# SCIENCE FOR ALL:

# EXPERIENCES AND OUTCOMES OF STUDENTS WITH VISUAL IMPAIRMENT IN A GUIDED INQUIRY-BASED CLASSROOM

by

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# DEDICATION

I dedicate this dissertation to my children, Nic, Nate, and Grace.  May you always dream big, set your sights high, and be driven to achieve whatever goal your heart desires.  You will always have my love, support and guidance in everything you do.

I love you through and through, yesterday, today, and tomorrow too.

# TABLE OF CONTENTS

TABLE OF CONTENTS - *Continued*

TABLE OF CONTENTS - *Continued*

# LIST OF TABLES

# LIST OF FIGURES

Figure

# ABSTRACT

The purpose of this study was to examine instructional experiences of students with visual impairment in an guided inquiry-based science classroom. Drawing from social constructive perspectives about teaching and learning, I focused on the initial attempts of students to participate fully in an inquiry-based astronomy unit. The astronomy unit incorporated features of project-based science inquiry and aligned with national standards. This study described the opportunities provided to and challenges faced by students with visual impairment as they participated in the guided inquiry-based learning environment. Additionally, discursive practices of students including student-generated questions, student discussions, and students' science notebook writing were examined. Also, students' alternative conceptions about scientific phenomena and changes in students' thinking during the course of instruction, if any, were described. Methods of data collection included classroom observations, video records, pre- and post- curriculum assessments, attitudes toward science measurement, student interviews, and student artifacts (i.e., science notebook entries, student-constructed models). Findings showed that student learning was enhanced when the instructor-researcher guided students in accomplishing inquiry tasks and in making sense of their inquiry experiences. Additionally, the use of appropriate reflective prompts assisted students with visual impairment to fully participate in the writing tasks of the inquiry-based learning environment. Results suggested that the quantity and quality of student-generated questions increased with

extended inquiry instruction.  Also, students used questions to not only establish verbal communication, but to elaborate on their own thinking and expand or explain the thinking of others.  Findings suggested also that students with visual impairment have similar alternative frameworks about scientific phenomena (i.e, causes of lunar phases, reason for the seasons) as do their peers with sight.  This study contributes to the literature about inquiry-based instructional strategies for all students and initiates the conversation about best practice for science instruction with students with visual impairment.

# CHAPTER I

# INTRODUCTION

Science for all students, including those with special needs, is a stated goal for current reform initiatives in science education (National Research Council [NRC], 1996). The underlying assumption is that with appropriate opportunities for learning, all students can succeed in the science classroom. This science for all view is shared by teachers, rating science as the class most suited for mainstreaming (Atwood & Oldham, 1985), and by students, indicating science as a "favorite" class (Scruggs & Mastropieri, 1994b). However, although science reform is widely accepted, little research is being done to examine and address the needs of students with disabilities in the science classroom (McCarthy, 2005).

## Social Constructivism

As a theoretical framework to support science for all students, social constructivism builds upon the traditions found in the field of special education. The social constructivist theory of learning and development was based primarily on the works of Lev Vygotsky and has been elaborated upon by educational theorists and researchers for several decades (Bruner & Haste, 1987; Rogoff, 1990; Wertsch, 1991). Detailed in his earliest works, Vygotsky was interested in the psychology of children with disabilities and believed that an understanding of how children with disabilities learn was "an indispensable aspect of the general theory of human development" (Kozulin, 1990, p. 195). Current interpretations of Vygotsky's work have emphasized the dynamic nature of cognitive processes occurring within culturally mediated social activities, social and contextual aspects of learning, and characteristics of child development (Collins, Brown, & Newman, 1989; Brown, Collins & Duguid, 1989; Lave, 1988, Wertsch, 1985). For the purpose of this study, four salient features fundamental to the social constructivist perspective and considered common ground between the much needed collaborative endeavors of special education researchers and science education researchers were identified: (a) active construction of knowledge, (b) situated learning, (c) community of learners, and (d) discourse.

### *Active Construction of Knowledge*

Although previous knowledge and experiences are the starting point of new learning for all students, active participation in learning is believed to lead to students' deeper understanding and use of knowledge, thereby supporting students' application of what they have learned (Krajcik, Blumenfeld, Marx, Bass, Fredricks, & Soloway 1998; Roth, 1994; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Brooks & Brooks, 1993). Within the social constructivist paradigm, learning is a socially situated activity mediated by expert scaffolding in which learners experience cognitive activities in the presence of a more knowledgeable learner (i.e., teacher, parent, peer). Through guided instruction, discourse, and discussions situated in meaningful contexts, learners gradually move from present skill levels and understanding to new, more complex levels (Palincsar & Brown, 1989; Rogoff, 1990). The cognitive space between the current level of performance and the potential level of performance when assisted by a more knowledgeable other is the learner’s zone of proximal development (Vygotsky, 1978). Through these repeated interactions, learners, including those with disabilities, internalize shared explanations and understandings, thus increasing their ability to participate at a more independent level.

### *Situated Learning*

Situated learning is a general theory of knowledge acquisition. Lave (1988) expanded this definition by stating that situated learning is learning that occurs as a function of the activity, context, and culture in which it happens. Therefore, according to Lave & Wenger (1991), learning is not the acquisition of knowledge, but the process of social participation as learners are acculturated into the cognitive practices and strategies of the content area (i.e., science, mathematics, language arts). Anecdotally, the education of students with disabilities has emphasized memorization and rote learning of skills and strategies detached from authentic contexts. However, learners with disabilities must be provided opportunities to acquire complex cognitive skills through participation in social interactions within purposeful contexts (Palincsar, Magnusson, Collins, & Cutter, 2001).

### *Community of Learners*

In the context of the social constructivist framework, student learning takes place within a collaborative environment that supports the sharing of tasks and the exchanging and critiquing of ideas for the purpose of building new knowledge (Magnusson & Palincsar, 1995; Wenger, 1998). Students' participation in a community of learners involves collaboration between peers, teachers, and members of the community to share and debate ideas as they construct understanding (Schneider, Krajcik, Marx, & Soloway, 2002; Crawford, Marx, & Krajcik, 1998). By being immersed in a community of practice, students learn ways of knowing in the discipline, what counts as evidence, and how ideas are substantiated and shared (Singer, Marx, Krajcik, & Clay-Chambers, 2000).

## How Students Learn

Students benefit from learning opportunities that actively engage them in examining their own ideas, evaluating evidence, and drawing conclusions. Educational researchers call attention to quality learning environments that focus on involving students in learning science through inquiry (NRC, 1996). In an inquiry-based learning environment, traditional teacher-centered practices supporting the acquisition of facts are replaced with student-centered, inquiry-based practices that support students in developing a deeper understanding of scientific ideas. An emphasis on learning science by doing science in ways that are similar to what practicing scientists do is the basis for inquiry as instruction (Minstrell & van Zee, 2000).

### *Inquiry*

Inquiry is a dynamic approach to learning and teaching that involves students in using the tools, language and ways of reasoning that are characteristic of the science community. For the purpose of this study, the definition of inquiry is derived from the *National Education Science Standards* (NRC, 1996). With educational roots expanding from Dewey (1933), Schwab (1966), and Rutherford (1964), inquiry is a process of making observations, posing questions, finding what is already known, planning investigations, using tools to gather and interpret data, proposing explanations, and communicating the results (NRC, 1996, 2000; Krajcik, Czerniak, & Berger, 2003). Thus, inquiry is an approach to teaching and learning that mirrors the process of doing real science. Learners engage in inquiry by gathering information through application of the human senses. As they pose questions about the information, learners seek answers by conducting research for genuine reasons, by making new discoveries, and by testing the discoveries to generate new knowledge and understanding. Students' direct experience and understanding of the natural world are necessary to the development of new knowledge and deeper understanding (NRC, 2004).

Children in inquiry environments are presented with many cognitive challenges. To develop competence in the area of inquiry, students must have a deep foundation of factual knowledge (Krajcik et al., 1998). In addition, students must organize knowledge in new ways (NRC, 2000). Learners use their knowledge in reading, writing, and speaking and in content areas such as math and science to collect data, generate evidence, evaluate claims, and share information (Bybee, 2002). Students are required to mesh these inquiry processes with scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science (NRC, 2000).

Despite these challenges, students with disabilities have been successful in inquiry-based learning environment (Bay, Staver, Bryan, & Hale, 1992; Palinscsar, Collins, Marano, & Magnusson, 2000; Dalton, Morocco, Tivnan, & Mead, 1997; McCarthy, 2005). The authors identified many positive student outcomes associated with inquiry-oriented approaches in science. First, science was an instructional context in which the child with a disability could demonstrate strengths. Adaptations such as reduced vocabulary demands, graphic organizers, and multiple representations of content materials gave the students with a disability ways to verbally engage in the science classroom. Structured questioning techniques were used to guide and facilitate students' thinking, demonstrating that the child with a disability could exhibit higher thinking skills and cognitive processes to work through a problem. The teacher's guided coaching strategies provided the students with a disability the opportunity to build upon prior knowledge and experiences and to create new knowledge of the materials presented. The authors revealed that in virtually all student interviews conducted, the students expressed a preference for inquiry-oriented activities over text-book based instruction. The preference for inquiry-oriented activities is not surprising given that students learn best by doing (NRC, 1996).

### *The Learner with Visual Impairment*

For the purpose of this study the term visual impairment, including blindness, was derived from the Individuals with Disabilities Act ( IDEA, 2004) and was defined as "an impairment in vision that, even with correction, adversely affects a child's educational performance" (p. 598), and may be broadly classified as low vision, legally blind, or totally blind (Turnbull, Turnbull III, Shank, & Leal, 1995). To determine eligibility for educational services, law has defined the severity of visual impairment. Low vision is a term that denotes a level of vision with an acuity level of 20/70 or less and which cannot be fully corrected with conventional glasses, and legal blindness is a level of visual impairment with a central visual acuity of 20/200 or less in the better eye with the best possible correction, or a visual field of 20 degrees or less (IDEA, 2004). Approximately 93,600 students with visual impairment and 55,200 students with legal blindness are served in special education in the United States (American Federation for the Blind [AFB], 2007). These figures derived from a multi-state survey of state special education representatives in 1999 (AFB) and reflect the most current information.

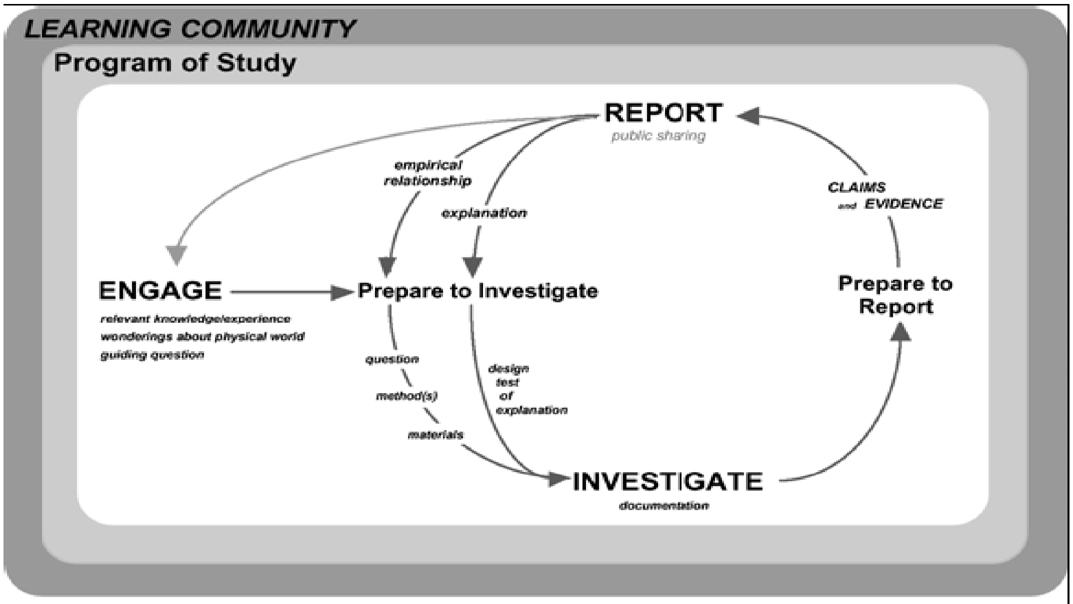
Scientists estimate that vision accounts for up to 90 percent of what a seeing child learns about the world in academic, social, and functional skill areas (MacCuspie, 1992). For this reason, special methods are required to teach children who are visually impaired (Lowenfeld, 1974; Koenig & Holbrook, 2000). First, a child needs a rich environment, with varied and consistent experiences. These experiences should include the use of concrete objects by which he can gain knowledge about the world around him and that aid in the development of meaningful concepts. Second, a child needs opportunities in which she can learn by doing. Third, unity within the lesson must be provided, giving the child an idea of the whole task and not just a fragmented portion of the task. A child needs to learn all steps involved in a task and not just two of the steps.  A child must learn to explore objects systematically so he can view all of its features by using all of his available senses. A child with a visual impairment needs to learn to explore objects by pairing her use of vision with tactile exploration (Lowenfeld, 1974). A child with a visual impairment will have a greater chance of academic success if modifications are made in the presentation of instruction and materials.

Inquiry-oriented approaches to science instruction and learning for a child with a visual impairment have shared characteristics. Learning through use of the senses, exploring concrete objects to further understanding, questioning discoveries, and testing the discoveries become a natural occurrence to the learner with a visual impairment. Using these common instructional approaches in science classrooms will increase the students' understanding, spark further interest, and provide new avenues for the students' futures. Hands-on experiences and enactments of scientific experiments in which students directly interact with the phenomena being studied are emphasized in an inquiry-based approach to instruction.  Including students with visual impairment in general education classes and preparing students to become better problem solvers and thinkers about the world around them are important opportunities that are provided to students in an inquiry-based classroom.

## Guided Inquiry Supporting Multiple Literacies

Guided inquiry science is a type of instruction in which teachers guide students' construction of scientific knowledge and reasoning through a process of inquiry regarding the physical world. The complex nature of guided inquiry instruction is highlighted in the GIsML heuristic (Magnusson & Palincsar, 1995).

Figure 1 GIsML Heuristic



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During first hand investigations in which students engage in direct exploration of a phenomenon, teachers guide students through different phases of activity. Beginning with engagement around a question, students work in groups to answer the question via systematic study. Following actual investigation, students analyze data and begin to make claims about the phenomenon under study. These claims, supported by evidence from the investigation, are discussed and adopted by the group of students working together, and then reported to the class. The teacher plays an important role in introducing students to the discourse of the scientific community. This knowledge includes, but is not limited to, vocabulary terms, standards for graphic representations, methods of engaging in inquiry, and norms of scientific reasoning.

The GIsML approach to instruction was chosen for this study because of the previous research conducted in which this approach was used with students with learning disabilities. Palincsar et al., (2000) and Palincsar et al., (2001) discussed how collaboration was used to help students with special needs realize success in inclusion science classrooms. Through observational methods, positive student outcomes were revealed (e.g. demonstrating success on inquiry-oriented tasks, seeking assistance in journal writing, engaging in scientific problem-solving, and actively participating in discussions). The authors concluded science is an instructional environment in which the child with disabilities could demonstrate strengths.

What implications do these studies using the GIsML approach to instruction have for the learner with a visual impairment? Object interaction and first-hand experiences were critical in facilitating the construction of knowledge in the learner with a disability (Palincsar et. al, 2001). The learner with a visual impairment builds knowledge of the world in the same manner as learners with sight and many researchers in the field of visual impairments have pointed out the importance of direct experiences. For example, Barraga (1983) emphasized the need for a child with a visual impairment to develop a relationship with the immediate environment, concluding experiences with the immediate environment would further facilitate a relationship between the child and the world around him. Similarly, Landau (1983) found a child with a visual impairment cannot develop concepts when relevant experience is deficient, and if the child's concepts are deficient, the child's learning and understanding of word meanings also will not develop. Although Landau's study was about the language development of children with a visual impairment, the relationship between experiences and learning is evident. In a related study, Andersen, Dunlea, and Kekelis (1984) found the language demonstrated by children with blindness appropriately "reflected their experience-specific conceptualizations of objects obtained through touch and other non-visual senses" (p. 662), again indicating the importance of experiences in helping to facilitate learning in the child with a visual impairment.

Social interaction is an essential component of learning (Vygotsky, 1986). Inquiry-oriented approaches can facilitate the development of social skills of students identified with a disability because peer interaction is promoted in the learner-centered environment. Arguably, social interaction to promote learning is essential for all students. However, students with a visual impairment may need more opportunities for educationally meaningful interaction (Hoben & Lindstrom, 1980; Kekelis, 1992; Kekelis & Sacks, 1992; McGaha & Farran, 2001). Wolffe and Sacks (1997) found students with a visual impairment spent more time alone than did peers with sight. Rosenblum (1998) found children with visual impairments had satisfying and supportive friendships; however, MacCuspie (1992) concluded as children with a visual impairment grow older, they participated less in social activities. Participating in a science classroom in which the teacher promotes peer interaction, the sharing of information, and discussions of findings may encourage the learner with a visual impairment to be socially aware and to practice social negotiation in problem solving.

