasons and express the scientific explanation for this phenomenon.

Not only did the inquiry-based learners appear to benefit from constructivist teaching but also from conceptual change theory. This theory has not been studied for students with visual impairments. It has influenced previous data collection for TVIs (Wild, et al., 2007) but not for students. In utilizing this theory, the teacher was able to attend to the beliefs of the students by assessing their preconceptions of seasons. She helped them to overcome some preconceptions through the lessons; addressing their
beliefs so that they could make a connection to change, as demonstrated by student 5 described above.

The inquiry-based teacher also motivated them to learn as outlined by Vosniadou (2001) when describing conceptual change in children. The lessons that were inquiry-based seemed to motivate the students. She would praise the students for their participation. After each lesson she would peek their interest with questions they would investigate the next day. The teacher also linked the lessons to previous instruction that the students enjoyed. The teacher never provided the students with answers to the questions they were investigating; the students would answer the questions on their own and were praised for their new conceptual understandings. Students appeared to be engaged in the lessons and were full participants as pointed out by the inquiry-based teacher in her interview. Student documents produced in the classroom and field notes verified her comments. The comparison group students were not motivated and did not participate fully as many of them had their heads down and were reminded to stay awake in their class.

Teacher Perceptions

The current study not only examined the learning of the students but also the presumptions of student learning made by the teachers involved. Both the comparison group teacher and the inquiry-based teachers’ interviews indicated that traditional teaching methodologies, as described in the literature, were typically utilized in their classrooms (Levitt, 2001; Roehrig & Kruse, 2005; Tsai, 2002). The teachers described using 3-D models and textbooks. Research has shown that science content educators’
beliefs affect the way in which the science curriculum is taught (Levitt, 2001; Roehrig &
Kurse, 2005; Tobin & Gallagher, 1987; Tsai, 2002). Specifically, the beliefs a science
content educator holds regarding the teaching and learning of science will determine, to a
great extent, the type of science education a child receives. In a traditional sense, there is
heavy emphasis on rote memorization and textbook reading. A teacher who utilizes
inquiry-based learning approaches entails hands-on experiences for the students (Levitt,
2001; Roehrig & Kruse, 2005; Tsai, 2002). The inquiry-based teacher spoke about
utilizing some inquiry-based learning techniques in her classroom in the past, but those
experiences were mixed with traditional methodologies. She expressed some fears and
hesitations about the new lesson plans adapted for her by the researcher; specifically time
issues and modifications that would be necessary for student participation.

After completion of each curriculum, both teachers felt their students benefited
from the curriculum they taught. The comparison group teacher felt that all of his lessons
benefited the students and they had successfully learned the materials. However, his
perceptions of his students’ learning did not reflect the actual learning which had taken
place. Following the intervention of the comparison groups’ instruction, none of his
students could scientifically identify the reasons for seasons. One student had added a
scientific fragment of the Earth orbiting the Sun to his alternative understandings and
alternative understandings were still present in all of his students as described above.

The inquiry-based teacher stated that her students had learned from the lessons,
and she spoke highly of the content of the lessons. She also said that she believed that
some of her students may still be a little confused, but overall, they had exhibited a
growth in understanding the content. Please note that not all students in the inquiry-based classroom participated in the study, so there was no way to provide evidence to support this statement. However, student participants in this group all exhibited at least a partial scientific understanding of the causes for seasons without any alternative conceptions after instruction.

Both teachers’ perceptions reflect the literature regarding teacher perceptions. Pajaras (1992) reported that teacher beliefs are personal and unaffected by persuasion. The beliefs can be formed through chance encounters, an intense experience, and a series of events. Beliefs include ideas about the person and about what others are like. Presumptions are entities that exist beyond the control or conceptual understanding of the individual and are believed by the individual because they are present. Students in the comparison classroom were interacting with the materials and answering the questions of the teacher; therefore, the teacher appeared to have presumed that the students had learned the concepts due to the series of events present in his classroom as described by Pajaras (1992). Similarly, the inquiry-based classroom teacher appeared to have made the same presumptions due to the series of events present in her classroom during instruction.

Students with Visual Impairments Conceptions of Causes of Seasonal Change

The purpose of this qualitative study was to understand and describe the misconceptions that exist among students with visual impairments and instructional techniques that may help them learn scientific concepts. In addition, this study examined the presumptions of teachers of the visually impaired in regards to student learning. To
explore these issues, 2 groups of students from residential schools for the blind were
examined as well as their teachers; one group was the comparison group while the other
was an inquiry-based group.

This investigation found that students with visual impairments have similar
understandings regarding causes of seasons before interventions were given. Students
believed that distance, rotation of the Earth on its axis, or a change in tilt resulted in
seasons. Before instruction, only one student could identify any fragment of a scientific
understanding, which was that the Earth orbited the Sun.

These conceptual understandings differed upon completion of instruction.
Students who were members of the comparison group participated in a curriculum using
traditional methods. Their peers in the inquiry-based group participated in lessons that
were taught utilizing constructivist methodologies and utilized science inquiry process
skills. After the instruction, students in the comparison group still exhibited conceptual
understandings similar to their pre-instruction ideas. All three of the students had
alternative understandings. Students 1, 2, and 3 believed the rotation of the Earth on its
axis caused seasons. In addition, student 2 also believed that the Earth’s tilt moved back
and forth during the orbit around the Sun which caused seasons. Only one student,
student 3 was able to demonstrate any type of scientific understanding of seasons. He
understood the Earth orbited the Sun. However, this scientific fragment was in addition to
the alternative fragments he held. Their peers in the inquiry-based group all had some
scientific understandings after participation in their intervention. Two students had a
complete scientific understanding of seasons.
The inquiry-based methods appeared to be a beneficial instructional methodology to help students learn the causes of seasons. These findings support the ideas of theoretical ideas of Vosniadou (2001) that conceptual change can occur in students. In this study, when the teacher was aware of the pre-conceptions of the students, which occurred during the discussion and tabulation of the first Sun-Earth survey results in lesson 2, and provided inquiry-based instruction, students can re-construct their own thinking regarding specific scientific phenomena. In addition, this study also supported previous work with students with disabilities stating the need for inquiry-based instruction (Lynch et.al., 2007; Mastropieri, 2005).

Finally, this study also reflects the work of Levitt (2001), Pajaras (1992), Roehrig & Kurse (2005), Tobin & Gallagher (1987) and Tsai, (2002) in which it is reported that teacher perceptions of student learning effects: 1) the teaching that takes place in the classroom and 2) views of student learning. Upon completion of the inquiry-based lessons, the inquiry-based teacher stated that she will continue to utilize these lessons in the future and will not change any lessons. The comparison group teacher stated he would not make any changes but would add only a few units before teaching seasons. Both felt that students learned the reasons for seasons. Data showed that students in the comparison group were not as successful as their peers in the inquiry-based group.

Limitations of the Study

This research project is limited by the sample of students who are involved in the study. In addition, research questions, curriculums, and the researcher could all mitigate interpretation of the results of this study as well as the ability to generalize the results.
The participants in this study were from two different states. The comparison group and the inquiry-based group of students were not exact in terms of demographics utilized for comparison. However, demographic information presented in chapter 3 showed many similarities in the participant groups, all of which were legally blind and attended a residential school for the blind. This information should assist the reader in determining the applicability of the findings to similar contexts.

The same teacher did not teach both the comparison group curriculum and the inquiry-based curriculum. Both teachers were experienced state licensed science educators and were pursuing a licensure for teaching students with visual impairments.

The interview questions are based upon known scientific phenomena: the causes for seasons. Therefore, the researcher is approaching this topic already aware of specific types of understanding that may be reported. Changes in the coding sheet were made when new data arose that were not reported previously in the literature. Another expert also assisted in coding and analyzing the data. The results were limited to the interpretations of the researchers. However, the results were subject to an interrater reliability check to ensure that the answers were properly coded.

The use of identical pre-instruction and post-treatment interview questions could influence the group of students receiving the intervention. The first interview may help in guiding students to key on particular concepts during the intervention that they may not have originally understood. However, according to Trundle et al. (2002) pre-instruction interview questions are not likely to influence the scientific accuracy of a response on post-treatment assessments. The results of this study show that students generally
exhibited a different conceptual understanding upon completion of the pre-instruction interviews and post-treatment interviews. Therefore, interview questions did not appear to have been an influence on students.

The curriculum utilized in instructing the inquiry-based group was modified by the researcher. The researcher was also the one evaluating the effectiveness of the instructional methods. Multiple forms of data were taken in order to assist in analyzing the effectiveness of the curriculum without bias: field notes, student documents, and interviews were utilized in reporting the results.

The curriculum utilized by the inquiry-based group involved approximately triple the instructional time of the comparison group. However, inquiry-based instruction takes longer and is a component of the instructional methodology chosen by the researcher. Beck, Czerniak, and Lumpe (2000) acknowledge that time can be a factor when teaching utilizing constructivist inquiry approaches. However, they suggest that once teachers are able to see the benefits utilizing this teaching methodology for their students, they are more apt to adapt this methodology and less likely to worry about the time difference. This was evident in the remarks made by the inquiry teacher. She was fearful of the time that the lessons were going to take, but upon completion of the curriculum, stated that benefits were worth the valuable time taken.

Ultimately, the results are limited to the interpretations of a panel of researchers. It is up to the reader to decide the applicability of this research study with similar situations and students.
Implications and Recommendations for Future Research

This study examines the conceptual understandings of middle school science students with visual impairments, who attended a residential school for the blind, before and after receiving instruction related to causes of seasons. As a result, several questions have emerged requiring further investigation. These questions are explored below and discuss the following topics: student misconceptions, instructional strategies, general education classroom placement versus special education placement, and science educators.

Students who participated in this study exhibited many misconceptions regarding causes of seasons. This is the first study of its kind in this field. What other types of misconceptions do students with visual impairments have in other areas of science? Science educators, science professors, science education professors, and preservice teachers need to know the common misconceptions held by their students in order to effectively plan their instruction concerning causes of seasons. Until this study, no other researcher had examined the misconceptions of causes for seasons of students with visual impairments. Since astronomy is typically taught by visual information, it is imperative that this work be continued.

The need for research-based practices in science education has been addressed by Congress in three pieces of legislation; Goals 2000, NCLB, and the Education Science Reform Act. Congress has mandated that instruction in the classroom should be the result of research-based best practices. The field of visual impairments has many manuals to explain how to teach students with visual impairments in the area of science (Dion et al.,
2000; Hadary & Cohen, 1978; Koenig & Holbrook, 2000; Kumar et al., 2001; Willoubhy & Duffy, 1989). However, very little research has been conducted to determine the effectiveness of these curriculum materials. The few research studies that have been conducted concerned adaptations made to specific curricula (Erwin et al., 2001; Linn & Their, 1975; Long, 1973; Struve et al., 1975; Waskoskie, 1980). Many of these curricula point to the release of Sputnik as inspiration for their work. These studies are out of date and do not reflect current content standards. Therefore, what methodologies are best to teach students with visual impairments?

Instructional strategies must be put into place that will allow the student to address misconceptions while assessing their own misconceptions in order to gain a deeper understanding of the world around them (Stathopoulou & Vosniadou, 2007). The results of this study suggest that instruction which utilizes inquiry-based methods and requires students to assess their own learning and ideas about causes of seasons has potential as a beneficial instructional methodology to help students to learn causes of seasons. However, this methodology needs to be tested in other areas of science as well.

All of the student participants in this study attend residential schools for the blind. Would the results be different if the students were members of a general education classroom? According to Waskoskie (1980), students with visual impairments did not have the same access to the general science education curriculum as their sighted peers. More recently, Wild, et al. (2007) reported that TVIs indicated that 55.85% of the students spent over 90% of their science instructional time in the general education classroom, whereas 9.09% of the students spend between 78-89% in the general
education classroom. Would the student participants in the general education science
classroom have similar misconceptions regarding causes of seasons? Would this
curriculum be beneficial to them? Would a resource science classroom show similar
results?

Science educators who teach students with visual impairments should be studied
as well. The current study showed that teachers’ perception of their students’ learning
was not always reflective of student learning. Future research should examine science
educator beliefs and the impact those beliefs have on student learning in the science
classroom.

These are only a few of the many research questions that the science education
community as well as the field of visual impairments, must address as it continues to
explore conceptual understanding of students in the development of scientific literacy.
LIST OF REFERENCES


Schnottz, W., & Preub, A. (1999). Task-Dependent construction of mental models as a
basis for conceptual change. In Schnottz, W, Vosniadou, S., & Carretero, M.

Seidman, I. (2006). Interviewing as qualitative research: A guide for researchers in
education and the social sciences. (3 ed.). New York, New York: Teachers
College Press.

Sage.

Research communities in the social sciences., In Somekh, B., & Lewin, C.


Stathopoulou, C., & Vosniadou, S. (2007). Conceptual change in physics and physics-
related epistemological beliefs: A relationship under scrutiny. In Vosniadou, S.,
Balta, A., Vamvokoussi, X. (Eds.). Reframing the conceptual change approach

science curriculum for the visually impaired on course objectives and
manipulative skills. Education of the Visually Handicapped, 7(1), 9-14.


School for the Blind.

Curriculum Studies, 19(6), 549-560.

Trumper, R. (2001a). A cross-age study of senior high school students’ conceptions of
basic astronomy concepts. Research in Science & Technological Education,

Trumper, R. (2001b). A cross-age study of junior high school students’ conceptions
of basic astronomy concepts. International Journal of Science Education, 23(11),
1111-1123.


Wentworth, B.L. (personal communication, August 2, 2007).


APPENDIX A

INTERVIEW QUESTIONS

Interviewer: Thank you for agreeing to help me with my project. I am going to ask you some questions today. You will not be graded on your responses. I want to understand what you think about causes for seasons. I may ask you to clarify your answers during this interview. Some of the questions will ask you to use a model in your answers. If you want to stop this interview at any time, please let me know. You will be audio-taped and video-taped so that I can look over your answers at a later time. Do you have any questions? Do you want to participate in this interview?

1. What causes the different seasons on Earth?

2. Why does the amount of sunlight vary from season to season?

3. If it is summer in your state, what season is it in Australia?

4. Do the North Pole and South Pole have seasons?

5. How do you know?

6. What happens during an equinox?

7. What causes autumn and spring?

8. Using a tactile globe and a lamp to represent the sun, can you explain to me why the seasons change?

9. What happens over time in your state as seasons change from summer to winter?

Thank you for your help. I appreciate you taking the time to answer my questions.
Interviewer: Thank you for agreeing to help me with my project. If you want to stop this interview at any time, please let me know. You will be audio-taped and video-taped so that I can look over your answers at a later time. Do you have any questions? Do you want to participate in this interview?