## Significance of Study

The importance of providing all students with opportunities for learning science though inquiry-based instruction has been emphasized in national science education reform documents (NRC, 1996, 2000). Engaging in inquiry is purported to deepen students' learning of science content and broaden their understanding of the nature of science. Inquiry is a promising approach for improving student achievement and enhancing student interest and motivation in science (Krajcik et al., 1998; Krajcik & Blumenfeld, 2006). However, very few studies have been conducted with students with disabilities in inquiry-based instructional settings. Research examining the science instructional experiences of students with disabilities, especially those students with visual impairment or blindness, is a critical need.

## Organization of the Dissertation

The dissertation is comprised of six chapters. This first chapter serves as the introduction to the dissertation and the three manuscripts. Chapter Two presents a review of the literature that draws centrally from the fields of education for children with visual impairment, special education, and science education. The focus of the literature review chapter is on relevant literature addressing the educational needs of children with visual impairment and provides a rationale for examining an inquiry-based approach to instruction for students with visual impairment. Chapters Three through Five are the three manuscripts. The purpose of the three manuscripts was to investigate instructional experiences of students with visual impairment in an inquiry-based science classroom. Drawing from social constructivists perspectives, I focused on the initial attempts of students to participate fully in an inquiry-based approach to instruction. Chapter Six presents a summary of findings from the three manuscripts and discusses implications of the study for the education of children with visual impairments, special education, inclusive education, and science education. Additionally, recommendations for professional development and further research are presented.

### *Overview of Manuscripts*

The first manuscript is a synthesis of case studies of five middle school students with visual impairment as they engaged in inquiry during two projects spanning 10 weeks. Details of how students asked questions, constructed models, carried out investigations, drew conclusions, and presented their understandings are discussed. Teacher support of student thinking and writing are examined. The goal of this manuscript is to describe realistically what middle school students with visual impairment do and what difficulties they have with inquiry learning. This information serves to inform general educators and special educators so they can anticipate what students with visual impairment may need help with and, therefore, design instructional practices to promote effective learning through inquiry. Specific research questions included the following:

1. What opportunities are provided to students with visual impairment during inquiry science instruction?
2. What challenges do students with visual impairment face during science inquiry instruction?
3. What is the impact of inquiry-based science instruction on motivation and achievement of students with visual impairment?

The second manuscript expands the focus of the first manuscript and examines how questioning and science notebook writing can support student learning and understanding in the inquiry-based classroom. Specific research questions were as follows:

1. What questioning patterns are prevalent in the inquiry-based classroom?
2. How often did student questions occur during specific dialogues (e.g. teacher initiated, inquiry)?
3. Under what condition did the students' questions occur (i.e. prompting by teacher, self-initiated, in response to a statement)?
4. What levels of questions, based on Bloom's Taxonomy, do students ask?
5. What types of instructional scaffolds are most conducive to student growth in writing science, specifically with the use of science notebooks?

Alternate conceptions and conceptual understandings of a middle school student with visual impairment about the cause of lunar phases are described in the third manuscript. Specific research questions included the following:

1. What model (i.e, eclipse model) of how lunar phases occur did students possess prior to inquiry-based instruction?
2. How do these pre-inquiry instruction models compare to those of sighted peers?
3. How did the use of physical models (i.e., varied sizes of Styrofoam balls to represent the sun, earth and moon) influence the development of scientific frameworks of students?
4. What evidence, if any, exists to support students' growth in conceptual change?

# CHAPTER II

# LITERATURE REVIEW

Science education reform necessitates purposeful and planned instruction for all students, emphasizing instruction aligned with the current thinking found in empirical research grounded in theory (National Research Council, 1996; Singer, Marx, Krajcik, & Clay-Chambers, 2000). Knowledge of science pedagogy for children with disabilities is continuing to increase (Mastopieri, Scruggs, & Butcher, 1997; Palincsar, Collins, Marano, & Magnussen, 2000; Palincsar, Magnusson, Collins, & Cutter, 2001; McCarthy, 2005). However, literature in science methodology for learners with a visual impairment is sparse (Erwin, Perkins, Ayala, Fine, & Rubin, 2001; DeLucci & Malone, 1982; Hadary, 1977). Although my primary interest was to review the literature available in science education for children with a visual impairment, the scarcity of the literature required me to broaden the search with the belief that studies including students with other disabling conditions would provide relevant similarities to the experiences of students with visual impairment in the science classroom. The purpose of this review was to answer the following questions: (a) What recent research has been conducted on science instruction for students with a disability? and (b) What implications does the current research in science education of students with disabilities have for the learner with a visual impairment?

## Literature Search Procedures

A systematic search of all literature was conducted. Modes of searching included reviews of subject related databases and recommended citations, consultation with members of both fields of interest, and hand searches of key journals. Learning/visually impaired/experiences, students with a visual impairment/education, science/visually impaired/education, disabilities/science education/visual impairment, and blind/science education were the phrases searched. Authors associated with science education, education of students with a visual impairment, and education of students with disabilities also were searched. A request for information was distributed via the internet on three education listservs related to science education and the education of students with a visual impairment. Colleagues from three universities were consulted. In addition, colleagues teaching science at two state schools for the blind were contacted for information. Journals specific to science education, education of students with a visual impairment, and education of students with disabilities were searched by hand.

## Early Studies in Science Education for All Students

Mastropieri and Scruggs (1992) conducted a comprehensive literature review of science education for children with disabilities. The authors analyzed 66 reports divided into two categories: (a) instructional strategies, and (b) science curriculum evaluation or comparison reports. The authors found activity-oriented science curricula were effective in facilitating knowledge of content, manipulative skills, and science process skills. Activities-oriented curricula also were found to increase both the enjoyment of and motivation for science in children with disabilities.

Of the 66, 14 of the studies included learners with a visual impairment (Mastropieri & Scruggs, 1992). Researchers studied the use of science activities-oriented curriculum materials or Braille programmed instruction. Curriculum adaptations, materials adaptations, and activities-oriented materials were reported as being successful for students with a visual impairment. However, these seminal studies were conducted between 1967 and 1978.

The search for current literature yielded four empirical studies involving students with low incidence disabilities (McCarthy, 2005; Erwin, Perkins, Ayala, Fine, & Rubin 2001; Mastropieri, Scruggs, Mantzicopoulos, Sturgeon, Goodwin, & Chung, 1998; Scruggs, & Mastropieri, 1994). Children diagnosed with a low incidence disability include children with (a) moderate and severe cognitive disabilities, (b) multiple disabilities, (c) sensory impairments, (d) orthopedic impairments, (e) traumatic brain injury, or (f) autism (Smith, 2001). A serious gap in the literature exists, and a need to address current thinking in the reform efforts of science education for all students is evident. The search was broadened to include studies in which students with high incidence disabilities were included as participants in the study. Children identified with a high incidence disability include children with (a) learning disabilities, (b) mild mental disabilities, (c) attention deficit hyperactivity disorder, (d) emotional disabilities, or (e) behavioral disorders (Smith, 2001). Altogether, 10 reports were located and reviewed. A descriptive breakdown of these studies is presented in Table 2.1.

Table 2.1: Disability Studies in Science Education: 1992-Present

| Citation | Sample | Intervention | Reported Results | Design |
|---|---|---|---|---|
| McCarthy, 2005 | N=18<br>6th-8th SC<br>ED | Textbook v/s inquiry-oriented instruction | Significant results on 3 of 4 measurements<br>Achievement: F(3,16)=15.77, p=.000<br>Short answer: F(1, 16)50.11, p=.000<br>Performance assess: F(1,16)=7.27, p=.016 | Pre/post on all measurements<br>NR: 2 conditions |
| Erwin et al., 2001 | N=9<br>1st, 4th SC<br>VI | PSCD Curriculum adaptation | Positive for activities-oriented instruction | Observational<br>NR: 1 condition |
| Palincsar et al., 2001 | Phase 1:<br>N=22<br>(3)4th, (1)5th<br>MS<br>LD, EI, PDD<br>Phase 2:<br>N=19<br>LD, EI | Phase 1: observation<br>Phase 2: GIsML | Phase 1: guidelines<br>Phase 2: statistically significant gains, p=.0129 and p=.0431 | Design experiment<br>NR: 1 condition<br>Observational |

Table 2.1 continued

| Citation | Sample | Intervention | Reported Results | Design |
|---|---|---|---|---|
| Palincsar et al., 2000 | N=1<br>4th MS<br>LD | GIsML | Positive for GIsML instruction | Case study<br>NR: 1 condition |
| Mastropieri et al., 1998 | N=5<br>(3) 4th MS<br>(2)LD,<br>(1)MMH,<br>(1)ED,<br>(1)Multiple | Text-book v/s activities-oriented instruction | SWD: At or above class mean on multiple choice, performance, and verbal fluency tests | Observational<br>Pre/post on all measurements<br>NR: 2 conditions |
| Dalton et al., 1997 | 8 schools<br>N=172<br>4th MS<br>N=33<br>LD | Supported Inquiry Science (SIS) v/s Activity-based Science (ABS) | Student gain scores: main effect for group SIS students outperformed ABS students, F(1, 156) = 40.00, p<.0001 Positive results for SWD | Pre/post<br>Observational<br>Partial RA: 2 conditions |
| Scruggs et al., 1994 | N=14<br>1st-5th SC<br>(6)MMH,<br>(8)LD | FOSS with activities-oriented instruction | Positive results:<br>SWD achieved success | Observational<br>NR: 1 condition |
| Scruggs et al., 1993 | N=26<br>6th – 8th<br>LD | Inquiry-oriented approach to instruction using FOSS materials | Positive effects inquiry-oriented condition (effect size=.42 and .49) | Cross over design<br>NR: 2 conditions repeated |

Table 2.1 continued

| Citation | Sample | Intervention | Reported Results | Design |
|---|---|---|---|---|
| Scruggs et al., 1994 | N=15<br>(3) 3rd, 4th, 5th MS<br>(2)HI,<br>(9)LD, (1)VI,<br>(3)physical | Inquiry-oriented activities | 7 variables reported as meaningfully associated with success | Observational<br>NR: 1 condition |
| Bay et al., 1992 | N=16<br>4th-6th<br>(10)LD<br>(6)BD<br>N=107 all students | Discovery teaching<br>versus direct instruction | LD discovery outperformed LD direct instruction (beta=.94, t=3.44, p<.001) | 2x5 factorial design<br>RA: 2 conditions |

*Note*. ED = emotional disability; NR = non-random assignment; VI = visual impairment; PSCD = Playtime is Science for Children with Disabilities; LD = learning disability; EI/ED = emotional impairment/disorder; PDD = pervasive developmental disorder; GIsML = Guided Inquiry Supporting Multiple Literacies; MMH = mild mental handicap; SWD = students with disabilities; RA = random assignment; FOSS = Full Option Science System; HI = hearing impairment; BD = behavioral disorder

Table 2.2: Characteristics of Participating Students Identified with a Disability

| | Total N of studies = 10 | Total N of participants = 156 |
|---|---|---|
| Disability area | N of studies | % of participants |
| Low incidence disabilities | | |
| Visual impairment | 2 | .06 |
| Hearing impairment | 1 | .01 |
| Multiple disability | 1 | .006 |
| Physical disability | 1 | .02 |
| High incidence disabilities | | |
| Learning disability | 8 | .66 |
| Behavioral disorder | 1 | .04 |
| Mild mental handicap | 2 | .04 |
| Emotional disorder | 3 | .15 |

## Current Literature (1992-present)

Studies were conducted with children identified with a variety of low and high incidence disabilities (see Table 2.2). As is typical of studies including students with disabilities, the participant sample sizes ranged from 1 participant to 33 participants, with 30% of the studies having less than 10 participants.

Settings were inclusion classrooms (60%) and self-contained classrooms (40%). Both quantitative and qualitative methods were used in 60% of the studies, with 40% of the studies using only qualitative methods. Following the format presented by Mastropieri and Scruggs (1992), the studies were grouped into two primary categories: (a) instructional strategies (50%), and (b) curriculum comparisons (50%).

### *Instructional Strategies*

Erwin, Perkins, Ayala, Fine, and Rubin (2001) studied the impact and implementation of Playtime is Science for Children with Disabilities (PSCD). The PSCD curriculum is an approach to activities-oriented science instruction that incorporates science and scientific thinking into the daily routines of children identified with a disability. Through implementation of PSCD, the teacher reinforces the connection between children's play and science learning. Erwin and colleagues adapted the PSCD curriculum to meet the needs of students with a visual impairment. Two classroom teachers and their nine students from the first and the fourth grades participated in the study. The students attended a state funded residential school serving students with a visual impairment.

Methods included observation with field notes, student and teacher interviews, and a teacher focus group. Student-related outcomes were identified through analyses of data. Positive peer-related skills, creating meaningful connections about the world, and teacher support of student learning had an impact on the students' knowledge and learning of scientific concepts.

The study by Erwin et al (2001) is important to the field of education of students with visual impairments and to the field of science education. Erwin et al focused on the impact of inquiry-based instruction for children with a visual impairment, and addressed a gap in the literature spanning two decades. Also, the authors concluded a meaningful learning environment for students with a visual impairment is one in which teachers provide guided opportunities for students to pursue their own interests and answer their own questions. This finding shows the importance of the current reform documents of the NRC in which inquiry-based instruction in science classrooms is promoted (1996). Erwin et al found active involvement, peer interaction, discussion, and the use of prior knowledge to construct new knowledge were essential in helping the students understand science concepts.

The small sample size of nine students is a limitation to the Erwin et al. (2001) study. Also, because the study was conducted in a residential school setting, comparisons between mainstreamed classrooms including both children with disabilities and children without disabilities cannot be made; therefore, generalizations across students and classrooms are restricted.

Although research on inquiry-oriented approaches in science education for children with visual impairments is limited, the use of inquiry-based instruction in science classrooms has been reported as successful for students with other disabilities. Palincsar, Collins, Marano, and Magnusson (2000) and Palincsar, Magnusson, Collins, and Cutter (2001) studied the engagement and learning of students with learning disabilities as the students participated in the Guided Inquiry Supporting Multiple Literacies (GIsML) approach to science instruction (cf. Magnusson and Palincsar, 1995). This approach is based on the authors' knowledge of research and practice of intentional learning and scientific activity. In GIsML instruction, inquiry is guided by a broad question that includes a general concept (e.g. Why do things sink or float?). Students are engaged in inquiry through cycles of investigation. The authors indicated learning occurs in a socially mediated community of inquiry (cf. The Cognition and Technology Group at Vanderbilt, 1994), in which small groups of students attempt to answer specific questions and whole groups of students compare and contrast their ideas and findings with the findings of others. In the course of GIsML instruction, students and teachers participate in two forms of investigations. In firsthand investigations, children have experiences related to the phenomena they are investigating. In secondhand investigations, children consult text for the purpose of learning from others' interpretations of phenomena or ideas.

As a second purpose to their study, Palincsar et al (2000) addressed how collaboration was used to help students with special needs realize success in inclusion science classrooms. Through observational methods, the researchers developed five case studies of students with learning disabilities that were used to create a set of claims concerning the engagement and learning of these students. The case study of a 4th grade boy identified with a learning disability was presented. Through the use of field notes from classroom observations, positive student outcomes were revealed (e.g. demonstrating success on inquiry-oriented tasks, seeking assistance in journal writing, engaging in scientific problem-solving, and actively participating in discussions). The authors concluded science is an instructional environment in which the child with disabilities could demonstrate strengths.

Continuing with the same design as the experiment presented in 2000, Palincsar et al (2001) reported on two phases of their several-year project. Teachers in four 4th or 5th grade classrooms used the GIsML approach to science instruction. In the first phase, the classroom teachers conducted the GIsML program without interventions to support the 22 of 168 students identified with a disability. Researchers collected observational data in the form of video and audio recordings, student and teacher interviews, and field notes. Although classroom teachers did not intervene directly, the researchers provided support to the students identified with a disability only if necessary and only as long as the intervention was needed for redirecting the students. The interventions were used to establish guidelines for advanced teaching practices needed to support learners in the next phase. Monitoring and facilitating student thinking, supporting print literacy, and improving group work were a few of the guidelines established.

In phase two, the teachers, participants from phase one, selected specific advanced teaching practices to add to their current GIsML approach to instruction. Students participating included 19 students with a disability of the total 111 participants. Pre and post test data were analyzed to determine the learning gains of (a) students identified with a disability, (b) students identified as low-achieving, and (c) students identified as normally-achieving. In two classes, students with a disability made statistically significant learning gains, p=.0129 and p=.0431. In a third class, the learning gains of students with a disability approached significance, p=.0679, and in the fourth class, the students with a disability did not make significant learning gains. Based on data analyses of classroom observations and of the teacher's personal journal, the authors attributed the lack of students' significant learning gains in the fourth classroom to the teacher's limited expectations of what was possible for her students. Overall, Palincsar et al (2001) found the advanced instructional content represented by guided inquiry science teaching enhanced the learning of students identified with a disability.

In a similar study, Scruggs and Mastropieri (1994) investigated how children with disabilities construct scientific knowledge in inquiry-oriented science classrooms. The study was conducted during two academic years with 14 students, six children identified with mild mental handicaps (MMH) and eight children identified with learning disabilities in 1st to 5th grades, and the two special education teachers.