Inquiry Group Teacher

1. How do you usually present seasonal change to your students?
2. What methodologies do you utilize?
3. What can I expect to see in your classroom as students begin this unit?
4. Overall, how do you feel the lessons were received by the students? (post-instruction only)
5. Overall, do your feel your students learned the topic presented? (post-instruction only)
6. Are there any lessons that were not beneficial to the students in your opinion?
7. Which lessons do you feel were most beneficial?
8. How do the inquiry-based methodologies compare with what you have done?
9. How comfortable are you with inquiry-based methodologies?
10. Would you use the inquiry-based methodology in the future?
11. What would you change when you teach this topic again in the future? (post-instruction only)

Comparison Group Teacher

1. How do you present seasonal change to your students?
2. What methodologies do you utilize?
3. What can I expect to see in your classroom as students begin this unit?
4. Overall, how do you feel the lessons were received by the students? (post-instruction only)
5. Overall, do you feel your students learned the topic presented? (post-instruction only)
6. Are there any lessons that were not beneficial to the students in your opinion? (post-instruction only)
7. Which lessons do you feel were most beneficial? (post-instruction only)
8. What would you change when you teach this topic again in the future? (post-instruction only)
## APPENDIX C

### CODE SHEET

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition of Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI_TILT</td>
<td>The Earth is tilted. (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
</tr>
<tr>
<td>SCI_ORB</td>
<td>The Earth moves in an orbit around the Sun. (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
</tr>
<tr>
<td>SCI_VARSUN</td>
<td>The tilt in relation to the orbit results in different places on Earth receiving varying amounts of sunlight throughout the year. (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
</tr>
<tr>
<td>SCI_TEMPDAY</td>
<td>This variable in the amount of sunlight results in changes of temperature and daylight. (AAAS, 1993; Jones &amp; Edberg, 1990; NRC, 1996; Ridpath, 1987)</td>
</tr>
<tr>
<td>ALT_DIS</td>
<td>The distance between the Earth and Sun vary (Atwood &amp; Atwood, 1996; Bakas and Mikropoulos, 2003; Kikas, 2003; Roald &amp; Mikalsen, 2001; Trumper, 2001a, 2001b, 2006; Zelik &amp; Bisard, 2000)</td>
</tr>
<tr>
<td>ALT_WOBBLE</td>
<td>The tilt of the Earth changes during orbit around the Sun (Atwood &amp; Atwood, 1996; Roald &amp; Mikalsen, 2001)</td>
</tr>
<tr>
<td>ALT_QUALITY</td>
<td>Sun demonstrates different qualities in the summer and winter (Roald &amp; Mikalsen, 2001)</td>
</tr>
<tr>
<td>ALT_SHADOWS</td>
<td>Shadow of the moon causes winter (Roald &amp; Mikalsen, 2001)</td>
</tr>
<tr>
<td>ALT_CLOUDS</td>
<td>Winter is caused by the clouds (Roald &amp; Mikalsen, 2001)</td>
</tr>
<tr>
<td>ALT_POLE</td>
<td>Pole of the Hemisphere having summer is directly pointed at the Sun (Atwood &amp; Atwood, 1996)</td>
</tr>
</tbody>
</table>
The Earth turns on an axis. The geographical position facing the Sun is having summer. The geographical position facing away is having winter (Atwood & Atwood, 1996)

Varying amounts of moisture cause the seasons to change

Student Number _________________________

Question:

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________
9. ____________________________
APPENDIX D

LESSON PLANS

Lesson 1: Name the Seasons
Lesson 2: Sun-Earth Survey
Lesson 3: Trip to the Sun
Lesson 4: What Shape is the Earth’s Orbit?
Lesson 5: Temperatures Around the World
Lesson 6: Days and Nights Around the World
Lesson 7: Tilted Earth
Lesson 8: Analyzing the Sun’s Rays
Lesson 9: Seasons Unraveled

Activity 1: Name the Season

Overview: Students will focus on their own experiences with seasonal change before moving into the reasons for seasons. Students will write paragraphs depicting scenes or events that have recognizable season-related elements, but that do not mention an actual season name. A game will be played to see if classmates can identify the season in which the student is depicting.

Materials:
For the Student:
• Writing materials in the media necessary for the student (Braillewriter, Braille paper, bold lined paper, markers, paper, pencil, pen)

For the Classroom:
• Prize for the winners of the game
• Classroom Whiteboard

Introducing the Seasons:
1. Introduce the unit by telling the class that they will be studying a number of relationships between the Earth and the Sun, and in particular what causes seasons.
2. Ask, “What kinds of changes occur with the seasons?” Accept a variety of answers and jot them down on the whiteboard. A student may help in writing the answers for the teacher.
3. Read each answer to the students and have them indicate if the given answer describes a biological change (plants and animals), sociological change (events, clothing, celebrations, holidays), or meteorological change (weather).
4. In small groups, have the students create a quick chart of seasonal changes by making a list of biological, meteorological, sociological, sports events, and school events that occur during each season under the heading Fall, Winter, Spring, and Summer. For example:
   - **Fall**
     - Leaves change color
     - Temperature begins to drop
     - Wear sweatshirts and jeans
     - OSU Football
     - School year begins
   Have each group share with the class the charts they have just created.
5. Tell the students that they will now play a game called “Name the Season”. Mention that they can use the chart information they have just created.
• Each student will write a paragraph describing a season. The student is to write their name on the paper, but not the season they are writing about.
• The paragraph should describe some events and include clues about what season it is. Without actually naming the season, each student should make it possible for other students to figure out the season.
• The teacher may want to give the students some examples of what is expected. For example:
  - “I have really enjoyed getting my warmer clothes out of the closet. It has been fun wearing my new coat to school and watching the snow fall on my shoulders.”
  - “I have never sweated so much in my life. All I want to do is stay inside in the air conditioning and eat ice cream.”
  - “Today my friend and I went to the park and walked along the many trails. It was a beautiful site to see all of the leaves changing colors and falling to the ground.”
• The teacher will collect all of the students’ paragraphs. The teacher will then shuffle the papers in his/her hand.
• The teacher will begin by telling the students to write the name of the author on a sheet of paper.
• The teacher will read the author’s written work to the students.
• Upon finishing the paragraph, the teacher will tell students to write down the season the author is writing about. The teacher will remind the students to keep quiet and not share their answers with their neighbors.
• The teacher will continue the process until all paragraphs are written.
• The student who has identified the most correct guesses is the winner.
Lesson 2: Sun-Earth Survey

Before students can understand the reason for seasons, students need to know that the Earth is spherical, spins daily on its axis (rotates), and orbits the Sun (revolves). They also need to know what causes day and night. This class session starts with a brief activity to review these important prerequisite concepts.

Students will then answer questions on a short survey that focuses them on the following additional Sun-Earth concepts: the exact shape of the Earth’s orbit and the distance between the Earth and the Sun. The survey includes a multiple choice question about the causes of the seasons. For homework, students will use the same survey questions to ask friends and family members. In the next session, the class will pool its data and discuss people’s ideas about the seasons. (The survey approach is inspired in part by the Annenberg CPB project web pages at http://www.learner.org/teacherslab)

Later in this unit, the answers to these survey questions will be revealed, as students shed their own misconceptions and surpass the Harvard grads in their understanding of what causes the seasons!

Materials:
For the Student:
- Thermoform image, large print image, or regular print image of the “Seasons Survey”
  * NOTE: The “Seasons Survey” can be found on pg. 26 of The real reasons for seasons: Sun-Earth connections referenced above.
- Paper and writing instruments in the student’s preferred media

For the Classroom:
- A heat lamp
- Extension cord
- 1 tactile globe
- Heavy Rope

Getting Ready:
Plug in the heat lamp and set it on a table or chair in a part of the room where students can gather in a circle around it. If necessary, tape the cord to the floor to prevent students from tripping over it. Have the tactile globe handy when the lesson is introduced.
Reviewing Some Key Sun-Earth Concepts:

*The Earth’s Shape and Its Revolution Around the Sun*

1. Tell students that today they are going to be looking at the orbit and the relationship of the Earth with the Sun.

2. Ask “Why is the Sun important to us on Earth? [It provides warmth, light, energy, drives photosynthesis—without the Sun, there could not be life as we know it.]

3. Tell the class that many ancient peoples worshipped or in some way paid tribute to the Sun. Ask “Why do you think they did that?” [Teacher referred back to a previous unit completed by the students regarding the Mayans for a discussion/review with the students.]

4. While the students are still seated at their desks, hold up a tactile globe, (explaining to students that you have a globe in your hands) and ask, “If the Earth is shaped like a ball, why does it often look flat or hilly to us when we travel?” [We are very small compared to the size of the Earth, and the part we can see is only a very small part.] “How can we see the entire Earth as a circular object?”

5. Point to Australia on the globe and describe the location to the students. Ask why people living there don’t “fall off.” [Gravity pulls us all toward the center of the Earth, so everyone around the globe feels that the Earth is “down” and the sky is “up”]

6. Tell students we are going to do an activity in the back of the room. Discuss with them the shape of the rope on the floor. Ask students about the orbit of the Earth. [ellipse] Discuss the shape and reference the shape to a smashed ball.

7. Turn on the heat lamp and turn off the room lights. Ask how the Earth moves in relation to the Sun. [The Earth revolves around the Sun in an orbit. It also spins or rotates on its axis.] Using the globe and heat lamp, demonstrate these two motions.

   - Create a tactile orbit on a large floor. Place a rope on the floor in the shape of the Earth’s orbit around the Sun. Tape down the rope on the floor.
   - Place the heat lamp in the center of the orbit.
   - Have the students follow the orbit of the Earth with their feet. Tell the students that their noses are the Earth and the heat lamp is the Sun. Tell students to walk the path of the ellipse, feeling tactually with their feet. They are the Earth and the heat lamp is the Sun.

8. Say that the heat lamp and the globe are a model to help us understand the motions of the Earth, but of course the model is not to scale and neither was our orbital model. The Sun, represented by the heat source, is much bigger and hotter and the Earth, much farther away than our model shows.
Night and Day on “Mount Nose”

1. Gather the students in a circle around the heat source. Tell the students they will now use the heat source model to explain what causes night and day. Instead of utilizing a globe, each of their heads will represent the Earth in the model.

2. Ask the students to imagine their nose is a mountain and that a person lives on the tip of “Mount Nose.” With the students facing the heat source, ask, “For the person standing on your Mount Nose, where in the sky is the Sun?” [high in the sky, over the person’s head] Ask, “What time of day do you think it is for the person on Mount Nose?” [noon]

3. Ask the students to turn to their left, and stop when their right ears are facing the Sun. Ask, “for the person on Mt. Nose, where in the sky does the Sun seem to be?” [near the horizon, low in the sky] Ask, “What time of day is it for the person?” [sunset]

4. Have the students continue to turn, stopping when their backs are to the heat source. Ask, “What time is it for the person on Mt. Nose?” [around midnight] “On what part of your head it is the daytime?” [the back of your head because it is now facing the Sun]

5. Have the students make another quarter turn, so their left ears face the Sun. “Where is the Sun in the sky now? [low in the sky, just ‘coming up’] What time is it” [sunset] Have the class turn back to face the heat source.

6. Have the students rotate once more through a complete day, observing as the Sun seems to set and rise. Have the students return to their seats.

7. Review with students the terms revolution and rotation. “When you were the Earth and moving around the Sun, what were you doing?” [revolving] “How long does this take?” [365 days] “When you were moving around as Mt. Nose, what were you doing?” [rotating] “How long does this take?” [24 hours]

The Sun-Earth Survey

1. Tell the class that before studying why seasons occur, they will first answer a few questions on a survey themselves. Emphasize this is not for a grade. Tell the students to write their answers to the questions. Have them look at the seasonal survey in their media format. Tell them that if they don’t know an answer, a careful guess is okay. Tell students to complete the survey on their own for homework.

2. Read the questions to the students in order to assure they understand the answers and the thermoform images that appear in the survey.

**Refrain from revealing the correct responses now. Instead tell them they will find out the answers to these and other questions like a scientist. We will investigate and explore the reasons for seasons together in the upcoming unit.

Surveying Family and Friends

1. Tell the students they will each get copies of the survey to take home and use with friends or family members. They should tell the survey subjects that they are
about to begin a unit on what causes seasons, and are gathering data about what most people think. They can tell people their responses will be anonymous, and they shouldn’t feel embarrassed if they aren’t sure of the answers because that very common. Students should try to find two people to take the survey.

2. Tell the students to record the answers on their own papers. Ask them to bring these answers to the next class.

Next Class Session: The Results of the Survey

Overview:
In this part of the activity, students pool the data from the Sun-Earth Surveys. They work in groups to tally the results, then determine the class totals. Each student prepares a graph to represent the results of the survey.

Materials:
For the class:
- Whiteboard
- Piece of paper for teacher

Pooling the Data from the Sun-Earth Surveys
1. Have the students take out their papers with the answers of the survey questions from their friends and families.
2. The goal of this activity is to try and come to some conclusions about what everyone surveyed thinks about seasons. Starting with question #1, each student will tell the recorder how many responses they got for answers A, B, C, and D. The recorder will tally them on the classroom whiteboard. The recorder will tally the totals for all questions on the survey in this way. The teacher will record student and family answers on a piece of paper for future use. Continue with rest of the survey in this way.
3. Ask the students what they can conclude from the data. Accept all answers, encouraging them to make generalizations. [For example: There was a big split in opinion on question #1, especially between answers A and C.] Ask “Were any of the results surprising to you? Why?”
4. End the class by telling the students that in the next few days they will find out if the majority opinions on the survey agree or disagree with the answers that most scientists give.

Lesson 3: Trip to the Sun

Overview:

The scale of the Earth-Sun system is key to understanding seasons. Students can create a scale model to reinforce the idea of the distance to the Sun is enormous compared with the size of the Earth. Finally, they reflect on Question 3 on the Sun-Earth survey and decide if they would now change their response.

Materials:

For the Class:

- 1 scale model (a car or toy made to scale is fine)
- 1 Model Sun (28 cm in Diameter). A manila folder cut our will do or a round object in the proper diameters.
- One Earth tactile globe or large ball such as a soccer ball, basketball, or other rigid ball
- 40 meters of string
- One ruler marker with the proper markings in Braille, large print, or regular print
- Dull Pin
- Paper and writing instruments in preferred media

Getting Ready:

Prepare to take the class outside for a short scale model activity. Find a spot that is about 30 meters away from the classroom. Do this by pacing off 30 long strides in a straight line. It’s helpful if the spot is easy to describe to students, like an object they are familiar with outside the classroom or something down the hall from the classroom.

A Sun–Earth Scale Model

1. Tell the students that you would like for them to get a true sense of the distance of the Earth to the Sun by making a quick scale model of the Sun-Earth system. Ask students “Do you know what a scale model is?” [A scale of something that is too big to make so we make smaller models that we utilize a key to understand their measurements compared to the real object.] (Teacher referred to models at the school of the White House and Eiffel Tower that the students have seen in the past. Hold up the scale model car, and explain that someone measured a real car, and made everything smaller by the same amount. Pass around the car and allow the students to explore it. We can look at a scale model and get a good idea of what the real thing looks like. Mention that the Earth globe is a scale model too.

2. If we made a scale model where 50,000 km = 1 cm, Ask “At this measurement, how big would the Earth be?” [The Earth would be much smaller than the globes we use in our classroom; the classroom globe would be 0.25 cm in diameter, or about the size of a pinhead.] Allow students to tactualy feel the pinhead of the
dull pin. Ask students to think about this representation and ask “At this scale, how big do you think the Sun would be?” After accepting a few guesses, hold up the 28 cm diameter circle you prepared earlier. Pass it around the class for students to explore. (be sure that students understand the Sun is a ball, like the Earth)

3. Ask, “At the same scale (50,000 km = 1cm), how far away from Earth do you think the Sun is?
4. Ask students for some guesses of how far away the Sun would have to be. Tell the students that at this scale, the Sun would be about 30 meters form the Earth.
5. Explain that a meter in very rough terms is about one “pace,” about the distance of one large step as one is walking.
6. If time and other conditions permit, invite the students to go outside onto a grassy area to pace off the distance to the Sun in this scale model. Have one student hold the Sun and hold one end of the string. Have another student move 30 paces away from the Sun and stand with the other end of the string in his hand. Have students move along the string to determine the distance of the Sun from the Earth in this model. Hold the pinhead at the other end of the string. Tell students that from this distance, the sun looks about the same size as the real Sun in the sky.
7. Tell the students that the Moon would be a speck. It would be about eight centimeters away from the Earth. If time allows, have a student measure this distance and stand along the string to represent the Moon location. Allow students to move the distance along the string to determine the distance of the Moon from the Earth at this distance. Tell students to imagine how much bigger the scale of the real Sun-Earth system is.
8. Refer back to question #2 of the Sun-Earth survey. Describe the drawings to the students. Ask “Which drawing most accurately represents the Sun-Earth distance?” [C]
Lesson 4: What Shape is Earth’s Orbit?