Observational research methods were used to collect data and included video and audio recordings during classroom observations, student and teacher interviews, and student work samples. The classroom teachers used the Full

Option Science System (FOSS) approach to science instruction. Students demonstrated difficulty in sorting and classifying, in making inferences, and in drawing conclusions. However, with adaptations such as reduced vocabulary demands, graphic organizers, multiple representations, structured questioning techniques, familiarizing students with science materials, and guided coaching the authors concluded students with disabilities could participate and be successful in an inquiry-oriented science classroom. A limitation to this study is that student participants met in a self-contained, small-group setting; therefore, results cannot be generalized to an inclusion setting. The authors addressed this limitation in future studies by implementing inquiry-oriented instruction with students in an inclusion setting.

Continuing their efforts to provide guidelines for science instruction with students with disabilities, Scruggs and Mastropieri (1994) conducted a three-year collaborative project to identify variables associated with successful inclusion of learners with a disability in an inquiry-oriented science classroom. In the first two years of the study, researchers met with administrators, special educators, and other specialists to develop and refine guidelines for including students with disabilities in science classrooms. In the third year of the study, classrooms were targeted for observational research to provide support for the guidelines. Three classroom teachers and 16 students identified with disabilities, representing 3rd, 4th, and 5th grades, participated in the study. Data gathered included field notes from classroom observations, student and teacher artifacts, video recordings, curriculum materials, and student interviews about their inquiry experiences.

Through data analyses, common variables were identified as meaningfully associated with mainstream success of students with a disability in science classrooms: administrative support, special education personnel support, an accepting and positive classroom atmosphere, appropriate curriculum and adaptations, effective general teaching skills, peer assistance, and disability-specific teaching skills. The authors concluded the students with disabilities in this study appeared to be generally representative of many students with disabilities in other schools. However, characterizing the teachers as generally representative would be difficult because the teacher participants were selected based on their prior experience and success with teaching students with disabilities in the mainstream classroom. Even with this limitation, the important evidence about how students with disabilities can be included in science classes is a contribution to the education field.

### *Curriculum Comparisons*

Two major curricular approaches to science instruction include the traditional textbook-based approach and the activities-oriented approach. Scruggs, Mastropieri, Bakken, and Brigham (1993) compared the effectiveness of inquiry-oriented versus textbook-based science curriculum materials in promoting science learning of 26 students identified with a learning disability (LD) enrolled in four self-contained classrooms. Students in both conditions were taught units on electricity and rocks and minerals. In the inquiry-oriented condition, the classroom teacher provided student-centered activities designed to encourage student thinking and problem solving to uncover scientific principles. The Full Option Science System (FOSS) curriculum materials were used. In the text-book based condition, the classroom teacher provided exactly the same content information, but used direct teaching strategies rather than inquiry-approaches to instruction.

A crossover design was used in which all students received instruction under both conditions. Students in the inquiry-oriented condition learned and recalled more information on immediate and delayed recall tests (effect size=.42 and .49) than the students participating in the text-book based condition. In interviews, virtually all students expressed preference for inquiry-oriented materials over textbook materials. The sample size of only 26 students and the self-contained setting are considered limitations to this study.

To determine the effectiveness of mainstreaming students with a disability into the general education science classroom; Mastropieri, Scruggs, Mantzicopoulos, Sturgeon, Goodwin, and Chung (1998) conducted a study of three 4th grade classrooms. Participants were all students in the selected classrooms, which included two students with LD, one student with mild mental handicap (MMH), one student identified as emotionally disturbed (ED), and one student with multiple disabilities. Students participated in either a textbook-based condition or an activities-oriented condition. Additionally, all students were measured with pre/post multiple choice tests, comprehension/performance tests, and verbal fluency tests. Overall, the students participating in the activities-oriented approach demonstrated statistically significant growth on all three measurements, F(1,65)=4.8, p=032; F(1,65)=68.35, p=.000; and F(1,65)=104.59, p=.000 respectively. Students with disabilities collectively scored above or at the class mean on the same measurements. The authors concluded the inquiry-based approach to instruction was beneficial to students identified with a disability in the general education science classroom.

An important limitation of the Mastropieri et al. study is that students with a disability only participated in the activities-oriented classroom and did not participate in the text-book based condition. Therefore, comparisons could not be made between students with disabilities in a text-book based approach to instruction and students in an inquiry-based approach to instruction. In addition, the presence of the special education inclusion teacher within the activities-oriented classroom may have contributed to treatment effects.

In a similar study, Bay, Staver, Bryan, and Hale (1992) compared the effect of direct instruction and discovery teaching on the science achievement of students with mild disabilities and students without disabilities. Discovery teaching was described as instruction in which students were engaged in gathering data, generating and implementing solutions, and observing consequences. Direct instruction was defined as teacher-focused processes and presentation and demonstration of specific skills or concepts. The researchers found neither method had a direct impact on immediate achievement; however, students' retention after two weeks was higher for those who participated in discovery instruction.

In a study to compare the development of conceptual understanding of electricity concepts in an inquiry-based condition to an activity-based condition, Dalton, Morocco, Tivnan, and Mead (1997) observed eight 4th grade classrooms enrolling 172 students in which 33 students were identified with LD. In the Supported Inquiry Science (SIS) condition, teachers took an active coaching role in the classroom; they guided students in recursive processes of experimenting and processing for meaning to promote conceptual change in students. In the activity-based science (ABS) condition, teachers engaged the students in a series of hands-on activities. However, in the ABS condition, little attention was given to students' conceptual understanding or to the social processes that mediate learning such as sharing of student findings, peer evaluation of projects, and group discussions to facilitate the development of meaning.

The study was conducted over a two month period. A pre/post questionnaire, a diagram test, and a pre/post concept test were used to collect important information regarding the learning gains of the students. An ANOVA of students' gain scores on the questionnaire administered before and after instruction yielded a main effect for group was found with the SIS students outperforming the ABS students, $F(1, 156)=40.00$, $p<.0001$. The SIS students had an average gain of 18.05 points, approximately twice that of the ABS students' gain of 9.41 points. A main effect for learner status also was found, F(3, 156)=6.90, p<.0002. As a group, students identified with LD demonstrated less conceptual growth than their peers without disabilities. Additionally, the SIS students obtained higher concept gain scores that the ABS group with a main effect for group found in each concept area (simple circuits, F(1, 156)=30.23, p<.0001; conductivity, F(1,156)=32.65, p<.0001; series circuits, F(1,156)=17.01, p<.0001; parallel circuits, F(1,156)=12.73, p<.0005). The positive effect of SIS instruction was consistent for students with diverse abilities, indicated by the lack of interaction effects. The authors concluded all students showed greater attainment of conceptual understanding in the inquiry condition, and the students with a learning disability benefited from the challenging SIS curriculum.

McCarthy (2005) conducted a study comparing text-book based instruction to hands-on, inquiry-based instruction with 18 middle school students identified with serious emotional disorders in a self-contained, partial hospitalization setting. Most of the students also had secondary disabilities. The students were assigned to one of two conditions based on current classroom enrollment. Overall, the author reported statistically significant gains in achievement for students participating in the hands-on approach, F(3,16)=15.77, p=.000. Several measurements were used in the analyses of data including pre/post multiple choice tests, short answer tests, and performance assessments. No significant differences were obtained on the multiple choice tests; however, on both the short answer and the performance assessments, students in the hands-on group outperformed the text-based instruction group, F(1,16)=50.11, p=.000 and F(1,16)=7.27, p=.016. The author concluded the inquiry-oriented approach to instruction was more effective for students identified as emotionally disturbed than was the text-book based instruction.

Teacher participants in the McCarthy study may have had an impact on the treatment effects. The teachers had specialized training in the education of students with behavior and emotional disorders and applied strong behavioral-management strategies in the classroom. Therefore, the experiences and training of the teachers may not be reflective of teachers working with students in other settings, including special education and regular education settings.

## Limitations of Studies Reviewed

General limitations to the studies reviewed should be discussed. First, most studies had a small number of students participating, which is typical of studies including students with disabilities. Small sample sizes do not allow for generalizations across simiilar situations. However, insight into the unique characteristics of children with a disability, and the knowledge gained about how children with a disability learn and are best supported in an inquiry-oriented approach are beneficial. Next, many of the teachers participating in the studies were selected because of their exceptional teaching skills and their experiences working with children with disabilities. The strategies and skills employed by the teachers may be unlike those of the general teaching population; therefore, generalizations across teachers would be difficult. Also, as previously stated, only two of the studies included children with visual impairments as participants, indicating a strong need for research in the area of science learning for children with a visual impairment.

Inquiry-oriented approaches to science instruction and learning for a child with a visual impairment have shared characteristics. Learning through use of the senses, exploring concrete objects to further understanding, questioning discoveries, and testing the discoveries become a natural occurrence to the learner with a visual impairment. Using these commonalities for instruction in science classrooms will increase the students' understanding, spark further interest, and provide new avenues for the students' futures.

## Implications for Practice/Discussion

The studies reviewed were focused on science education and instruction for children with a variety of disabilities. Because the authors reported positive findings for inquiry-oriented approaches, one may conclude students with a disability can achieve success in the science classroom with appropriate adaptations and accommodations. One also may conclude the use of inquiry-oriented approaches in science education can be an effective method to use with students identified with a disability. All but one study (Erwin et al, 2001) was focused on accommodations and adaptations to the general science education curriculum, again indicating students with a disability can be successful with appropriate supporting techniques such as the facilitation of student thinking, guided coaching, and multiple representations of content and processes (NRC, 1996; Singer et al., 2000).

Collectively, these studies can provide educators important information regarding inquiry-oriented approaches to science instruction for students identified with a disability. Support for the value of inquiry-based approaches is evident. Students with a disability demonstrated knowledge construction in both special education classrooms and in mainstreamed classrooms. Knowledge construction was facilitated by the meaningfulness of materials presented, by active participation and exploration, and by building these experiences into the students' prior knowledge. Personal construction of knowledge is a fundamental philosophy of the social constructivism models of teaching emphasized in current science education reform efforts (Mergendoller, Maxwell, & Bellisimo, 2006; Sawyer, 2006; Krajcik, Czerniak, & Berger, 2002).

Many positive outcomes were demonstrated in the reviewed studies connecting the effects of inquiry-oriented approaches in science and students with a disability. First, science was an instructional context in which the child with a disability could demonstrate strengths. Adaptations such as reduced vocabulary demands, graphic organizers, and multiple representations of content materials gave the students with a disability ways to verbally engage in the science classroom. Structured questioning techniques were used to guide and facilitate students' thinking, demonstrating that the child with a disability can exhibit higher thinking skills and cognitive processes to work through a problem.

The teacher's guided coaching strategies provide the students with a disability the opportunity to build upon prior knowledge and experiences and to create new knowledge of the materials presented.

An additional positive outcome of the inquiry approach to science instruction in virtually all student interviews conducted is that the students expressed a preference for inquiry-oriented activities over text-book based instruction. The preference for inquiry-oriented activities is not surprising given that students learn best by doing (NRC, 1996).

What implications do the studies reviewed have for the learner with a visual impairment? Object interaction and first-hand experiences were critical in facilitating the construction of knowledge in the learner with a disability, as demonstrated in the studies reviewed. The learner with a visual impairment builds knowledge of the world in the same manner, and the importance of direct experiences has been noted by many researchers in the field of visual impairments. For example, Barraga (1983) emphasized the need for a child with a visual impairment to develop a relationship with the immediate environment, concluding experiences with the immediate environment would further facilitate a relationship between the child and the world around him. Similarly, Landau (1983) found a child with a visual impairment cannot develop concepts when relevant experience is deficient, and if the child's concepts are deficient, the child's learning and understanding of word meanings also will not develop. Although Landau's study was about the language development of children with a visual impairment, the relationship between experiences and learning is evident. In a related study, Andersen, Dunlea, and Kekelis (1984) found the language demonstrated by children with blindness appropriately “reflected their experience-specific conceptualizations of objects obtained through touch and other non-visual senses” (p. 662), again indicating the importance of experiences in helping to facilitate learning in the child with a visual impairment.

The unique social needs of students identified with a disability were not discussed in the studies reviewed. However, social interaction is an essential component of learning. Inquiry-oriented approaches can facilitate the development of social skills of students identified with a disability because peer interaction is promoted in the learner-centered environment. Arguably, social interaction to promote learning is essential for all students. However, students with a visual impairment may need more opportunities for educationally meaningful interaction than students with sight (Hoben & Lindstrom, 1980; Kekelis, 1992; Kekelis & Sacks, 1992; McGaha & Farran, 2001). Wolffe and Sacks (1997) found students with a visual impairment spend more time alone than peers with sight. Rosenblum (1997) found children with visual impairments have satisfying and supportive friendships; however, MacCuspie (1992) concluded as children with a visual impairment grow older, they participate less in social activities. Participating in a science classroom in which the teacher promotes peer interaction, the sharing of information, and discussions of findings may encourage the learner with a visual impairment to be socially aware and to practice social negotiation in problem solving.

## Conclusion

The studies reviewed contribute to the literature in several ways. First, inquiry-oriented approaches to science instruction were shown to be effective and successful for children with disabilities. Although direct instruction methods may be useful in some situations, these studies have shown students with disabilities seemingly thrive in inquiry-oriented learning environments. However, additional research is needed to increase the knowledge base about science education for students with a visual impairment. Future research can provide information on the following questions yet unanswered in the current literature: (a) How may the social constructivist models of science learning, prevalent in science reform efforts, promote meaningful engagement of students with a visual impairment in the science classroom? (b) What are the optimal methods for facilitating scientific knowledge construction in students with a visual impairment? (c) What type and amount of support is required by special educators, science teachers, and peers to successfully include students with a visual impairment in the mainstream science setting? Strong support for inquiry-oriented approaches to science instruction for children with disabilities was provided by the studies reviewed. However, this review is also a call for research that provides support for inquiry approaches in science education for the learner with a visual impairment.

# CHAPTER III

## WHAT DO STUDENTS DO IN SCIENCE?

## LEARNING EXPERIENCES OF STUDENTS WITH VISUAL IMPAIRMENT IN A GUIDED INQUIRY SCIENCE CLASSROOM

All students need opportunities to find solutions to real problems by asking and refining questions, designing and conducting investigations, gathering and analyzing information and data, making interpretations, drawing conclusions, and reporting findings (Krajcik & Blumenfeld, 2006; Palincsar, Collins, Marano & Magnussen, 2000; Palincsar, Magnusson, Collins & Cutter, 2001; Bay, Staver, Bryan & Hale, 1992; McCarthy, 2005; National Research Council, [NRC] 1996, 2000). These opportunities are congruent with contemporary educational reform documents that call for the teaching of science to be inquiry based (NRC, 2000). The assumption guiding these documents is that as students engage in inquiry activities, they acquire the knowledge and skills to help them develop a deep understanding of science ideas and concepts.

However, children in inquiry environments are presented with many cognitive challenges. To develop competence in the area of inquiry, students must have a deep foundation of factual knowledge (Krajcik, Blumenfeld, Marx, Bass, Fredricks, & Soloway, 1998). In addition, students must organize knowledge in new ways (NRC, 2000). To successfully engage in scientific practices such as collecting data, generating evidence, and reporting results, learners need to use reading, writing, and speaking skills and draw from knowledge across content areas. (Bybee, 2002). In this way, learners are expected to integrate knowledge, and use and apply this knowledge as they reason through inquiry investigations (NRC, 2000).

Despite these challenges, students with disabilities have been successful in inquiry-based learning environments (Bay et al., 1992; Mastropieri, Scruggs & Magnusen, 1999; Palincsar, Collins, Marano, & Magnusson, 1999; Dalton, Morocco, Tivnan, & Mead, 1997; McCarthy, 2005). Many positive student outcomes have been associated with inquiry-oriented approaches in science. First, science is an instructional context in which the child with a disability can demonstrate strengths. Adaptations such as reduced vocabulary demands, graphic organizers, and multiple representations of content materials can give the students with a disability ways to verbally engage in the science classroom. Structured questioning techniques have been used to guide and facilitate students' thinking, demonstrating that the child with a disability can exhibit higher thinking skills and cognitive processes to work through a problem. The teacher's guided coaching strategies provided the students with a disability the opportunity to build upon prior knowledge and experiences and to create new knowledge of the materials presented. The researchers revealed that in virtually all student interviews conducted, the students expressed a preference for inquiry-oriented activities over text-book based instruction.

## The Visually Impaired Learner

For the purpose of this paper the term visual impairment, including blindness, is derived from the Individuals with Disabilities Act (2004) and is defined as "an impairment in vision that, even with correction, adversely affects a child's educational performance" (p. 598), and may be broadly classified as low vision, legally blind, or totally blind (Turnbull, Turnbull III, Shank, & Leal, 1995). To determine eligibility for educational services, the severity of visual impairment has been defined by law. Low vision is a term that denotes a level of vision with an acuity level of 20/70 or less and which cannot be fully corrected with conventional glasses, and legal blindness is a level of visual impairment with a central visual acuity of 20/200 or less in the better eye with the best possible correction, or a visual field of 20 degrees or less (IDEA, 2004). Approximately 93,600 students with visual impairment and 55,200 students with legal blindness are served in special education in the United States (American Federation for the Blind [AFB], 2007). These figures derived from a multi-state survey of state special education representatives in 1999 (AFB) and reflect the most current information.