Overview:
In this activity, students discover that the true shape of the Earth’s orbit around the Sun is very nearly a perfect circle. This begins to dispel a common misconception that seasons are caused by variation in the distance from the Sun to the Earth. Students look back at the results of the class survey on this question, and reflect on why so many people think the seasons have to do with the Earth’s distance from the Sun.

Materials:
For students:
- 25 cm piece of string or twine – not stretchy
- Writing utensil - marker
- 3 sheets of blank paper
- 2 push pins or thumb tacks
- Stack of newspaper, at least the thickness of the pins or tacks students will use
- Ruler (with centimeters) in both Print and Braille
- Thermoform images of possible elliptical shapes from the Sun-Earth Survey
- Tactile Science Images Book – from the American Printing House for the Blind

For the class:
- 40 cm piece of string or twin – not stretchy
- Paper at least 14 x 14 inches
- Bulletin board
- Large piece of paper, size of a bulletin board
- 2 push pins or thumb tacks
- 1 hula hoop

Getting Ready:
1. Make the 40 cm piece of string into a loop by tying the ends together so that the loop measures 17 cm when stretched flat. An easy way to do this is to stick two push pins in a thick piece of cardboard, 17 cm apart, and tie the string around the push pins. Test to make sure the knot won’t slip. Once you have made a set of string loops, them may be used over and over again for many classes.
2. You’ll need one smaller loop per pair of students. Cut one 25 cm piece of string per pair of students. Decide if you or a volunteer will tie the loops, or if you will have students tie them at the beginning of the activity. If students will tie them, you need to provide rulers for them to measure the loops.
The Shape of the Earth’s Orbit

1. Tell the class that in this session they will learn about the shape of the Earth’s orbit around the sun. This knowledge will help them later as they zero in on what really causes the seasons. Provide each student with the thermoform of the three elliptical images. Describe the images to the students.

2. Poll the students, “Which drawing most correctly shows the shape of the Earth’s orbit around the Sun: A, B, or C?” [If they have heard that it is an ellipse or oval, it is likely they will choose B or C.]

3. Explain that an ellipse is an oval shape, but at a very precise and symmetrical oval. Tell the class that they will be exploring a couple of ellipses representing real orbits of Earth and Pluto, which both orbit around the Sun in the solar system. The goal is to find out the shape of each orbit, and how much Earth’s orbit deviates from a perfect circle. Tell the students that you will demonstrate the ellipse by demonstrating the orbit of a comet.

4. Take students out into the hallway. Place the paper on the bulletin board and demonstrate how to make the ellipse. Demonstrate the ellipse as follows:
   a. Make two pen marks 12 cm apart on the large paper.
   b. Stick a push pin through each pen mark into the bulletin board
   c. Drape the string loop you made from a 40 cm piece of string over the push pins
   d. Have a student hold one of the push pins steady.
   e. Hold the other push pin steady and pull the string taut with the tip of the marking pen.
   f. Draw the ellipse, keeping the string taut at all times. Emphasize while you are drawing the importance of keeping the string taut as you draw the ellipse as well as having two people work together to make sure the push pins stay firmly in place while making the ellipse.
   g. Make sure to voice all steps within the process.
   h. Allow students to trace the ellipse you just made on the board.

5. Explain that each point where a push pin goes in is called a focus of the ellipse. Mention that the plural of focus is foci. Point out that the comet orbit that you drew is fairly skinny or elongated, not circular. Explain that in the orbits of planets (as well as comets or asteroids) the Sun remains fixed at only one of the foci of the ellipse.

6. Explain that they will be making the shapes of orbits of Earth and Pluto. Emphasize that the drawings are not to scale, that Pluto’s orbit is actually almost 40 times the diameter of Earth’s orbit, but for now we only want to compare the shapes of the orbits. They will work with a partner, and take turns: One will keep the push pins steady while the other is drawing with the pen. Each pair of students will get a string loop, two push pins, and a stack of newspapers with a piece of paper place don top. Explain that the newspapers are being used to prevent damage of the desk tops.
7. Say that Pluto and Earth have foci separations of 5 cm and 0.4 cm respectively. Have students create the two orbits, utilizing the different lengths, as described above. Make sure to help students trace the orbits they have created in order to differentiate the size and shape of each orbit.

8. When everyone has finished, collect the strings, newspaper, and push pins.

Dispelling a Common Misconception about the Earth’s Orbit.

1. Ask the students to examine the orbits they created. Ask “Is Earth’s orbit really larger than Pluto’s?” [No, it’s actually much smaller.] Remind them that we are concentrating here only on the shapes of the orbits.

2. Ask, “Which orbit is more circular, Pluto or Earth’s?” [Earth’s] Explain that, while it is true that Earth’s orbit is slightly elliptical, it is very nearly a circular ellipse. Pluto has the least circular orbit of all the planets, and it still looks pretty circular. Pluto’s Sun would be at the placement of your foci. The Sun is a little off center. However, the Earth’s orbit had the Sun in the center.

3. Ask students to recall the results from the Sun-Earth Survey.

4. Ask students “Which of the four drawings do you think best shows the shape of the Earth’s orbit around the Sun?”

5. Ask students where the Sun should be in the drawings of the Earth’s and Pluto’s orbits that they have made. Reveal that, not only is the Earth’s orbit almost circular, but the Sun is in the center of the orbit. So, when considering survey question #1, answers A and B, which is correct? [A]

6. Ask students why they think many people pick answers C or D. [Drawings of the solar system in books and on posters often make the orbits look like fairly skinny ellipses. This is because the orbits are drawn from the side, as though viewed at an angle] Show students the APA Science Tactile book that shows the orbits of the Sun. Allow the students to explore these diagrams. The diagrams do not look circular – they look very elliptical.

7. Use a hula hoop to demonstrate how the shape appears to change depending on the angle at which you view it. Have students feel the hula hoop from both angles – on its side and on its top. Verbalize this angle change to the students.

8. Remind students of Question 3 of the Sun-Earth Survey: Why do you think it is hotter in New York in June that in December? If we look at this question, is there any difference between the placement of the Sun. Discuss with students that the Sun is actually closer to the Earth in winter and farther from the Sun in summer. Tell the students this is very minor – it is not enough to change the temperature drastically from summer to winter.

Going Further

Apparent Changes in the Sun’s Size with Season

If people believe that the Sun is closer to Earth in the summer, then it should appear larger during the summer. Have your students tactually feel how much of the Sun’s size
appears to change using real photographs of the Sun at different seasons. (Use Noreen Grice’s “Touch the Sun” tactile astronomy book for this activity)

Lesson 5: Temperatures Around the World

Overview:

In this session, students analyze temperature data taken from the Globe project, a network of schools around the world dedicated to providing scientifically valid data on environmental characteristics related to weather, climate, and ecology.

The graph of the data will allow students to discover interesting relationships in temperature changes – that the pattern of temperature change from summer to winter in one hemisphere is reversed with respect to the opposite hemisphere. This activity further dispels the idea that the Earth-Sun distance may be responsible for seasons.