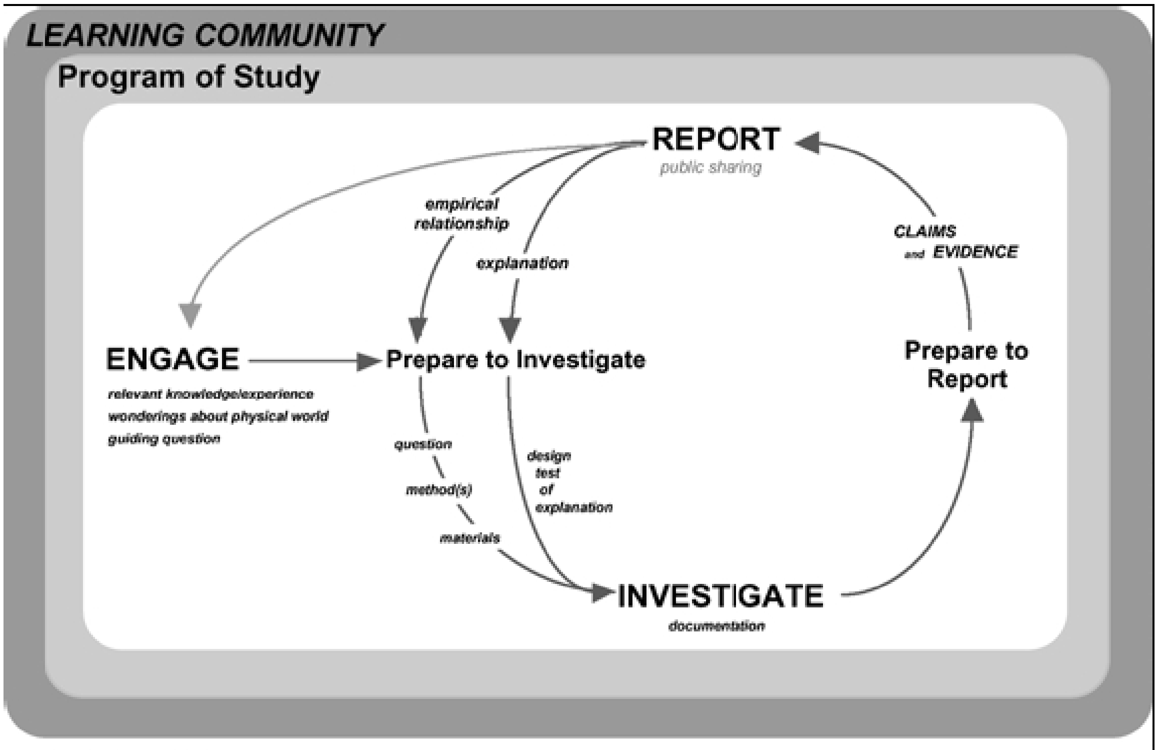
Scientists estimate that vision accounts for up to 90 percent of what a seeing child learns about the world in academic, social, and functional skill areas (MacCuspie, 1996). For this reason, special methods are required to teach children who are visually impaired (Lowenfeld, 1974; Holbrook & Koenig, 2000). First, a child needs a rich environment, with varied and consistent experiences that include the use of concrete objects to help build knowledge about the physical world around him and aid in the development of meaningful concepts. Second, a child needs opportunities for learning by doing. Third, unity within the lesson must be provided, giving the child an idea of the whole task and not just a fragmented portion of the task. For example, a child with visual impairment needs to learn all steps involved in a task rather than just a few of the steps. A child must learn to explore objects systematically by using all of his available senses. A child with a visual impairment needs to learn to explore objects by pairing her use of vision with tactile exploration (Lowenfeld, 1974). Overall, the researchers suggested that a child with a visual impairment will have a greater chance of academic success if modifications such as the ones highlighted here are made in the presentation of instruction and materials.

Inquiry-oriented approaches to science instruction and learning for a child with a visual impairment have shared characteristics. Learning through use of the senses, exploring concrete objects to further understanding, questioning discoveries, and testing the discoveries become a natural occurrence to the learner with a visual impairment. Using these common approaches instructional approaches in science classrooms will increase the students' understanding, spark further interest, and provide new avenues for the students' futures. Hands-on experiences and enactments of scientific experiments in which students directly interact with the phenomena being studied are emphasized in an inquiry-based approach to instruction. Including students with visual impairment in general education classes and preparing students to become better problem solvers and thinkers about the world around them are important opportunities that are provided to students in an inquiry-based classroom.

## Guided Inquiry Supporting Multiple Literacies

Guided inquiry science is a type of instruction in which teachers actively guide students' construction of scientific knowledge and reasoning as they participate in the inquiry process. The complex nature of guided inquiry instruction is highlighted in the GIsML heuristic (Figure 3.1).

*Figure 3.1 GIsML Heuristic*



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The inquiry cycle, as illustrated in Figure 3.1, begins with first hand investigations in which students engage in direct exploration of a phenomenon, and teachers guide students through different phases of activity. With student engagement centered around a question, students work in groups to answer the question via systematic study. Following actual investigation, students analyze data and begin to make claims about the phenomenon under study. These claims, supported by evidence from the investigation, are discussed and adopted by the group of students working together, and then reported to the class. The teacher plays an important role in introducing students to the discourse of the scientific community. This knowledge includes, but is not limited to, vocabulary terms, standards for graphic representations, methods of engaging in inquiry, and norms of scientific reasoning.

The GIsML approach to instruction was chosen for this study because of the previous research conducted in which this approach was used with students with learning disabilities. Palincsar, Collins, et al., (2000) and Palincsar, Magnusson, et al., (2001) demonstrated how a guided inquiry approach can be used to help students with special needs realize success in inclusion science classrooms. Through observational methods, positive student outcomes were revealed (e.g. demonstrating success on inquiry-oriented tasks, seeking assistance in journal writing, engaging in scientific problem-solving, and actively participating in discussions). The researchers concluded that thoughtfully guided science instruction supports an instructional environment in which the child with disabilities can demonstrate strengths.

What implications do these studies using the GIsML approach to instruction have for the learner with a visual impairment? Object interaction and first-hand experiences were critical in facilitating the construction of knowledge in the learner with a disability (Palincsar et. al, 2001). The learner with a visual impairment builds knowledge of the world in the same manner as learners with sight and many researchers in the field of visual impairments have pointed out the importance of direct experiences. For example, Barraga (1983) emphasized the need for a child with a visual impairment to develop a relationship with the immediate environment, concluding experiences with the immediate environment would further facilitate a relationship between the child and the world around him. Similarly, Landau (1983) found a child with a visual impairment cannot develop concepts when relevant experience is deficient, and if the child's concepts are deficient, the child's learning and understanding of word meanings also will not develop. Although Landau's study was about the language development of children with a visual impairment, the relationship between experiences and learning is evident. In a related study, Andersen, Dunlea, and Kekelis (1984) found the language demonstrated by children with blindness appropriately "reflected their experience-specific conceptualizations of objects obtained through touch and other non-visual senses" (p. 662), again indicating the importance of experiences in helping to facilitate learning in the child with a visual impairment.

Social interaction is an essential component of learning (Vygotsky, 1986). Inquiry-oriented approaches can facilitate the development of social skills of students identified with a disability because peer interaction is promoted in the learner-centered environment. Arguably, social interaction to promote learning is essential for all students. However, students with a visual impairment may need more opportunities for guided meaningful interaction (Hoben & Lindstrom, 1980; Kekelis, 1992; Kekelis & Sacks, 1992; McGaha & Farran, 2001). Wolffe and Sacks (1997) found students with a visual impairment spent more time alone than did peers with sight. Rosenblum (1997) found children with visual impairments had satisfying and supportive friendships; however, MacCuspie (1992) concluded as children with a visual impairment grow older, they participated less in social activities. Participating in a science classroom in which the teacher promotes peer interaction, the sharing of information, and discussions of findings may encourage the learner with a visual impairment to be socially aware and to practice social negotiation in problem solving.

The purpose of this study was to describe what middle school students with visual impairment did and what difficulties they had with inquiry learning. A synthesis of case studies of four students as they engaged in inquiry during two projects spanning 10 weeks was the basis for this study. Details of how students asked questions, constructed models, carried out investigations, drew conclusions, and presented their understandings were discussed. Additionally, teacher supports for student learning through multiple discourses were revealed.

A secondary goal of the study was to share the results with educators in hopes they will anticipate what students with visual impairment may need help with and design instructional practices to promote effective student learning through inquiry. Specific research questions included the following:

1. What opportunities are provided to students with visual impairment during guided inquiry science instruction?
2. What challenges do students with visual impairment face during guided inquiry instruction?
3. What is the impact of guided inquiry-based science instruction on motivation and achievement of students with visual impairment?

## Design and Procedure

### *Setting*

A state specialized school for the visually impaired in the southwestern United States was chosen as the site for this study. The school enrolls children with a visual impairment, and children with a visual impairment and additional disabilities. Students representative of diverse cultures from various regions of the state attend the residential school. Class sizes generally range from 6 to 8 students and include a classroom teacher specially trained in the education of students with visual impairments, and often a paraprofessional to assist as needed. Students in grades 5-8 are taught science as a collective group.

### *Inquiry-based Instructional Unit*

Students participated in an inquiry-based astronomy unit four days per week for about an hour each day for 10 weeks. Topics included the relationship between the sun, moon, and earth; day and night; the phases of the moon and the reason for the seasons. Because the students were novices to inquiry-based processes, a guided approach to inquiry instruction (Palincsar, Collins, et al., 2000) was chosen to deliver content material. The classroom teacher had limited experience as a facilitator of an inquiry-based approach to instruction; therefore, the role of the researcher was that of instructor. Content materials, lesson planning, necessary adaptations, and accommodations were discussed with the classroom teacher to ensure an appropriate level of instruction for all students.

The researcher-instructor adapted existing instructional materials, a project-based Full Option Science System (FOSS) unit Planetary Science (version 2008), to best meet the needs of the learner with visual impairment. The adapted unit was designed to help students use knowledge and evidence to construct explanations for the structure and motions of objects in the Solar System and content was delivered through a guided inquiry approach to instruction (see Appendix A for goals and student outcomes). FOSS has roots in the multi-sensory approach developed in the Science Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps (SAVI/SELPH; 1976,1980). SAVI/SELH was originally developed to meet the learning needs of students with disabilities, but because of the hands-on approach, the program found application with general education students. Developed by the Lawrence Hall of Science, the procedures and features of the SAVI/SELPH program were incorporated into the materials and procedures used with all students in the FOSS program. The FOSS unit was chosen for this study because the unit was designed to maximize the science learning opportunities for students with disabilities.

Instruction of the Planetary Science unit occurred September through November. The five students enrolled in the class explored two questions: *What causes the lunar phases?* and *What is the reason for the seasons?* Students designed models, made observations, recorded questions, observations and understandings in their science notebook, and drew conclusions. Students were given multiple opportunities to present their findings to the class and to explain their understanding.

The researcher-instructor used various tasks to introduce inquiry. Students learned to create models and to describe the role and function of each model component. Students learned to make accurate observations and identify changes in patterns. To help students to learn to record observations carefully and completely, the researcher-instructor offered suggestions about what to include in student's science notebook (e.g., what they observed, where they were during the observation, time of day, changes viewed, if any, predictions of what would happen next). The researcher-instructor provided feedback to students on their notebook writing, model construction, accuracy of observations and explanations. Several times throughout the unit, benchmark lessons (i.e., how to use a model and how to construct a graph) were used in conjunction with student-crafted models to help students learn and apply the main concepts (i.e., relationship of the sun, moon, and earth; positioning, and key terms such as revolution and rotation).

### *Students*

A middle school level, multiethnic classroom including one boy and four girls of primarily Hispanic culture participated in this project. The students' visual impairments can be characterized as moderately low vision (2 students, large print readers), legal blindness (2 students, braille readers), and total blindness (1 student, braille reader). Additionally, one child with legal blindness and one child with moderately low vision had physical disabilities and all students were identified with a learning disability. The mean age of students was 13 years, 2 months (see Table 3.1). Although five students participated in the inquiry-based instruction, only four of the students were able to obtain parental permission to be included in the study. The classroom teacher, with 5+ years teaching students with visual impairment, participated by observing and assisting students and providing feedback to the researcher-instructor. The classroom teacher had a Doctor of Philosophy (Ph.D.) degree in special education with a major in the education of children with visual impairment.

Table 3.1: Characteristics of Participating Students

| Name | Gender | Visual Impairment | Visual Acuity | Age |
|---|---|---|---|---|
| Kyle | Male | Optic nerve hypoplasia | 10/225 OD<br>Hand motion OS | 15.7 |
| Aspen | Female | Retinopathy of prematurity – retinal detachment | No light perception | 11.9 |
| Camille | Female | Retinopathy of prematurity | 10/80 OU | 12.1 |
| Carrie | Female | Optic nerve atrophy | 1/225 OU | 12.9 |

A composite description of each student was created from teacher verbal reports, observations of demeanor and participation during lessons, and information from interviews with students prior to beginning the unit. A brief profile of each student, crafted from the composite notes, is presented below.

- Kyle was very social, often gaining the attention of others through his jokes and laughter. Kyle maintained a leadership role in the group and readily voiced his opinions or knowledge about the topic. Kyle volunteered during discussions and openly talked about his enjoyment of the hands-on approach to science instruction. Other students depended on his ability to" know something" about the topic and often waited for Kyle to first speak about the subject before joining in the discussion. Kyle was proficient at both reading and writing Braille. Kyle's science notebook entries were detailed and reflected his confidence about his knowledge of the topics. Prior to instruction, Kyle reported that he was a successful student at school in the area of science and enjoyed science activities at home as well. Kyle had Optic Nerve Hypoplasia with a visual acuity of 10/225 (OD, right eye) and hand motion (OS, left eye). Kyle self-reported that he was able to see the moon in the sky during both day and night.

- Camille was quiet initially, but then became more social as the projects continued. Camille tended to keep her ideas to herself unless asked directly to share with the group. Camille had low vision (retinopathy of prematurity with visual acuity of 10/80 OU, both eyes) and was able to read regular print. Camille enjoyed writing in her science notebook and her responses were thoughtful and often accompanied by drawings or illustrations. Prior to the study, Camille reported that science was not something she thought about when she was not at school and that she did not like reading science books.
- Carrie was shy and quiet. Carrie had recently moved to the United States from Mexico and was still acquiring the English language. Because she was learning a second language, Carrie often shared her thoughts and opinions in Spanish, translated by the teacher or by another student. Carrie was learning to read and write Braille and had difficulty

independently writing in her science notebook. Therefore, Carrie dictated many of her entries to the classroom teacher who would Braille the response for Carrie. Prior to instruction, Carrie reported that she did not particularly like science because she did had difficulty reading the (text) book and did not always understand what she was reading. Carrie had optic nerve atrophy with a visual acuity reported as 1/225 OU, both eyes. Carrie self-reported that she could see the moon in the sky when it was large and full.

- Aspen was popular and animated. Aspen was active in classroom discussions and did not hesitate to ask questions about the topic. Aspen was social and interacted well with her peers. A Braille reader and writer, Aspen preferred to share her opinions and understandings orally; therefore, science notebook writing proved a difficult task and her responses were limited. Prior to this study, Aspen reported that she did not like science and she felt science was only "done in school." Aspen had retinal detachment resulting in total blindness.

## Methods and Analysis Procedures of Data Collection

The overall purpose of the study was to describe what middle school students with visual impairment did and what difficulties they had as they participated in guided inquiry science learning. Both quantitative research methods and qualitative research methods were employed to construct the case studies of the four participating students.

*Assessments*

To measure student learning, a pre- and post assessment of the students' knowledge of the astronomy topics were used. The assessment was modified from the original FOSS Planetary Science unit assessment. Modifications included revision of questions that required use of visual representations (i.e., Look at the picture of the Earth, Moon and Sun) and removal of questions that addressed content other than the objectives identified. The assessment was comprised of 27 multiple choice questions and 5 open-response questions. (Appendix B). Assessments were printed in the students' medium of choice and the students completed the assessment in this same medium choice (i.e., Braille, print). Additionally, questions were read orally to the class to avoid confusion or missed questions.

Pre- and post assessments of students' attitudes toward and beliefs about the nature of science and scientific reasoning were conducted also. An existing instrument, the Attitude Toward Science Inventory (ATSI), was completed by all students at the start and at the end of the study. Several aspects of students' attitudes toward science are measured with the ATSI: (1) perception of the science teacher, (2) anxiety toward science, (3) value of science in society, (4) self-concept of science, (5) enjoyment of science, and (6) motivation in science (Weinburgh & Steele, 2000). Changes in students' views of science and their motivation toward pursuing further science courses and careers in science fields were examined. Assessments were printed in the students' medium of choice and the students completed the assessment in this same medium choice (i.e., Braille, print). Additionally, questions were read orally to the class to avoid confusion or missed questions. Survey results were compared to each student's learning gains (if any) as they participated in the inquiry-based approach to instruction.

The formal measures were used for several purposes. One purpose was to gather information about the students' prior knowledge to inform the researcher's thinking and decision-making as instruction progressed. A second use was to compare the entering knowledge and beliefs of identified children with their unidentified peers. A third purpose was to assess changes in students' thinking following the program of study.