Materials:

For each group of students:

- Tactile thermoform image of graph – Each line on a different thermoform image

For the Class:

- Tactile globe
- Raised flat map of the world with raised longitudinal and latitudinal lines.

Getting Ready

1. Make overheads of the blank “Temperatures Around the World” graphing sheet and the completed Temperature Graph if accessible for students. Color codes the temperature lines with colored transparency pens. Make an overhead transparency of the sample data as well as sample data in the preferred media of the students.

2. Check to see if your students understand how and are proficient at finding things on Earth by latitude and longitude. If not, a short lesson will be given.

3. Create thermoform images of the each data location on a separate sheet of thermoform paper for the class. Utilize the following data points from Project GLOBE schools around the world. Temperatures are in Celsius:

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Minnesota: 47 degrees N

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S. Africa: 26 degrees S

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Alaska: 58 degrees N
Jan 1999 -0.9
May 1998 10.8
Jun 1998 10.8
Jul 1998 12.8
Aug 1998 12.9
Sep 1998 9.9
Oct 1998 5.3
Nov 1998 2.7
Dec 1998 -1.5

**For those cities that are missing data, plot the data you have and draw lines connecting these plots in order to obtain overall trends in the data. Students will be asked to view/feel the lines on the thermoform pages and will be able to assess the trends in temperature for each location.

Temperatures Around the World
1. Ask students to think back to the “Name the Season” game, when they wrote about things that change with the seasons. Point out that one thing they mentioned was temperature.
2. Tell the students in many places around the world measure the temperature throughout the year, as part of an international environmental monitoring project known as Project Globe. Today, your students will get to see how those temperatures changed throughout the season, and how the patterns of change differ depending on where in the world you are.
3. Tell student they will get this kind of information for each of nine places.

Longitude and Latitude
1. Hold up the tactile globe and point out the longitude lines that run vertically from pole to pole. Allow students to track these lines with their fingers.
2. Point out to students the Equator on the tactile globe. Explain that the set of lines that goes around the globe horizontally, parallel with the equator are latitude lines. The latitude and longitude lines form a grid on maps and globes, so that we can describe exactly where a place is with the two lines that cross there. Allow students to track the equator with their fingers.
3. Tell the class that on maps and globes, each line of latitude and longitude is numbered by degrees. Relate latitude and longitude to angles along the spherical surface of the Earth by completing the following activity:
a. Tell students to hold their arm out horizontally pointing towards something at eye level like a window or poster on a wall. Tell them that their arm should be in a straight line with their shoulder.

b. Tell students to sweep their arms through a full circle vertically. Students should make a sweeping circle with their arm by making a full circle in front of their bodies. Ask students “How many degrees are in a full circle” [360]

c. Have students point to their original horizontal arm position and say if we call this angle zero degrees, then what angle is made when you raise your arm straight in the air? [90]

d. Now tell students to move their arm in a straight line across the front of their bodies. Their arms should be parallel with the floor across their chest. Ask students when angle they have just made keeping in mind their starting position. [180]

4. Allow students to explore the raised map with the longitudinal lines and latitudinal lines.

5. On the tactile map and globe, show the students that the equator is zero degrees latitude, and each latitude line to the north adds five degrees until the North Pole, which is 90 degrees north latitude. Going south from the equator, each latitude also increases by 5 degrees and the South Pole is 90 degrees south. You may point these facts out to students, or allow them to find these numbers and voice to you what is happening with the numbers as they move north and south along the map. Emphasize the importance of saying north or south along with the number of degrees of latitude.

6. Point out that the longitude lines go from 0 degrees to 180 degrees and increase 5 degrees to the east and west. Again, allow students to tell you these facts or point them out as appropriate for the class.

7. Demonstrate how to find Chalatenango, El Salvador on the world map using its latitude (14 degrees north) and longitude (89 degrees west).

8. Point out to students the nine cities on their thermoform maps.

Graphing Temperatures Around the World

1. Tell the class that they will look at the temperature during the year in the nine different places on Earth they have just located on their maps.

2. Have students examine each of the graphic representation of the temperature data for each location. Tell students that the top of their thermoforms contain the location name and location. Ask the following questions for each graph:
   - What is the latitude?
   - What do you notice in this graph?
   - When does this location have the warmest temperatures?
   - When does this location have the coolest temperatures?
   - When does this location have summer? Winter?
   - Are these temperatures consistent?
   - What hemisphere is this location?
• What would you expect to see at this location?

Analyzing Temperature Graphs
1. Ask, “What have we found out?” “What patterns do you see in your graphs?”
2. Make sure students notice that the pattern is reversed between the Northern and Southern Hemispheres. In the Northern Hemisphere, the hottest months are June-August, while in the Southern Hemisphere, hottest months are December-February. Ask, “What season is it where we live in July?” [Summer]. “What season is it in Antarctica in July?” [Winter]. You may ask about other locations as well.
3. Ask, “What is the pattern of temperature change for locations near the equator?” [There is not much variation in temperatures through all the seasons.]
4. Remind students of question #3 in the Sun-Earth Survey. Ask them what they think of answer B in light of what they have observed on their global temperature graphs.

Lesson 6: Days and Nights Around the World

Overview:

By analyzing graphs of the number of daylight hours per day in cities around the world, students find a very symmetrical pattern of daylight hours that is exactly opposite for the Southern and Northern Hemispheres. Students discover months when the Sun never sets in Alaska, and never rises in Antarctica. They also discover the meaning of the equinoxes, as they find day and night hours are equal in September and March everywhere on Earth.

Materials:

For each group of 4-6 students:

- Tactile thermoform image of graph – Each line on a different thermoform image

Getting Started:

1. Create a thermoform image of the day length data below. Make one graph for each location. (Data generated from Voyager, by Carolina Software, Hayward, California)

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<th>Latitude</th>
<th>January Hours</th>
<th>February Hours</th>
<th>March Hours</th>
<th>April Hours</th>
<th>May Hours</th>
<th>June Hours</th>
<th>July Hours</th>
<th>August Hours</th>
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### Hours of Daylight

1. Have students think back to yesterday’s activity. Review the differences between the temperatures in the Northern and Southern Hemispheres and at the equator. Review question #3 in Sun-Earth Survey. Ask students “Based upon what we learned yesterday, what choices would be correct?”

2. Have the students think back to Activity 1, when they wrote about changes that occur with the seasons. Ask how many of them wrote about the changes in the “length of day.”
3. To review their experience with changes in the number of daylight hours, ask the following questions:
   - Does the Sun always set at the same time each day? [No]. Show the photograph of the setting Sun in order to add a vivid element to this discussion.
   - At what times of year does the Sun stay up latest (and rise the earliest)? [Summer, Don’t reveal the answer if no one knows.]
   - Is the number of hours of daylight the same each day?” [No]
   - When are the “shortest days”? [Winter]
4. Ask, “Is the number of hours of daylight on a certain day the same all over the world?” Tell the students that in this session, they will look at day length data from different places around the world.
5. Have the students examine each of the graphic representations of the day length data.