### *Classroom Observations*

Video records were used to provide a view of classroom processes and to capture the complexity inherent in an inquiry-based classroom. One advantage to using video was that classroom activity could be slowed down and viewed multiple times, allowing for detailed descriptions of instructional interactions. To capture students' experiences, video recordings were collected each instructional period of the 10 week study for a total of 40 lessons. In the event that students were sharing or presenting information to the class, the researcher-instructor positioned the video camera to record individuals. Otherwise, the video camera was set to capture the class as a whole group.

As described, one focus for classroom observations was the entire class. Within GIsML instruction, there are several phases when the participant structure is whole-class presentation and/or discussion (Palincsar, et al., 2000). Whole-class presentation may include discussion of the guiding question, student reporting of observations, and student comparison of observations. However, important to note was that the class was comprised of five students; therefore, whole-class instruction was small group interaction. A detailed description of each video record was prepared and included what students did and what they discussed. Descriptions also included evidence about (a) reflections of content, including explanations and justifications, alternative ideas and solutions; (b) interactions between students and between students and instructor; and (c) motivation, including expressions of interest and investment.

### *Student Interviews*

Student interviews were informal, and although the researcher-instructor had guiding questions, the questions were open-ended allowing for a departure from the guiding questions to obtain more relevant responses. Individual interviews with the four participating students were conducted at the beginning, the middle, and at the end the unit. The interviews were designed to probe students' understandings of the science content, the role of writing in learning science, and the students' ways of participating in a science learning community. Interviews were captured by video record and were intended to be short in duration (5 to 10 minutes). Students were asked the following questions: (a) What happened in class today? (b) What did *you* do today? (c) What did you learn about [topic under study]? (d) What did you write about today? (e) How did writing about what you learned help you today? and (f) What else would you like to tell us? Engaging the identified students as informants served the following purposes: (a) to ascertain the student's perspective on the day's events, and (b) to provide elaboration upon the field notes for the day. The interviews allowed for juxtaposition of the child's reflections on the day's events with the other records of the day's events. Interviews were transcribed for data collection purposes.

### *Student Artifacts*

The participating students' written work was collected and photocopied throughout implementation of the unit. Writings included the students' science notebooks and group-constructed writing tasks such as technical drawings. During the four-day instructional week, students recorded in their science notebooks twice per week for a possible 20 entries per student or 80 total entries. However, because of student absences, 52 science notebook entries were collected. Science notebook entries were written in each student's medium of choice, including Braille writer, notetaker, or spiral bound notebook. Braille entries were transcribed by the researcher-instructor.

Students constructed various models during the guided inquiry-based instructional unit about astronomy. Directions and step-by-step demonstration were provided by the researcher-instructor for each model crafted by students. When necessary, tactile components were used to increase student understanding. For example, when students constructed moon models, wikki stix, a thin strip of tacky string, were applied to one half of the moon to represent the side of the moon not visible from the students' place on Earth.

## Constructing the Case Study

Using the multiple data sources previously described, case studies were designed to represent the experiences of each student in a way that captured both the activity of the student and the context of the guided inquiry instruction. A written synopsis of each student was prepared and included the following: (a) overall student participation in the inquiry-based learning environment, (b) student initiated questions, (c) student motivation, (d) student-student interactions, (e) instructor-student interactions, (f) types of instructor feedback provided to each student, and (g) types of instructor support provided to each student. Additionally, students' interview responses and student artifacts (i.e., students' science notebook entries and group tasks) were examined to determine the progress in students' understanding.

Drawing from research conducted by Palincsar, Collins, et al. (2000), a set of claims with supporting evidence obtained from the data analyses was crafted to aid in developing the case studies (see Table 3.2) Additionally, the following components of guided inquiry instruction were targeted: (a) participation in a learning community, (b) discursive practices of talking and writing science, and (c) drawing conclusions.

Table 3.2: Claims and Supporting Components of Guided Inquiry

| Claim | Targeted Guided Inquiry Component | Student Evidence | Data |
|---|---|---|---|
| Student to student interaction influenced by researcher-instructor's verbal prompting (e.g., share with your partner, share with the group) | Participation in the Learning Community | Kyle, Camille, Carrie, Aspen | Video records |
| The opportunity to engage in one-on-one conversation with the researcher-instructor appeared important to the students for developing a learning community. | Participation in the Learning Community | Kyle, Camille, Carrie, Aspen | Video records |
| Students' written communication about the topic supported fully when assistance was provided (i.e., verbal prompts, dictation, word spell). | Discursive practices: the ability to write science | Kyle, Camille, Carrie, Aspen | Video records; science notebook entries |
| Students' conceptual understanding typically demonstrated partial to adequate understanding. | Discursive practices: the ability to write science | Camille, Carrie, Aspen | Science notebook entries |
| Students' conceptual understanding (in an oral response format) typically demonstrated adequate to advanced understanding. | Discursive practices: the ability to talk science | Kyle, Camille, Carrie, Aspen | Video records; student interviews |

Table 3.2 continued

| Claim | Targeted Guided Inquiry Component | Evidence | Data |
|---|---|---|---|
| Student initiated questions occurred frequently and increased in level as the instructional unit progressed. | Discursive practices: the ability to talk science | Kyle, Camille, Carrie, Aspen | Video records; data collection sheets |
| Questioning techniques used by the researcher-instructor positively influenced student participation. | Ability to draw conclusions | Kyle, Camille, Carrie, Aspen | Video records |
| Researcher-instructor supports (e.g., prompts, repeated instructions) were essential for students to fully engage and participate in the learning community. | Discursive practices: the ability to talk and write science; Collaboration | Kyle, Camille, Carrie, Aspen | Video records |
| Multiple representations (i.e., 3-D models, graphs, demonstrations, manipulatives) were essential to help students understand scientific concepts and draw conclusions. | Ability to draw conclusions | Kyle, Camille, Carrie, Aspen | Video records; student interviews |
| Verbal prompts were necessary to help students draw conclusions about observed phenomena. Examples: "What do you think?" "What will happen next?" | Ability to draw conclusions | Kyle, Camille, Carrie, Aspen | Video records; student interviews |

## Findings

In this section, the claims generated were compared to the evidence found in data sources, the targeted components of guided inquiry instruction and the first two research questions: (1) What opportunities were provided to students with visual impairment during guided inquiry science instruction? and (2) What challenges do students with visual impairment face during guided inquiry instruction? The section is organized according to the targeted components of guided inquiry instruction previously identified.

### *Participation in the Learning Community*

Crawford et al., (2006) identified six components of a learning community. Four components, authentic tasks, negotiation of understanding, public display and shared responsibility for learning and teaching were used to frame the results and discussion of student participation in the learning community and corresponding claims.

#### Authentic Tasks

Authentic tasks are situated in meaningful contexts and reflect the way tasks might be approached in real life (Marx & Harris, 2009). Similar to the ways of practicing scientists, students engaged in doing “real” science by actively participating in learning rather than attempting to complete worksheets about astronomy topics. For example, students participated in daily observations of lunar phases to construct understanding of the moon’s patterns, relationships between the sun, moon, and earth, and the students’ perceptions from their positions on earth. With appropriate researcher-instructor support, students learned to construct authentic questions and participated in ways to answer those questions. By constructing models of the moon and earth systems, students were presented with opportunities to engage in authentic tasks designed to examine prior knowledge, construct new knowledge, and build understanding.

### Negotiation of Understanding

Negotiating understanding occurs when participants in a learning community (i.e., students, teacher) debate ideas and collaborate shared meaning. Initially, students experienced difficulty with this component of a learning community. During the first month of instruction, most discussions were initiated by the researcher-instructor; however, students participated in the discussions with appropriate verbal prompting (i.e, asking students a question, asking student to expand or tell more). As instruction progressed and opportunities for public sharing increased, students initiated discussions more frequently. For instance, students entered the room excited to share their observations of the moon from the night before. Students debated the shape of the moon observed and defended their observations with specific details (i.e., where, what time, color, possible viewing obstructions). Students discussed ways to “prove” their observations were accurate and used student-crafted models and charts to make sense of the data and negotiate shared understandings.

### Public Sharing

Initially, students expected the researcher-instructor to *tell* them the information they needed to know and learn about astronomy topics. This idea of the teacher transmitting the information and the students receiving the information is characteristic of traditional approaches to instruction (i.e., text-book, lecture), and students self-reported that they were more familiar with traditional types of instruction than inquiry-based approaches. Strategies to assist students to publicly share their own ideas and questions included modeling interactions, using reciprocal teaching strategies to help students generate questions, and coaching students' responses to include discipline specific content. Independence in this area was not fully achieved by students; however, students were supported in their endeavors to participate and openly share their ideas and feedback for others.

### Shared Responsibility in Learning and Teaching

Many opportunities were presented to students to share responsibility of learning. For example, students collected and compared data about lunar phases and worked with each other and the researcher-instructor to design ways to best display the data. Students discussed theories about the seasons and participated in crafting models to represent their understandings. However, perhaps because inquiry-based approaches were new to the students, shared responsibility for teaching did not occur during this study. The role of the researcher-instructor was that of a guide; assisting students as needed to understand science concepts and to make sense and apply the understandings.

*Discursive Practices: Science Notebook Writing*

Characteristics of students' science notebook entries varied from entry to entry to reflect the diversity of activities during instruction. The following excerpts were included to demonstrate changes in students' understanding reflected in their writing as they participated in the guided inquiry-based unit about astronomy.

Beginning of Instruction: Kyle

- I think the moon change happens because of the earth's orbit. I think it takes the moon two months to go through the changes.
- On Friday night the moon was a full moon. It was not close to the Earth but it was still a full moon. On Saturday night the moon was full again but this time is was close to the earth because it was brighter than the night before. We see the same side of the moon because the moon does not turn like the earth.
- The sun has nothing to do with the seasons. The earth just knows when to change and it gets hotter or colder.

End of Instruction: Kyle

- The moon has one light side and one dark side. We see the same side of the moon from Tucson. It has several phases that the moon goes through. This is a half moon and this is a new moon and a full moon (accurate drawings accompany this statement). We've been watching the moon for a month so it takes the moon a month to change.

- The sun has something to do with the seasons. The position of the earth is key in the starting of each season. The sunlight is key in the seasons. The sun stays in the same spot but the earth moves around the sun. It's the revolution. Some used to think that it would get cooler because the earth would move away from the sun. But that is not true. The reason it would get cooler is because of the indirect light.

The excerpt about seasonal change was noteworthy for several reasons. First, the word "key" was used by the researcher-instructor during class discussion to describe the roles of the sun and earth during seasonal change. Interestingly, Kyle used this same vocabulary in his written description. Next, Kyle indicated that the Earth revolves around the sun and that this movement has an impact on seasonal change, yet he does not yet believe that the Sun rotates. Additionally, Kyle paraphrases a myth about seasonal change and provides a solution to the myth using discipline-specific terminology. Kyle describes the type of light received on earth at times during seasonal change as indirect light. Whether Kyle had full conceptual understanding about seasonal change was not yet evident from reading this excerpt; however, Kyle demonstrated change in his thinking about the role of the sun and the Earth.

Beginning of Instruction: Aspen

- I don't know how day happens. The sun hides at night.

End of Instruction: Aspen

- The earth spins and the sun is shining on it. The sun and earth help each other. The earth spins in its orbit. The sun is facing me on the earth and that means that it is daytime here. And the earth is spinning and the sun is shining on a different part and that is nighttime here.

Aspen demonstrated growth in her written communication throughout instruction in the guided-inquiry based classroom. Aspen preferred communicating about her thinking and ideas during class discussions rather than in her science notebook. However, as instruction progressed, Aspen's written abilities improved in grammar use, sentence structure, and content depth.

Beginning of Instruction: Camille

- I saw the moon after the party and it was full. Full means round and it was bright. But the weekend was not full. Maybe there is a shadow covering the moon.
- The earth is in different positions around the sun and the sun shines on different places.

End of Instruction: Camille

- I see one side of the moon and the sun shines on the moon and the moon moves. This is the moon's phases. Clouds can still cover the moon but that is not why the moon changes. It's not shadows either. The moon changes because it moves and earth moves too.
- There are four seasons – winter, spring, summer and fall. We are in fall right now. It will be winter in November. The sun shines on earth. Earth

moves around the sun. This is called revolution. The light that comes on us from the sun makes the seasons. Sometimes it is full light and its hot and sometimes it is not full light and it is cold.

In the first entry, Camille revealed her initial theory of lunar phases had changed, indicating her previous beliefs about cloud cover and shadows were in conflict with her new understanding of lunar phases. Although Camille does not completely explain her ideas about lunar phases in her science notebook entry, evidence of change is apparent in her entry. In Camille's next entry, she has expanded her previous thinking about the sun shining on different places on Earth. Camille includes both science vocabulary (e.g., revolution) and personally meaningful phrases (e.g., full light; not full light) to discuss the reason for the seasons.

Beginning of Instruction: Carrie

Carrie was a beginning Braille reader and writer. Carrie often dictated her notebook entries to the classroom teacher. Parentheses were used when the classroom teacher asked Carrie to elaborate on her thinking.

- I don't know why it (moon phases) is happening. I think the moon is changing for the earth. The clouds cover it (moon). I see the moon on Saturday and it looks almost the whole circle.
- Animals hibernate in winter. This is why seasons happen. The earth just knows.

During the class discussion, Kyle had been very animated about his beliefs about the seasons stating that the earth simply knows when to become hot or cold and that the sun does not affect the temperature change on earth. Interestingly, in this excerpt, Carrie has assumed Kyle's opinion from the class discussion that the earth just knows when to change.

End of Instruction: Carrie

- The moon has lots of changes. It can be crescent, full, new and half moon. There is no cheese on the moon. The moon changes because the earth moves.
- The seasons happen when the earth rotates in the sun. It (earth) moves around the sun. Sometimes warmer and sometimes colder where the sun is (It is sometimes warmer when the sun shines on earth and sometimes colder). It is where the earth is when it moves (around the sun).

In these excerpts, Carrie's descriptions of science phenomena have advanced from assuming the opinion of an outspoken peer to personal descriptions of what she has observed (i.e., moon phases) and participated in during guided inquiry instruction (i.e., demonstrations of direct light and indirect light).

As previously discussed, writing tasks were seemingly difficult for students and students preferred to discuss their thoughts and ideas as a whole class. However, writing was beneficial for students as evidenced in the above excerpts and descriptions. Students demonstrated knowledge of discipline-specific vocabulary and their ability to expand, adapt, and sometimes change their prior beliefs about a concept. Students used writing to make connections between their observations and their understanding. Most importantly, students had specific reasons to participate in science writing.

Three categories of supports needed by students during writing instruction were identified from the observational data: (1) functional – helped the learner understand how to do something, (2) metacognitive – helped the learner be aware of his/her own thinking and learning by reflection, and (3) interpersonal – helped the learner facilitate social interaction such as turn taking and interaction with peers.

Functional supports included assisting students with spelling, Braille contractions, and grammar. Additionally, students needed support to format science notebook entries (i.e., date, title). Students required these functional supports during each writing opportunity.

Metacognitive supports included the repeated prompts to encourage student thinking about these three areas: (1) Claim – What do you think? (2) Evidence – How do you know? and (3) Reasoning – Why do you think this? As indicated occurred with functional supports, the use of metacognitive supports was necessitated each time students engaged in science notebook writing. Three attempts were made over time to fade this metacognitive support; however, students immediately asked for the three questions to be written on the white board and verbally repeated. Therefore, although the students' written entries evidenced the value of the repeated prompts, the support cannot be defined as a scaffold because the tool was not successfully faded or removed over time.

Interpersonal supports were defined as supports that allowed students to fully participate in the learning community (i.e., facilitate social interaction such as turn taking and peer interaction). Students with a visual impairment need more opportunities for educationally meaningful interaction (Hoben & Lindstrom, 1980; Kekelis, 1992; Kekelis & Sacks, 1992; McGaha & Farran, 2001). To facilitate the social interaction within the context of the learning community, interpersonal supports consisted of peer sharing about science notebook entries and whole class sharing about responses to reflection prompts. Engaging in peer interaction around written communication provided students with opportunities to share their own thinking and to value, or at the very least, consider the thinking of others.

### *Discursive Practices: Questions*

Reciprocal teaching strategies (Palincsar & Brown, 1984) were used specifically to assist students with the task of generating questions. Reciprocal teaching involved first modeling the cognitive process of crafting questions and then providing support and coaching for the students as they attempted to formulate their own questions about astronomy. As students became more proficient in generating questions at the classification levels identified, then the researcher-instructor faded the support provided for that level. One such strategy were Know, Wonder, Learn (KWL) charts. For each of the three sections, students shared their thoughts and ideas about the topic, what they *Know* about the topic, what they *Wonder* about the topic, and finally what they *Learned* about the topic. The Wonder section provided an avenue for helping students develop authentic science questions. By formulating authentic questions, the science topic is situated in a framework that is likely to be of interest and personally meaningful to students (Krajcik, et al., 2000) within the context of an authentic task (Harris & Marx, 2009).