Discussing the “Day Length” Graphs
1. Ask, “What patterns do you see?”
2. Point to the Ecuador data, and ask, “If the data make a straight horizontal line across the graph, what does that say about how the length of day changes at that latitude?” [Day length stays the same all year.] Ask, “What do the lines that go up and down steeply tell you?” [At that latitude, day length changes greatly with the seasons.]
3. Be sure that students notice that locations at opposite latitudes in Northern and Southern Hemispheres have day lengths which are mirror images of each other. Ask students to predict what they will see. Ask, “What season is it in Scotland in July?” [Summer] “What season is it in New Zealand in July?” [Winter] Students should be able to perceive that there is a high degree of symmetry: Moreover, each plot line is highly symmetrical on either side of the month of June. Ask students “What are the differences in the graphs?” “Why are they different?” [Southern and Northern Hemispheres] “Do these graphs resemble the graphs from yesterday?” [opposites for each hemisphere, similar to last lesson]
4. Ask, “Are there any places where the Sun never comes up (Zero day length) in certain parts of the year? [Yes, Antarctica, Alaska, Norway, Canada.] At what times of the year does that happen? [It happens at opposite times of the year in the far south and far north. The Sun never comes up from November through January at latitudes north of 70 degrees north. From May through July, the Sun never comes up at latitudes south of 70 degrees south Latitude.]
5. “Where and when does the Sun stay up for 24 hours?” [The Sun never sets from May through July above 70 degrees north latitude (Alaska); Also November through January at latitudes south of 70 degrees south (Antarctica). This is sometimes called the “midnight sun”]
6. Explain that there is a special name for the exact date, when the number of hours of daylight equals the number of hours of night time. Ask if anyone knows what
those special days are called. [Equinoxes – Spring equinox and fall or autumnal equinox] They occur near March 21 and September 21 each year.

7. Remind students of question #3 in the Sun-Earth Survey. Ask, “Do your observations about the number of daylight hours help you rule out any of the answers?”

8. Tell the class the next activity will make clear for them why the day length changes with the seasons the way it does.

Lesson 7: Tilted Earth

Overview:
Having explored the distance to the Sun, the Shape of the Earth’s orbit, and the differing temperatures and day lengths around the world, your class is ready to gain a deeper and more scientifically accurate and complete understanding of what causes the seasons.

Using small polystyrene spheres or Earth globes as model “Earths,” with a light-bulb as a model “Sun”, students create a model that shows how the tilt of the Earth’s spin axis causes seasons. This model is especially effective in showing what causes seasonal variation in day length.

Materials:
For the Students:
• Paper
• Writing utensil

For the Class:
• One polystyrene ball for each student
• 1 pencil for each student
• Heat Lamp/Lamp with bulb
• Tactile Globe
• 4 different textured and colored beads for each student (red, blue, green, and black)
• String
• Hot Glue

Getting Ready
1. Set up the heat lamp near the center of the room.
2. Make the polystyrene balls with the beads and string as follows:
   a. Glue a string around the center of the ball to represent the equator
   b. Glue a red bead at the “North Pole” of the ball.
   c. Glue a blue bead roughly halfway from the equator to the pole. This will represent a mid-latitude city like San Francisco or your home town if this applies.
   d. Glue a green bead at a latitude roughly 70 degrees, i.e., closer to the pole than the equator. This will represent a far northerly locale such as Tromso, Norway or Prudhoe Bay, Alaska.
   e. Place a black bead halfway from the equator to the South Pole to represent a mid-latitude Southern Hemisphere city like Melbourne, Australia.
Introducing the Model:
1. Ask students to remember the shape of the Earth’s orbit that they examined in Activity 3. [almost circular] Does the Earth’s distance from the Sun change very much during the year? [no]
2. Point out that if the Earth did move closer or farther from the Sun it would be colder or hotter everywhere on Earth at the same time. Ask, “Is it summer at the same time everywhere on Earth? [No – in the last two activities, we found that summer and winter happen at the same time on different parts of the world.]
3. Ask, “If it is not the distance to the Sun that causes seasons, what are some other possible causes?” [It may have something to do with the direction of the Earth is tilted.] If a student mentions this idea, proceed, otherwise, mention it yourself.
4. Tell the class that they will make a Sun-Earth model to explain the seasons, with the Sun represented by a heat source. This time, instead of their heads representing the Earth, they will each get a polystyrene sphere to represent the Earth. Show them how to put the sphere on a pencil to spin it. Say that this represents how the Earth rotates on a “spin axis” that runs roughly from the north to the South Pole.
5. Caution the students to be respectful and quiet during the activity so that everyone can hear and understand your directions. Also caution them not to write or poke their spheres to damage them.

A Model with No Tilt
1. Hand out the model Earths. Have each student put a pencil into the hole in the sphere. Gather everyone in a circle around the light bulb, and turn off the lights in the rest of the room.
2. Ask students to find the Equator and the North Pole on their spheres, and the Northern and Southern Hemispheres. Identify the other three marks:
   • The first bead under the North Pole represents a high-latitude location (like northern Alaska) in the Northern Hemisphere
   • The second bead represents a mid-latitude location in the Northern Hemisphere (like most places in the continental U.S. – can use hometown)
   • The string in the center represents the Equator
   • The last bead under the equator represents a mid-latitude location in the Southern Hemisphere, such as Melbourne, Australia.
Have students practice finding the various locations and naming the proper location names of each bead.
3. First, have the students hold their earth models with the spin axis (pencil) vertical, slowly spinning them, and notice their dot cities move from daylight into night and back again. Ask, “With your pencil vertical, do the beads stay in the light the same amount of time?” [Yes, roughly]
4. Ask, “Is this really how the Sun-Earth system works?” [No. The spin axis should be tilted.] Instruct everyone to tile the Earth towards the Sun in the model – not with the pole pointing directly towards the Sun, but tilted roughly halfway down (45 degree angle). The real angle is 23.5 degrees, but let’s exaggerate for now.
5. Instruct the students to spin the Earth again and pay attention to the beads. You may want the students to work in partners so each can fully explore what is happening with the beads in relation to the heat source. Ask them to compare what is happening at the third and fourth beads (mid-latitude north and Southern Hemisphere). Do they both get day and night? [yes, but the city in the Northern Hemisphere has long days and short nights, while in the Southern Hemisphere, there are long nights and short days.]

6. Ask, “How about the second bead – does it have day and night?” [No. it receives light the whole 24 hours; it has midnight Sun.] What is happening near the South Pole? [24 hours of darkness]

7. Have students compare what is happening in the two Northern Hemisphere cities. Ask, what season is it in the city closest to the equator? How about our hometown? [both have summer] How are they different? [The day length is longer in the more northern city]

8. Say that all their Northern Hemispheres are tilted toward the Sun, and have summer. Is this how it always is? How does the season change from summer to fall, winter, and spring during the year? Does the Earth rock back and forth? [no]

Titling the Earth toward the North Star (Demonstrated on the *The real reasons for seasons* CD Rom)

1. Tell the students that, as the Earth moves around the Sun, the North Pole always points to the North Star.

2. Pick a spot in the classroom to represent the North Star, e.g. the clock or a poster mounted high on a wall. Ideally, make your model North Star in the direction of the real North Star. Ask all the students to tilt the North Pole bead of their spheres toward the North Star. Have them practice spinning their spheres while keeping the North Pole pointed at the North Star.

3. Go around checking that students standing between the Sun and the North Star are keeping their North Poles tilted way from the Sun, and toward the North Star. Students standing on the opposite side of the “orbit” should have their North Poles tilted toward the Sun (and the North Star). Students midway between these positions will have the North Pole pointing “sideways” to the Sun.

4. Stand near the part of the class who has North Poles tilted toward the Sun. Ask, When the Earth is in this part of its orbit, which Hemisphere is tilted more towards the Sun?” [Northern.] “Is it the same in both Northern and Southern Hemispheres?” [No. In the Northern Hemisphere, its summer, and in the Southern Hemisphere it’s winter.]

5. Move counterclockwise (as seen from above) around the circle of students, following the tactile orbital line on the floor, stopping at 3 positions. ¼ of the way around, halfway around, and ¾ of the way around. At each stop, ask, “For the model Earths in this part of the orbit, is the North Pole pointing towards the Sun or away from the Sun?” [At the ¼ and ¾ stops the answer is neither – it’s pointing “sideways” to the Sun.] “what season is this?” [1st stop it’s fall in the Northern Hemisphere; spring in the Southern Hemisphere; 2nd stop it’s winter in
the Northern Hemisphere and summer in the Southern Hemisphere; 3rd stop it’s spring in the Northern Hemisphere and fall in the Southern Hemisphere.]