Through the use of verbal prompts and examples of investigative questions, students' Wonder questions progressed from *Is there really a man on the moon?* to *Is the part of the moon we don't see always on the right (side)?* and *I wonder if the Earth is about the same distance from the Sun all the time?* Although the student may have been interested in knowing if a man truly lived on the moon, the first example question demonstrated the students' inability to initially formulate relevant and authentic science questions. Additionally, this first example revealed the student's lack of scientific knowledge and understanding of astronomy needed to support the student in developing questions that can be answered by examining the evidence. However, as the instructor's modeling of question format and types continued during the course of instruction, students' questions increased in quality and level of cognitive difficulty, and verbal prompting by the instructor decreased. Also, the researcher-instructor anticipated non-scientific questions students might ask and engaged students in analyzing why the example would not be considered a strong and meaningful science question. For example, the researcher-instructor provided the students with three questions, one of which could not be answered by the evidence collected (i.e., students' observations of moon phases). The class then engaged in conversation about how to rephrase and focus the question into one more meaningful and authentic.

Question levels were categorized using Bloom's Taxonomy, revised by Anderson and Krathwhol (2001). Bloom's Taxonomy is a multi-tiered, hierarchical model of classifying thinking according to six cognitive levels of complexity: (a) remembering, (b) understanding, (c) applying, (d) analyzing, (e) evaluating, and (f) creating (see Table 3.3). Although this classification system is generally applied to the types of questions teachers ask to elicit a higher level of response from students, the researcher-instructor applied the classification levels to the types of questions generated by students. The reason for this adaptation was that with modeling and class discussion about authentic questions, coupled with the components of guided inquiry instruction, students would produce questions at a higher level of thought during the course of instruction. The nature of students' questions during the instructional unit on astronomy consisted of remembering questions (66 or 30%), understanding questions (108 or 49%), applying questions (38 or 17%), and analyzing questions (8 or 4%).

Table 3.3: Identifying the Level of Students' Questions: Bloom's Taxonomy

| Classification Level | Definition/Description |
|---|---|
| Remembering | Define, duplicate, list, memorize, recall, repeat, reproduce |
| Understanding | Classify, describe, discuss, explain, identify, locate, recognize, report, paraphrase |
| Applying | Choose, demonstrate, illustrate, interpret, sketch, solve, write |
| Analyzing | Compare, contrast, discriminate, examine, experiment, test |
| Evaluating | Appraise, argue, defend, support, evaluate |
| Creating | Construct, create, design, develop, formulate |

Remembering questions, the first level of Bloom's Taxonomy, were described as questions that help to define and recall information. Many of the remembering questions were asked when students were engaged in science notebook writing. Examples included *How do you spell Earth?* and *What is the contraction for "ar"?* The second level, understanding questions, were defined as questions that help to explain, identify and classify. Typically recognized as –wh questions, examples included *Why does the moon look yellow?* and *What is making the half moon?* Applying questions, the third level, included questions that demonstrate understanding. Examples included *If I go from here to Mexico and back to here, is that my orbit?* and *Is this the pattern – crescent, new, full, crescent?* Analyzing questions, the fourth level, were described as questions that compare, contrast, and examine. Example questions included *If we see the* *crescent moon today, then we'll see the new moon tomorrow?* and *Is the part of the moon we don't see always on the right side?* Based on evidence from transcripts of classroom observations, students' frequency of generated questions increased with time and the number of remembering questions decreased. However, the levels of student-generated questions were characterized primarily as lower-level thinking questions, with only eight of students' questions described as higher-level thinking questions. Students did not produce questions in either the evaluating level nor the creating level.

The findings about the level of questions generated by students were remarkable. Researchers have established that students with visual impairment ask questions to establish orientation (Balikov & Feinstein, 1979), to seek new information (Burlingham, 1961) and to maintain conversational control (Kekelis & Anderson, 1982). Likewise, Erin (1986) confirmed these three purposes in her study of the questioning behavior found in the spontaneous language of students with visual impairment. Arguably, these three functions of questions are vitally important for the student with visual impairment in the science classroom. However, in the context of the classroom, the researcher-instructor observed that students' questions served another purpose. By watching and listening to their peers ask questions and by watching and listening to the instructor's response, students learned through observation that asking questions would help them to elaborate on their own thinking and expand or explain the thinking of others. Students used questions to focus and clarify ideas and to participate fully in the context of the learning community, demonstrating personal investment in the discussions.

*Drawing Conclusions*

Sense making of their observations to draw conclusions proved the most difficult task for students. For example, students did not use the class created charts about their observations of the moon to predict the next phase without researcher-instructor prompting. Additionally, although students would write about their observations on a daily basis, they did not often refer back to their science notebook entries to make sense of new observations. Students required prompting about how to use these written entries and drawings to help them understand the patterns they were observing and to make logical arguments to justify their conclusions. Consider the following excerpt from classroom observation transcripts:

> Students have been observing the moon and recording their observations for two weeks. Students were asked to predict the moon phase they will observe over the weekend and to write about this phase in their science notebooks. Aspen looked around the room seemingly thinking about the question. Aspen recorded in her notebook "I don't know. I think full (moon)." However, Aspen did not attempt to re-read her previous notebook entries nor did she use the observation chart to help her with her prediction. On the other hand, Camille recorded in her notebook "I think the moon will be invisible to me. It will be a new moon and I won't see it

> but it will be there." Camille was observed looking back through her notebook at her previous drawings of the moon's phases. Additionally, Camille asked to move closer to the large classroom observation chart. Camille based her prediction on data, drawing personal conclusions about the moon's next phase. Students were asked to share their predictions with the class. When Aspen read her prediction, Kyle remarked that he did not think the next phase would be a full moon because "we have already seen the full moon." Following Kyle's comment, the researcher-instructor asked Aspen if anything in the classroom would help her to think about the next phase. Aspen replied "The chart?" Aspen's query was confirmed and, after studying the observation chart, she added the following to her science notebook entry: "I think the moon will be new. You can't see new moons." Students used their predictions to complete the metacognitive writing support designed to encourage student thinking: (1) Claim – What do you think? (2) Evidence – How do you know? and (3) Reasoning – Why do you think this? (discussed in detail in the Discursive Practices: Writing section of this paper).

This excerpt was interesting for several reasons. First, Aspen demonstrated she was not certain about how to use her previous notebook entries and the class crafted charts to help her draw conclusions. Although the class had been recording observations, working with dough shapes, crafting moon models, and participating in the daily construction of the class observation chart for two weeks, Aspen was dependent on verbal prompting to assist her in using the evidence to form her prediction. Next, Camille used her drawings and the class chart to structure her prediction. Camille's prediction was accurate and she was able to publicly share her thinking about the patterns she was observing. Also, Kyle made an interesting point about having previously observed the full moon, demonstrating his ability to draw conclusions about the observed phases and use the data to inform his thinking. Important to note was that when students shared their thinking by reading their science notebook entries, opportunities were provided to discuss what students had learned; therefore, students were able to add to their knowledge and understanding about the topic and further advance their abilities to draw conclusions.

### *Assessments and Surveys*

This section was crafted to address the third research question: What is the impact of guided inquiry-based science instruction on motivation and achievement of students with visual impairment?

#### Content Assessment

Students' conceptual understandings and knowledge of astronomy concepts were revealed using a content assessment. All participating students demonstrated learning gains from their pre- to post-assessment results (see Table 3.4).

Table 3.4: Individual Student Gain for Pre-Post Content Assessments

| Student | Pre-content score | Post-content score | Individual student gain |
|---|---|---|---|
| Kyle | 4/20 (20%) | 18/20 (90%) | 3.5 |
| Camille | 1/20 (5%) | 15/20 (75%) | 14 |
| Carrie | 2/20 (10%) | 17/20 (85%) | 7.5 |
| Aspen | 1/20 (5%) | 12/20 (60%) | 11 |

## Student Attitudes Toward Science

The Attitude Toward Science Inventory (ATSI) was given to students pre- and post-instruction to measure students' attitudes toward and beliefs about the nature of science and scientific reasoning (Weinburgh & Steele, 2000). Changes in students' views of science and their motivation toward pursuing further science courses and careers in science fields were examined. The ATSI consisted of 20 items using a five point Likert scale with assigned scores to response categories as follows: 5 - strongly agree, 4 - agree, 3 - neutral or uncertain, 2 - disagree, and 1 - strongly disagree (see Table 3.5).

Table 3.5: Change in Attitude Toward Science as Measured by ATSI

| Student | Pre-survey score | Post-survey score | Individual gain |
|---|---|---|---|
| Kyle | 63/100 (63%) | 89/100 (89%) | .41 |
| Camille | 55/100 (55%) | 69/100 (69%) | .25 |
| Carrie | 63/100 (63%) | 74/100 (74%) | .17 |
| Aspen | 56/100 (56%) | 73/100 (73%) | .30 |

## Discussion

There have been concerted efforts in the science education community to provide opportunities for students with disabilities to conduct inquiry (McGinnis, 2000; McGinnis & Stefanich, 2007). The current study contributes to the knowledge base by examining the experiences and outcomes of students with visual impairment in a guided inquiry-based science classroom. The results of this study contribute to the literature in several ways. First, the results demonstrate that students' with visual impairment active participation in guided inquiry-based instructional approaches may facilitate the acquisition of content knowledge as demonstrated by students' learning gains on the pre- and post- unit assessments. Additionally, students reported that the inquiry-based activities (i.e., constructing models, use of dough to represent lunar phases, creating a moon log) were favored over traditional textbook activities. Students indicated that the inquiry activities were more motivating and more enjoyable than textbook based activities. These findings support those of previous investigations conducted with students with learning disabilities suggesting that students with visual impairment are aware of the relative effectiveness of various instructional strategies in which they have participated, and prefer approaches that are most effective for them (see Klingner & Vaughn, 1999 for a review of studies involving students with learning disabilities).

The results of this study demonstrated that supports are needed for students' engagement in scientific practices. Providing carefully guided opportunities for students to engage in investigations and other elements of scientific practice advanced the students' learning about astronomy content. Students did encounter challenges during the course of instruction; however, with appropriate verbal and written prompts, students rose above these challenges and demonstrated success in the guided inquiry science classroom.

## Conclusions

The purpose of this study was to describe what middle school students with visual impairment did and what difficulties they had with inquiry learning. As the first study to examine the learning experiences of students with visual impairment in a guided inquiry-based classroom, the findings are remarkable. Students with visual impairment were shown to demonstrate strengths within the inquiry-based learning environment. Students engaged in meaningful discourse during classroom discussions and through science notebook written entries. Students actively participated in learning by observing scientific phenomena, recording observations, analyzing data, and drawing conclusions. Through the use of guided inquiry-based approaches to instruction, students engaged in authentic tasks, generated relevant and personally relevant questions, and participated in the discursive practices of knowing and understanding science. Students with visual impairment were shown to be capable of “doing” science similar to the ways of scientists.

As demonstrated in the assessment results, students made significant progress with both conceptual understanding and attitudes toward science. Science class became more than textbook illustrations and lectures; science class became interesting, fun, and meaningful. Students also faced challenges within the guided inquiry classroom. Expressing themselves in written format proved difficult for students without the use of verbal and written prompts. Likewise, verbal prompts were needed to assist students when debating ideas and negotiating understanding of scientific concepts. However, these challenges should be considered positive results, indicating the need for educators to design supports and scaffolds to assist students’ full participation in the inquiry-based learning environment.

Implementation of inquiry instruction is not without challenges as well. As indicated in this study, extended time was necessary for students to fully participate in active construction of knowledge about the astronomy topics. Additionally, designing and adapting instruction (i.e., tactile components, appropriate writing instruments, hands-on materials, student-involved demonstrations) to meet the needs of students with visual impairment requires preliminary planning, and additional time and resources.

## Limitations

Results of the study are limited by the sample of students involved and should not be seen as representative of all students with visual impairment. Demographic information presented along with supporting descriptions of the participating students should assist in determining the applicability of the findings to similar contexts.

The students attended a specialized school for the blind and visually impaired and four students and their teacher were purposefully selected to participate. To extend the findings of this study, replication of the study should be considered in multiple specialized schools for students with visual impairment and blindness, inclusive classrooms in public school systems, and with larger populations of students with visual impairment. Additionally, a comparison between students participating in a traditional approach to instruction (i.e., text-book; lecture format) and students participating in an inquiry-based approach to instruction would provide further support for the results of this study.

Another potential limitation to the study may be that the GIsML approach to instruction (Palincsar et al. ) was modified and adapted to best meet the needs of the learner with visual impairment. However, multiple forms of data were used to assist in analyzing the effectiveness of the guided inquiry approach including classroom observations, student artifacts, and student interviews.

## Future Directions

Many science education researchers advocate the need for research-based instructional practices for all students, emphasizing inquiry-based instructional strategies (NRC, 2000). Research about the experiences of students in general education classrooms supporting the use of inquiry-based learning environments is abundant and the literature base about inquiry-based instruction for students with disabilities continues to increase. However, research about inquiry-based learning for students with visual impairments is extant in the literature. Additional research is needed to examine the components of inquiry-based instructional strategies and how these strategies can best support students' with visual impairment learning and understanding in the science classroom.

The written communication of students with visual impairment to support learning and understanding is extant in the literature. Further research is imperative to support educators in the writing instruction for students. For example, this researcher discovered three specific types of supports were needed to guide students in the task of writing including functional supports, metacognitive supports and interpersonal supports. What additional categories of supports may be necessary for the learner with visual impairment when participating in general writing tasks and discipline-specific writing tasks?

Finally, middle school students from a specialized school for the blind and visually impaired participated in this study. Additional research is needed with students with visual impairment from a variety of grade levels and instructional settings (i.e., specialized settings, public school settings, inclusive settings, resource room settings) to examine how students with visual impairment and individual differences learn best.

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# CHAPTER IV

## STUDENT QUESTIONS AND SCIENCE NOTEBOOK WRITING: SUPPORTING STUDENTS WITH VISUAL IMPAIRMENT IN THE GUIDED INQUIRY-BASED SCIENCE CLASSROOM

To teach science, one must involve students in understanding the language of science. The literature base is continuing to increase on the nature of dialogue during science instruction in the general education classroom (Abell, Anderson, & Chezem, 2000; Driver, Newton, & Osborne, 2000; Kelly & Crawford, 1997; Lemke, 1990; Moje, Collazo, Carrillo, & Marx, 2001), and ways of speaking science to develop student discursive practices have been documented by science education researchers (Roth, 1996; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). However, discursive practices of children with disabilities have not yet been acknowledged in the literature. Inadvertently, researchers have documented the value of discourse in studies including children with disabilities. For example, using their Guided Inquiry Supporting Multiple Literacies (GIsML) approach to science instruction, Palincsar, Collins, Marano, and Magnusson (2000) and Palincsar, Magnusson, Collins, and Cutter (2001) identified positive student outcomes for children with learning disabilities to include students seeking assistance in journal writing and actively participating in discussions. Additionally, Erwin, Perkins, Ayala, Fine, and Rubin (2001) studied the impact and implementation of Playtime is Science for Children with Disabilities (PSCD), an inquiry-based science curriculum, with children with visual impairment. The authors concluded that providing guided opportunities for students to pursue their own interests and answer their own questions had an impact on the students' knowledge and learning of scientific concepts.

Drawing from socio-linguistic and socio-cultural perspectives, I focused on the importance of knowing and understanding the language of science and the significantly central role language plays in student learning. Both quantitative and qualitative methods were used to learn about the ways students with visual impairment engaged in talking and writing science as they investigated concepts of the seasons and of lunar phases.  Research questions included the following:

1. What questioning patterns were prevalent in the inquiry-based classroom?
2. What types of instructional scaffolds were most conducive to student growth in writing science, specifically with the use of science notebooks?

## Theoretical Framework

### *Discourse*

Discourse processes and practices (oral, aural, visual, and written) are cultural tools used by members of a group to construct knowledge (Hicks, 1995; Kelly & Crawford, 1997).  Discourse studies in science education have provided a range of community practices that influence learning opportunities for students (Alexopoulou & Driver; Bianchini, 1997; Richie, 1999; Fairbrother, 1997; Hogan, Natasi, & Pressley, 1999; Moje, 1995, 1997; Roth & Lucas, 1997; Shepardson, 1996; van Zee Iwasyk, Kurose, Simpson, & Wild, 2001).

### *Sociolinguistic Theory in Discourse Studies*

Sociolinguistics has been applied in multiple ways in science education settings. Lemke, in his seminal work (1990), suggested that teachers move away from triadic dialogue, and instead emphasize students' opportunity to talk science. Lemke suggested a variety of ways to expand student discourse including providing opportunities to ask questions, to work in small groups, to produce oral and written reports, and to engage in science writing activities (1990). Carlsen (1991, 1993) used a sociolinguistic perspective to investigate the multiple functions of particular discourse processes, specifically addressing teacher questioning. Carlsen considered questions served multiple purposes for science teachers, and when teaching subject matter less familiar, teachers tended to ask more questions, rather than opening up the conversation. These teachers' questions were of a lower cognitive level and were fact oriented. Similarly, Kelly, Crawford, Chen, and Brown applied sociolinguistic perspectives to the analysis of classroom discourse in a series of studies (Crawford, Chen, & Kelly, 1997; Crawford, Kelly, & Brown, 2000; Kelly & Chen, 1999). Using ethnographic studies and detailed analysis of student and teacher talk, Crawford et al. demonstrated that the classroom teacher created discursive space over an extended time and encouraged students to articulate their ideas.

### *The Role of Questions in the Science Classroom*

The value of student questioning has been emphasized in current reform documents found in science education. The *National Science Education Standards* states "inquiry into authentic questions generated from student experiences is the central strategy for teaching science" (National Resource Council [NRC], 1996, p.31). Questions can indicate that students are engaged actively in making sense of what they are learning. Additionally, questions generated during discussion can form the basis for the next steps in instruction.

Questions by students and teachers are essential components of science talk, especially questions that elicit what students believe and why (van Zee & Minstrell, 1997 a,b). However, student questions rarely occur in classroom settings (Dillon, 1988) because traditional classroom structures typically involve teacher lectures and teacher-led, large-group discussions (Polman, 2004). Mehan (1978) characterized the standard classroom lessons as "initiation-reply-evaluation" (I-R-E). In an I-R-E sequence, the teacher initiates discussion by asking a question with a known answer, students reply by attempting to provide the correct response, and the teacher evaluates the responses, beginning the sequence again as needed. This same sequence was found to be dominant in science classrooms also (Lemke, 1990). Such interactions do not allow for the open-ended discursive practices necessary to draw out students' understandings in the inquiry-based science classroom.

The literature base is on the nature of dialogue during science instruction continuing to increase (Abell et al., 2000; Driver, Newton, & Osborne, 2000; Kelly & Crawford, 1997; Lemke, 1990; Moje et. al., 2001). Most studies have been about teacher and student questioning, and the studies have contributed to the understanding of what constitutes effective questioning practices to elicit student understanding (Roth, 1996; van Zee et al., 2001). Roth described a case study in which the teacher formulated questions in an attempt to “draw out” students’ knowledge. The purposeful questioning was a means for the teacher to scaffold students’ discursive activity, and to promote student-centered discussion independent of teacher direction. Additionally, Scardamalia and Bereiter (1992) found that fifth and sixth grade students tended to generate low-level factual questions rather than questions that could extend their understanding of a topic. In their study to investigate ways of speaking to foster student questioning, van Zee et al. identified ways of speaking in the science classroom as including lecture, recitation, guided discussion, student-generated inquiry discussions, and small group interactions. Through case study analyses, the authors presented specific examples of approaches to science teaching to encourage students to formulate insightful questions about science topics, and to engage students in reflective discussions during three specific speaking environments: (a) guided discussion, (b) student-generated inquiry discussions, and (c) peer collaborations. The authors reported students’ questions occurred more often when discourse structures were designed explicitly to elicit student questions (e.g. engaging students in conversation, establishing student collaborative groups).

### *The Role of Questions for the Student with Visual Impairment*

For the student with a visual impairment, questions are important tools for communication. Information that may not be available to the student visually can be provided by the student’s use of questions. Additionally, questions are a means for the student to establish verbal contact with the listener (Erin, 1986). For example, the child with visual impairment learns that his statement “This is pepperoni pizza” may not produce an answer from another person, but the child’s question “Is this pepperoni pizza?” is almost certain to elicit a spoken response. A limited amount of research has been conducted on the importance of questions and questioning skills for children with a visual impairment; therefore, discussing what is known about this topic is imperative. In a comparative study to measure the frequency of questions, Maxfield (1936) concluded that children with blindness spontaneously asked more questions than children without blindness. Similarly, Erin (1981) and Mulford (1983) found that the questions of children with blindness, ranging from 24.5% to 33% of all utterances; were substantially higher than those reported for children with sight. However, Erin noted that the frequency of questions asked by children with visual impairment decreased as students increased in age. Additionally, students with visual impairment use questions for three purposes: (1) to seek new information (Burlingham, 1961), (2) to keep in contact with and oriented to others (Balikov & Feinstein, 1979), and (3) to maintain conversational control; allowing the children to choose the topic, specify the information needed, and override the absence of nonverbal cues (Kekelis & Andersen, 1982). Arguably, these three functions of questions are vitally important for the child with visual impairment in the science classroom.

### *The Role of Writing in the Science Classroom*

Although the role of writing in the science classroom has received extensive attention, these studies primarily have derived from the Writing Across the Curriculum movement of the 1980's including Writing to Learn and Writing in the Disciplines (see Rivard, 1994 for a full review). Writing in science can promote "the intellectual and cultural traditions that characterize the practice of contemporary science" (NRC, 1996, p. 21). However, a search for literature in the last decade to include research on writing in science revealed little empirically based information on the discursive practices used by students in writing science, how these practices are demonstrated in the classroom, and what instructional supports are needed by students to actively participate in science writing. The importance of writing science is evident. Participating in discipline specific writing practices will help students develop a personal ownership of ideas conveyed in the classroom, and students involved in inquiry-based approaches to science instruction have authentic purposes for writing (e.g., recording observations, procedures, and data; technical drawings, and reflecting on findings).

### *Relevance of Discourse to Inquiry*

Discourse through a social constructivist lens is defined as the use of language in social contexts from which meanings are developed, expressed, expanded, and exchanged during teacher' and students' repeated participation in meaningful social activities (Rogoff, 1990). In the context of the inquiry-based science classroom, discourse includes the underlying rules or ways of describing and understanding the processes of science and the science content. However, as Lemke (1990) pointed out, students are not very adept at using the language of science because it has its own structure and syntax, and engaging in these practices is often difficult because these practices are new to the students (Krajcik, Blumenfeld, Marx, Bass, Fredericks, & Soloway, 1998). Therefore, it cannot be assumed that students will automatically know how to use oral and written language tools, the discursive practices of science, for constructing scientific knowledge with others. Support for learning these new practices of knowing, doing, and talking science is required or students may not relate to science and even may actively resist learning (Lee & Fradd, 1998 as cited in McNeil et al., 2006).

Communicating through spoken and written discourse can provide opportunities for students to develop conceptual understanding and for teachers to assess student learning. In the only empirical study found in which the role of talk and writing in relation to student learning was examined, Rivard and Straw (2000) used a quasi-experimental design to identify the roles of talking, writing and talking, and writing on science learning, The authors focused on middle school ecology lessons and sought to make sense of the various roles of discourse processes in student learning. By separating students into various treatments, Rivard and Straw reported that student talk was important for sharing clarifying, and distributing knowledge, while writing helped developed more structured and coherent ideas for the participating students. Similarly, in this study, I examined the use of discursive practices by students with visual impairment and how questioning and science notebook writing can support student learning and understanding in the science classroom.

Specific research questions included the following:

1. What questioning patterns are prevalent in the inquiry-based classroom?
    a) How often did student questions occur during the specific dialogues (e.g. teacher initiated, inquiry)?
    b) Under what condition did the students' questions occur (i.e. prompting by teacher, self-initiated, in response to a statement)?
    c) What levels of questions, based on Bloom's Taxonomy, do students ask?
2. What types of instructional scaffolds are most conducive to student growth in writing science, specifically with the use of science notebooks?

## Design and Procedure

### *Participants/Setting*

A state residential school for the visually impaired in the southwestern United States was chosen as the site for this study. The school enrolls children with a visual impairment, and children with a visual impairment and additional disabilities. Students representative of diverse cultures from various regions of Arizona attend the residential school. Class sizes generally range from 6 to 8 students and include a classroom teacher specially trained in the education of students with visual impairments, and often a paraprofessional to assist as needed. Students in grades 5-8 are taught science as a collective group.

A middle school level, multiethnic classroom including one boy and four girls of primarily Hispanic culture participated in this project. Etiologies of the students with visual impairments can be characterized as moderately low vision (2 students, large print readers), legal blindness (2 students, braille readers), and total blindness (1 student, braille reader) (see Table 4.1 for identifying characteristics). Additionally, one child with legal blindness and one child with moderately low vision had physical disabilities and all students were identified with a learning disability. The mean age of students was 13 years, 2 months. Although five students participated in the inquiry-based instruction, only four of the students were able to obtain parental permission to be included in the study. The classroom teacher, with 5+ years teaching visually impaired students, participated by observing and assisting students and providing feedback to the researcher-instructor.

Table 4.1: Characteristics of Participating Students

| Name | Gender | Ethnicity | Visual Impairment | Visual Acuity | Age |
|---|---|---|---|---|---|
| Kyle | Male | Caucasian | Optic nerve hypoplasia | 10/225 OD<br>hand motion OS | |
| Camille | Female | Hispanic | Retinopathy of prematurity | 10/80 OU | |
| Carrie | Female | Hispanic | Optic Nerve Atrophy | 1/225 OU | |
| Aspen | Female | Hispanic | Retinal detachment | No Light Perception | |

## Methods of Data Collection

### *Procedures*

An hour each day of a four-day instructional week for 10 weeks, students participated in an inquiry-based approach to instruction of astronomy. Topics included the relationship between the sun, moon, and earth; day and night; and the phases of the moon. Because the students were novices to inquiry-based processes, a guided approach to inquiry instruction (Palincsar, Collins, Marano, & Magnusson, 2000) was chosen to deliver content material.

The classroom teacher had limited experience as a facilitator of an inquiry-based approach to instruction; therefore, the role of the researcher was that of instructor. The classroom teacher assisted by helping individual students with journal writing, by providing additional explanations to clarify directions, and by assisting students with content models (e.g., sun and earth models). Content materials, lesson planning, necessary adaptations, and accommodations were discussed with the classroom teacher to ensure an appropriate level of instruction for all students.

### *Inquiry-based Instructional Unit*

A project-based Full Option Science System (FOSS) unit, Planetary Science (version 2008) was implemented using a guided approach to instruction. The unit is designed to help students use knowledge and evidence to construct explanations for the structure and motions of objects in the Solar System. The FOSS program has roots in the multi-sensory approach developed in the Science Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps (SAVI/SELPH; 1976,1980). SAVI/SELH was originally developed to meet the learning needs of students with disabilities. Because of the hands-on approach, the program found application with general education students. Developed by the Lawrence Hall of Science, the procedures and features of the SAVI/SELPH program were incorporated into the materials and procedures used with all students in the FOSS program. The FOSS units were chosen for this study because the units were designed to maximize the science learning opportunities for students with disabilities. Each lesson was an hour in length and instruction occurred four days each week for eight weeks.

### *Classroom Observations*

Video records were used to provide a view of classroom processes and to capture the complexity inherent in an inquiry-based classroom. One advantage to using video recordings was that classroom activity could be slowed down and viewed multiple times, allowing for detailed descriptions of instructional interactions. To capture students' experiences, a video camera was set on a tripod in the corner of the classroom. Video recordings were collected daily for a total of 40 lessons (40 hours of videotape). Video records were captured with the use of a tripod. In the event that students were sharing or presenting information to the class, the researcher-instructor positioned the video camera to record individuals. Otherwise, the video camera was set to capture the class as a whole group. Video records were transcribed immediately following instruction.

### *Student Artifacts*

Students' written work was collected and photo-copied throughout implementation of the unit. Writings included the students' science notebooks entries and group-constructed writing tasks such as technical drawings. Ruiz-Primo (1998) defined science notebooks as a compilation of entries that provided a partial record of the instructional experiences a student had in his or her classroom for a certain period of time (e.g., the length of an instructional unit or a semester). Characteristics of students' entries varied from entry to entry and reflected the diversity of activities within the instructional context. During the four-day instructional week, students recorded in their science notebooks twice per week for a possible 20 entries per student or 80 total entries. However, because of student absences, 52 science notebook entries were collected. Science notebooks were written in student's medium of choice, including Braille writer, electronic Braille writer or spiral bound notebook. Braille entries were transcribed by the researcher-instructor. Because science notebook writing was a new experience for these students, verbal prompts were used to spark student response. For example, the students were asked to *Describe what you observed about the moon last night. Think about what your classmates observed. How is this different or similar to your observations?* or *Write about something you discovered today. How is this different from what you were thinking before?*

## Description of Methods of Data Analyses

### *Frequency, Types, Condition of Questions*

Frequency of students' questions were collected and calculated by the researcher using an observation protocol (Appendix C) during review of transcribed video records. A question was defined as any query posed by the students in an interrogative form. Using the same observation protocol, students' questions were analyzed for level of question posed and the condition under which the question occurred.

### *Reliability Procedures*

Three additional independent observers collected interobserver reliability data. Observers engaged in a training process in which the researcher identified and defined the target behavior. Continuing with the training process, observers were instructed in how to categorize the question using Appendix C. Ambiguities and unusual circumstances were discussed. Observation protocols were used during training for three lessons, or until the observers were comfortable and efficient in recognizing the target behavior, to ensure the observers fully understood the process. Observers and the researcher compared results following each necessary practice session until an understanding was reached.

Following training, observers reviewed video clips and recorded for frequency of students' questions for 10 of the 40 sessions. The researcher's rate of frequency of students' questions was compared to each of the three observer's rates of frequency of students' questions. Dividing the smaller number by the larger number and multiplying by 100 calculated the level of agreement.

### *Student Artifacts*

Students' science notebooks were collected daily to provide timely feedback to the students, to track students' progress, and to observe students' understanding of content. Relevant to this study were the types and frequency of supports used when students engaged in science notebook writing. Transcripts of video records were analyzed to determine the supports needed during students' science notebook writing.

Reflection prompts were purposefully crafted to help students articulate their thoughts about how and why something occurs (i.e., the cause of lunar phases, the cause of seasons). Researchers have examined the use of reflection prompts designed to guide students in evaluating their work during inquiry-based instruction (White & Frederiksen, 1998, 2000; Davis (2003). The researchers found that greater understanding of inquiry practices resulted when students used reflection prompts. Drawing from the work of McNeil, Lizotte, Krajcik and Marx (2006), generic and context specific supports were developed using a repeated format. Within the *Planetary Science* unit, students were introduced to the terms claim and evidence. The repeated prompt developed by McNeil et al. also included reasoning (i.e., the connection between the claim and evidence). Therefore, students in this study used repeated prompts that included these three areas: (1) Claim – What do you think? (2) Evidence – How do you know? and (3) Reasoning – Why do you think this? Because helping students develop authentic questions was a focus of this study, the researcher-instructor chose to define the terms of the prompt using questions, thereby supporting students in repeating the question, thinking about their answer and providing a more complete response.

## Results and Discussion

The study had two purposes: (1) to discover what questioning patterns of students with visual impairment were prevalent in the inquiry-based classroom, specifically the frequency of questions, the level of questions, and the condition under which the question occurred and (2) to determine the types of instructional scaffolds most conducive to student growth in writing science, specifically with the use of science notebooks.

### *Generating Questions: Instruction*

In addition to the components of guided inquiry-based instruction, reciprocal teaching (Palincsar & Brown, 1984) was used specifically to assist students with the task of generating questions. Reciprocal teaching involved first modeling the cognitive process of crafting questions and then providing support and coaching for the students as they attempted to formulate their own questions about astronomy. As students became more proficient in generating questions at the classification levels identified, then the researcher-instructor faded the support provided for that level. One such strategy were Know, Wonder, Learn (KWL) charts. For each of the three sections, students shared their thoughts and ideas about the topic, what they *Know* about the topic, what they *Wonder* about the topic, and finally what they *Learned* about the topic. The Wonder section provided an avenue for helping students develop authentic science questions. By formulating authentic questions, the science topic is situated in a framework that is likely to be of interest and personally meaningful to students (Krajcik, et al., 2000) within the context of an authentic task (Harris & Marx, 2008).

Through the use of verbal prompts and examples of investigative questions, students' Wonder questions progressed from *Is there really a man on the moon?* to *Is the part of the moon we don't see always on the right (side)?* and

*I wonder if the Earth is about the same distance from the Sun all the time?* Although the student may have been interested in knowing if a man truly lived on the moon, the first example question demonstrated the students' inability to initially formulate relevant and authentic science questions. Additionally, this first example revealed the student's lack of scientific knowledge and understanding of astronomy needed to support the student in developing questions that can be answered by examining the evidence. However, as the instructor's modeling of question format and types continued during the course of instruction, students' questions increased in quality and level of cognitive difficulty, and verbal prompting by the instructor decreased. Also, the researcher-instructor anticipated non-scientific questions students might ask and engaged students in analyzing why the example would not be considered a strong and meaningful science question. For example, the researcher-instructor provided the students with three questions, one of which could not be answered by the evidence collected (i.e., students' observations of moon phases). The class then engaged in conversation about how to rephrase and focus the question into one more meaningful and authentic.

### *Questioning Patterns*

#### Question Frequency

Students generated a total of 220 questions during the 10-week instructional unit about astronomy. Overall agreement between three independent observers and the researcher instructor about the frequency of students’ questions was reported as 87%, 92%, and 90%, acceptable interobserver reliability rates. The students’ etiologies varied within the group and, interestingly, differences between students characterized with low vision (2) and students with blindness (2) existed in the frequency of student-generated questions. Students with blindness generated 147 questions (67%) and students with low vision generated 73 questions (33%). This relationship between question frequency and vision confirms the frequency differences noted by Erin (1986) in her study of frequencies and types of questions in the language of children with visual impairment. However, this finding was presented with caution. In a collection of case studies related to this research, two students with blindness were characterized as social and outgoing and the two students with low vision were described as shy and quiet. The number of student-generated questions in this study may be directly related to the students’ personalities and not to their level of vision. The frequency of students’ questions was presented in Table 4.2. The number of questions per student for each week was presented in Tables 4.3 – 4.6, representing an individuals’ questioning patterns and changes in types of questions asked during the course of instruction.