6. Point to the students you started with, who have North Poles tilted toward the Sun – the Northern Hemisphere’s summer position.

7. Review by asking students to raise their hands if their Earth position has:
   - Longer days at the South Pole
   - Longer days at the North Pole
   - Day length that is about the same in both Hemispheres.

8. Collect the spheres and have students return to their seats.

Discussing the Model and What Causes Seasons
1. Ask students to write down on paper what they learned about the causes of seasons. Give them four or five minutes to do this, then ask a few volunteers to explain what they learned from the model.

2. Ask, “If a planet was not tilted on an axis, would it have seasons?” [No]

3. Say that many people think that the tilt of the Earth causes seasons because it makes one part of the Earth much closer to the Sun.

4. Remind them of their scale model in Activity 3 – if the Earth were the size of a pinhead, the Sun would be a 28 cm beach ball thirty meters away. Ask, “Does it make much difference in the 30 meter distance to the Sun if the pinhead it tilted?” [No] Emphasize that the distance from the Earth to the Sun is enormous – much greater than in the light bulb model they just used.

5. Refer to question #3 on the Seasons Survey. Ask which answers are supported by the model they just made.
Lesson adapted from: Gould et al., 2004. *The real reasons for seasons: Sun-Earth connections.* Lawrence Hall of Science, University of California at Berkeley.

- Observer from Space lesson and Hemisphere Path lesson provided by Grice, N. (personal communication, August 27, 2007)

Lesson 8: Analyzing the Sun’s Rays

Overview:
Students have now seen how the tilt of the Earth causes day length to change with the seasons. In this closing activity, they are able to see more clearly how the Earth’s tilt also changes the angle at which the sunlight hits the ground. In winter, rays of sunlight strike the ground at a slant and are less concentrated than the more perpendicular rays of the summer months.

Materials:
For the Student:
- Two pencils
- Paper

For the Classroom:
- 3 Hula Hoops
- Duck Tape
- Dowel Rod
- Tactile Globe

Getting Ready:
1. Join the three hula hoops together at east and west, separated most at the southern direction.

Pencil Models of Light Rays
1. Have students practice holding the markers at a perpendicular angle and at an oblique angle. Describe these angles to the students.
2. Take two pencils and tell students to imagine that each pencil is a bundle of millions of light rays.
3. Tell the students to hold the two pencils together and touch them to the paper so that they are perpendicular to the paper, which represents the highest possible Sun Angle. Have the students wiggle the pencils so that they leave marks on the paper. Tell the students that the marks are close together. Ask, “What season is represented by the pencil marks?” [In summer, the angle of the sunlight hitting the ground is higher. The light is more concentrated, so the ground gets hotter.] Discuss the summer solstice [longest day of the year] with the students as well as the Earth’s angles at the Tropic of Cancer. Tell students that cultures used to celebrate this special day.
4. Tell the students to hold the pencils so they touch the paper at a very oblique angle, sliding one pencil along the other until both tips touch the paper as shown.
5. Tell the students to wiggle the pencils again to make marks on the paper. These marks are farther apart, representing a lesser concentration of sun. Ask, “Which season is represented by the pencil marks?” [Winter] Tell students that the Earth gets less heat and less light when the Sun is less intense than in the summer. Again discuss with students the winter solstice as well as the Earth’s angle at the Tropic of Capricorn.

Observer From Space
1. Review with students that the Earth is at a 23 ½ degree tilt. Tell them that they are going to pretend they are observers from space.
2. An observer from space (with Sun and Earth visible), would see where the most intense sunlight fell on Earth. When the Northern Hemisphere experiences winter, and the southern Hemisphere experiences summer, Ask the students, “Where is the North Pole?” [tilted away from the Sun] Ask, “Where is the most intense sunlight?” [It would be focused at 23 ½ degrees south latitude.] “Where is the South Pole pointing? [away from the Sun, less light, colder temperatures]
3. Ask the students “When it is spring or autumn in the Northern Hemisphere, what happens at the equator?” [The equator faces the sun most directly and the most intense sunlight would be focused at the equator]
4. When it is summer in the Northern Hemisphere (winter in the Southern Hemisphere) Ask the students “When the North Pole is titled toward the Sun, where is the most intense sunlight focused?” [23 ½ degrees north latitude.]
5. In small groups, have the students use dowel rods to locate the latitudinal locations where the Sun is the most intense during the different seasons. Tell the students to use dowel rod to represent the angles of the Sun hitting the Earth.
   - As the dowel rod is aligned at 23 ½ degrees north, it is summer in the Northern Hemisphere and winter in the Southern Hemisphere.
   - As the dowel rod is aligned at 23 ½ degrees south, it is winter in the Northern Hemisphere and summer in the Southern Hemisphere.
   - When the dowel is pointed at the equator, it is either fall or spring.

Hemisphere Paths
1. Now students can compare the view from space with the view of an observer on Earth.
2. The three hula hoops model will simulate the three different paths of the sun across the sky, as seen by a person standing on Earth at mid-latitude North America.
3. A partner will hold the hula hoop model above an observer’s head so that the observer can reach out with his/her hands to touch the sun paths. (East is the observer’s left, south is straight ahead, west is to the observer’s right, and north is behind the observer)
4. The lowest hula hoop (nearest the observer’s waist) is the shallow path of the sun at winter.
5. The next hula hoop path up represents the path of the sun at the equinox (either first day of spring or summer)
6. The highest hula hoop path represents the path of the sun at summer.
7. Ask students to describe what they are feeling as they explore each hula hoop. Try to have students tell you about the sun’s path and which season is represented instead of giving them the answers.
8. Describe to the students the path of the Sun. Have the students move their hands across the hula-hoops from and east to west direction discussing with the students the rising and setting of the Sun.

Lesson 9: Seasons Unraveled

Overview:
The closing discussion brings home the fact that the Earth is a spinning globe whose axis tilts with respect to its orbit around the Sun, and this gives rise to: (a) a varying number of daylight hours in different seasons, and (b) variations in concentration of sunlight on the ground related to the angle the light strikes the ground. These are the main factors that cause seasons and since they stem from the relation between the Sun and the Earth, they are considered a “Sun-Earth connection.”

Materials:
- Copy of Sun-Earth Survey for all students

Seasons Unraveled:
1. Remind the students that the purpose of the original Seasons Survey was to find out what students (and their families and friends) understood about the causes of seasons. Have students take the Seasons Survey again, or go over it together with them now.
2. Have students record their answers on their preferred media form.
3. Ask students the questions and poll the class about their answers.
4. Discuss the correct answer for each question on the survey.
5. Ask what they now think about question #3.
6. Ask what questions they would pick now. [D and E]
7. Discuss the different answers, referring back to the activities students completed. If they pick C, remind them that the United States is tilted toward the Sun in June, so it’s technically a bit closer, but that doesn’t change its distance from the Sun enough to make it hotter there due to the change in distance. (See the discussion in “Behind the Scenes” for more responses)
8. Explain that the Earth’s axis is tilted by about 23 degrees with respect to the Earth’s orbit around the Sun.
9. Ask students if they have additional questions or issues to rise about the reasons for seasons. Some of these questions may provide a chance to re-emphasize the main ideas of the unit. Others may raise new and interesting issues. If so, discuss ways that you and the class could investigate these new questions and issues, and consider assigning individual or group projects to research and investigate these topics.
10. Conclude by pointing out that this unit, designed to help them work through the reasons for seasons themselves, demonstrates that the main causes of the seasonal changes we experience on Earth derive from the relation of the Sun to the Earth. What astronomers call a Sun-Earth Connection.
11. Praise your students for the excellent scientific work throughout the unit and the leaps they’ve made understanding. Encourage them to go home and discuss what they’ve learned about the real reasons for seasons – and explain the correct survey responses to their families and friends.