Table 4.2: Frequency of Students' Questions

| Level of Question | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Remembering | 4 | 8 | 10 | 12 | 8 | 5 | 2 | 3 | 3 | 3 |
| Understanding | 5 | 8 | 13 | 13 | 10 | 15 | 12 | 8 | 4 | 2 |
| Applying | 0 | 0 | 0 | 1 | 5 | 6 | 7 | 8 | 6 | 5 |
| Analyzing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 6 |

Table 4.3: Frequency of Student's Questions: Kyle

| Level of Question | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Remembering | 1 | 1 | 2 | 2 | 3 | 1 | 0 | 0 | 0 | 0 |
| Understanding | 1 | 2 | 3 | 2 | 4 | 2 | 2 | 2 | 3 | 1 |
| Applying | 0 | 0 | 0 | 1 | 3 | 3 | 3 | 3 | 2 | 2 |
| Analyzing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 |

Table 4.4: Frequency of Student's Questions: Camille

| Level of Question | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Remembering | 1 | 1 | 3 | 4 | 1 | 1 | 0 | 0 | 1 | 0 |
| Understanding | 1 | 1 | 2 | 3 | 1 | 6 | 4 | 1 | 0 | 1 |
| Applying | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 3 | 1 | 1 |
| Analyzing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 4.5: Frequency of Student's Questions: Carrie

| Level of Question | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Remembering | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 1 | 0 | 1 |
| Understanding | 2 | 3 | 4 | 3 | 2 | 3 | 2 | 2 | 1 | 0 |
| Applying | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 1 |
| Analyzing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Table 4.6: Frequency of Student's Questions: Aspen

| Level of Question | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Remembering | 1 | 4 | 3 | 4 | 3 | 3 | 2 | 2 | 2 | 2 |
| Understanding | 1 | 2 | 4 | 5 | 3 | 4 | 4 | 3 | 0 | 0 |
| Applying | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Analyzing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

## Question Levels

Question levels were categorized using Bloom's Taxonomy. Revised by Anderson and Krathwohl (2000), Bloom's Taxonomy is a multi-tiered, hierarchical model of classifying thinking according to six cognitive levels of complexity: (a) remembering, (b) understanding, (c) applying, (d) analyzing, (e) evaluating, and (f) creating (Table 4.7). Although this classification system is generally applied to the types of questions teachers ask to elicit a higher level of response from students, the researcher-instructor applied the classification levels to the types of questions generated by students. The thought behind this adaptation was that with modeling and class discussion about authentic questions, coupled with the components of guided inquiry instruction, students would produce questions at a higher level of thought during the course of instruction. The nature of students' questions during the instructional unit on astronomy consisted of remembering questions (66 or 30%), understanding questions (108 or 49%), applying questions (38 or 17%), and analyzing questions (8 or 4%).

Table 4.7: Identifying the Level of Students' Questions: Bloom's Taxonomy

| Classification Level | Definition/Description |
|---|---|
| Remembering | Define, duplicate, list, memorize, recall, repeat, reproduce |
| Understanding | Classify, describe, discuss, explain, identify, locate, recognize, report, paraphrase |
| Applying | Choose, demonstrate, illustrate, interpret, sketch, solve, write |
| Analyzing | Compare, contrast, discriminate, examine, experiment, test |
| Evaluating | Appraise, argue, defend, support, evaluate |
| Creating | Construct, create, design, develop, formulate |

Remembering questions, the first level of Bloom's Taxonomy, were described as questions that help to define and recall information. Many of the remembering questions were asked when students were engaged in science notebook writing. Examples included *How do you spell Earth?* and *What is the contraction for "ar"?* The second level, understanding questions, were defined as questions that help to explain, identify and classify. Typically recognized as –wh questions, examples included *Why does the moon look yellow?* and *What is making the half moon?* Applying questions, the third level, included questions that demonstrate understanding. Examples included *If I go from here to Mexico and back to here, is that my orbit?* and *Is this the pattern – crescent, new, full, crescent?* Analyzing questions, the fourth level, were described as questions that compare, contrast, and examine. Example questions included *If we see the crescent moon today, then we'll see the new moon tomorrow?* and *Is the part of the moon we don't see always on the right side?* Based on evidence from transcripts of classroom observations, students' frequency of generated questions increased with time and the number of remembering questions decreased. However, the levels of student-generated questions were characterized primarily as lower-level thinking questions, with only eight of students' questions described as higher-level thinking questions. Students did not produce questions in either the evaluating level nor the creating level.

The findings about the level of questions generated by students were remarkable. Researchers have established that students with visual impairment ask questions to establish orientation (Balikov & Feinstein, 1979), to seek new information (Burlingham, 1961) and to maintain conversational control (Kekelis & Anderson, 1982). Likewise, Erin (1986) confirmed these three purposes in her study of the questioning behavior found in the spontaneous language of students with visual impairment. Arguably, these three functions of questions are vitally important for the student with visual impairment in the science classroom. However, in the context of the classroom, the researcher-instructor observed that students' questions served another purpose. By watching and listening to their peers ask questions and by watching and listening to the instructor's response, students learned through observation that asking questions would help them to elaborate on their own thinking and expand or explain the thinking of others. Students used questions to focus and clarify ideas and to participate fully in the context of the learning community, demonstrating personal investment in the discussions.

### Classroom Context of Questions

As previously stated, there were five students enrolled in the middle school classroom. Therefore, the student-initiated questions primarily occurred within the context of whole group instruction. Because of the small number, students were provided limited opportunities to work in pairs and groups of two and three. These small group opportunities were characterized as a time to share information, not necessarily to engage in questions or to examine and question evidence. When working in these smaller groups, students generated 12 questions. These questions were classified as remembering questions and examples included *Like this?* and *Hold it here?* Given the small class number, these results were not surprising.

### *Supporting Science Notebook Writing*

As previously stated, the purpose of this portion of the study was to determine the types of supports and scaffolds needed to assist students with visual impairment in their science notebook writing, how often the support was used, and the tools used to provide the support.

Three categories of supports during writing instruction were revealed during analyses of the observational video records: (1) functional – helped the learner understand how to do something, (2) metacognitive – helped the learner be aware of his/her own thinking and learning by reflection, and (3) interpersonal – helped the learner facilitate social interaction such as turn taking and interaction with peers.

Functional supports included assisting students with spelling, Braille contractions, and grammar. Additionally, students needed support to format science notebook entries (i.e., date, title). Students required these functional supports during each writing opportunity.

Metacognitive supports included the repeated prompts to encourage student thinking about these three areas: (1) Claim – What do you think? (2) Evidence – How do you know? and (3) Reasoning – Why do you think this? As indicated occurred with functional supports, the use of metacognitive supports was necessitated each time students engaged in science notebook writing. Three attempts were made over time to fade this metacognitive support; however, students immediately asked for the three questions to be written on the white board and verbally repeated. Therefore, although the students' written entries evidenced the value of the repeated prompts, the support cannot be defined as a scaffold because the tool was not successfully faded or removed over time (Schunk, 1996).

Interpersonal supports were defined as supports that allowed students to fully participate in the learning community (i.e., facilitate social interaction such as turn taking and peer interaction). Students with a visual impairment need more opportunities for educationally meaningful interaction (Hoben & Lindstrom, 1980; Kekelis, 1992; Kekelis & Sacks, 1992; McGaha & Farran, 2001). To facilitate the social interaction within the context of the learning community, interpersonal supports consisted of peer sharing about science notebook entries and whole class sharing about responses to reflection prompts. Engaging in peer interaction around written communication provided students with opportunities to share their own thinking and to value, or at the very least, consider the thinking of others.

## Summary

### *Student Questions*

Students with visual impairment ask questions for many reasons; therefore, students' questions are important tools for learning. Within the context of the inquiry-based classroom, the results of this study revealed that students used questions for more than obtaining information or establishing verbal contact. Students used questions to elaborate on their own thinking and expand or explain the thinking of others. Questions provided students opportunities to focus and clarify ideas and to participate fully in the context of the learning community, demonstrating personal investment in the discussions. Educators must recognize the importance of questioning for students with visual impairment and provide opportunities for students to engage in questioning skills. One such avenue is the inquiry-based classroom. The inquiry-based classroom, as compared to the traditional text-book based approach to instruction, provides multiple opportunities for students to generate questions about observations, evidence, analysis, and the ideas of others.

Although the instructional unit about astronomy was complete before conclusive evidence was found, with instructor modeling and class discussion about authentic questions, coupled with the components of guided inquiry instruction, students did produce questions at a higher level of thought during the course of instruction. Students asked eight analyzing type questions, all occurring during the final two weeks of instruction. Further research is needed to determine if a relationship exists between students' active participation in an inquiry-based classroom and an increase in cognitively complex questions.

### *Supporting Student Writing*

Written communication has been anecdotally documented as difficult for students with visual impairment, particularly for students with blindness. First, written communication requires a specific tool such as the Perkins Braille writer or an electronic Braille writer and written communication is dependent upon the student's skills and efficiency when using the tool. For those students with low vision, written communication could prove difficult if the appropriate tools (i.e., larger writing area, specific writing instrument, necessity for raised lines) are not immediately accessible. Next, participating in written communication is attitudinal, meaning that students with visual impairment prefer to verbally explain their thinking rather than write about their thinking. Results of this study indicate that with appropriate supports (i.e., reflective prompts, functional prompts), students with visual impairment can engage in authentic writing about science concepts. Further research is needed to document students' reasons for verbal communication rather than written communication and to examine students' motivation during the writing process.

## Limitations of the Study

Questioning behavior of students depends largely on the particular classroom and instructor; therefore, the results reported reflect the interactions between the researcher-instructor and the students participating in this study. Additionally, the small sample size of students with visual impairment at the middle school level makes generalizing these findings inappropriate. These results need to be replicated at other grade levels with larger student populations. Another limitation is that the study does not address the questions posed by the researcher-instructor and the influence of these questions on student interactions. The questioning behavior of students should be interpreted in terms of the instructor's behavior. For example, if the instructor asks more questions of a certain type, do students ask the same types of questions?

## Implications for Teachers and Teaching

Results documented in this study demonstrate the necessity of discursive practices for students with visual impairment in the science classroom to build connections, to think critically, to bridge learning and understanding of content, and to engage in meaningful participation with others. This study serves to inform teachers of the impact that language and forms of communication have on student learning and the importance of knowing and understanding the language of science to effectively communicate about observations and evidence with others.

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# CHAPTER V

# INVESTIGATING PRECONCEPTIONS AND CONCEPTUAL UNDERSTANDING ABOUT LUNAR PHASES WITH STUDENTS WITH VISUAL IMPAIRMENT: THE CASE OF KYLE

To grasp the complexity of the cause of lunar phases, students must relate light and perspective and the motion of the sun, moon and earth. However, children have incomplete knowledge about the cycle of lunar phases (Trundle, Atwood, & Christopher, 2002, 2006, 2007b; Abell, Martini, & George, 2001). Although most children are aware of the crescent phase of the moon, many do not have knowledge of the half-moon or gibbous phases and lack the ability to describe why these phases occur (Baxter, 1989; Trundle et al., 2002). Understanding lunar concepts is a part of scientific literacy targeted in the National Science Education Standards (*NSES*; National Research Council, 1996) and the Benchmarks for Science Literacy (*Benchmarks;* American Association for the Advancement of Science [AAAS], 1993). Astronomy and space science concepts are either explicitly or implicitly described as an important part of a student's science education. For example, in the NSES, students enrolled in grades 5-8 are expected to explain the cause of moon phases. Similarly, the Benchmarks suggest the topic of moon phases for students in grades 6-8 and acknowledge the complexity of the topic, identifying the topic as a learning challenge for students (p.66).

Scientists, cognitive psychologists and educational researchers have been interested in how people explain the phases of the moon and the cause of these phases for more than 80 years (Piaget, 1929; Cohen & Kagan, 1979; Treagust, 1988; Driver & Oldham, 1986, Vosniadou, 1991). Researchers found that most students subscribed to non-scientific representations when asked to explain the cause of lunar phases. As a pioneer in the study of conceptual understanding, Piaget documented children's non-scientific conceptions about the cause of the moon phases, supported in later years by, among others, Broadstock (1992); Stahly, Krockover, and Shepardson (1999); and Roald and Mikalson (2001). Lunar phases have been examined in both qualitative and quantitative methods to uncover students' conceptual understandings at various grade levels. Cross-age studies and studies of college students indicated the pervasiveness of a conceptual understanding problem on the cause of moon phases, with the eclipse model (i.e., the moon phases are caused by the Earth's shadow) to be the most commonly held non-scientific conception (Trundle, Atwood, & Christopher, 2002, 2006; Baxter, 1989; Schoon, 1988; Bisard, Aron, Francek, & Nelson, 1994; Chae, 1992; Abell, Martini, & George, 2001).

Many studies of students' alternate frameworks of science concepts and conceptual change have been undertaken with normally achieving students (Pfundt & Duit, 1991). Although curriculum studies have been conducted with students with disabilities (Mastropieri & Scruggs, 1992, 1994; Palincsar, Magnussen, Collins & Cutter, 2001), there is limited research that describes scientific preconceptions or conceptual growth with students with disabilities (Dalton, Morocco, Tivnan & Mead, 1997; Mastropieri & Scrugss, 1994), and no studies that describe preconceptions or conceptual growth have been conducted with students with visual impairment. The present investigation was intended to provide some initial descriptive information on the type of prior understandings students with visual impairment may have about lunar phases and how they may respond when an event is discrepant with, or consistent with, their stated preconceptions. The information is not considered as "normative" for students with visual impairment. Rather, I studied the preconceptions and reasoning processes qualitatively, using participant observation techniques (Maxwell, 2005) and case study methods (Merriam, 1998) to determine how students with visual impairment might think about science concepts. I also wanted to determine if responses appeared consistent with previous observations of sighted students, and whether some qualitative differences would emerge from the use of the inquiry-based instructional strategies enacted during an instructional unit on lunar phases.

## Theoretical Framework

Constructivist theorists posit children are active learners from a very early age, constructing and revising their worldview based on observations and interactions of their surrounding world (Linn, 1987; Novak, 1988). Information about the physical world can come from firsthand observations and explanations given by other people (Kikas, 2003; Vosniadou, 2002), and this early knowledge can lead to deeply held beliefs about the way the world works. Students' existing knowledge plays an important role in the learning process. When an interaction occurs between existing knowledge and new social, cultural and personal experiences, then learning takes place. However, by the time a child enters elementary school, the child arrives with many initial concepts about the physical world that may be incomplete or off the mark. Variously termed misconceptions, preconceptions, or alternative frameworks, these ideas are grounded in children's everyday experience and are often highly resistant to change (Fisher, 1985; Posner, Strike, Hewson, & Gertzog, 1982).

In science, children's ideas are often very different from scientific conceptions (Driver & Oldham, 1986) and change is complex because students have difficulty questioning their current beliefs. Therefore, children need time to ponder, experience, collect evidence, discuss, and explain a science concept. Traditional teaching methods (e.g., whole class instruction, not considering students' prior knowledge, little time for in-depth discussions, emphasis on factual knowledge) have proven insufficient in changing students' misconceptions (Vosniadou et al., 2001). As a result of these traditional teaching methods, students tend to memorize facts (Kikas, 1998; Vosniadou, 1994) or form new synthetic non-scientific models (Diakidoy et al., 1997). For conceptual change learning to occur, students must actively generate and test their alternative conceptions to help them explain observed phenomena (Tyson, Venville, Harrison, & Treagust, 1997). Additionally, conceptual change may be time intensive and gradual, occurring only with multiple experiences over extended periods of time (Vosniadou, 1999, 2002).

A conceptual understanding problem on the cause of the moon phases exists across a wide range of ages and grade levels. Stahly, Krockover, and Shepardson (1999) investigated understanding of lunar phases of four third graders using pre and post interviews. Prior to instruction, two of the students believed that an individual's place on Earth in relation to the moon caused the moon phases, either because of the Earth's rotation on the axis or the Moon's revolution around the Earth. Another student firmly believed in the cloud cover theory (i.e., the phases of the moon are caused by clouds covering portions of the moon) and the fourth student was not able to explain the cause for moon phases. Baxter (1989) surveyed the understanding of moon phases among children in fourth through tenth grades. Most students held four alternative notions of the moon phases involving either an object obscuring part of the moon or casting a shadow on its surface. Very few students held a notion that explained the phases of the moon in terms of a portion of the illuminated side of the moon being visible from the earth. Schoon (1992) investigated the understanding of Moon phases of 1200 students in grades 5, 8, 11 and college-level seniors. Only 34% of all students surveyed correctly identified the cause of lunar phases, while 48% of the students believed that Moon phases were caused by the Earth's shadow on the Moon. Similarly, Bisard et al. (1994) assessed 708 students in middle school, high school, undergraduates, graduates, and pre-service teachers. 39% of participants chose the correct answer. The authors compared the percentage of participants in each age group who correctly responded and found no significant difference between age groups. Lightman and Sadler (1993) used a multiple-choice instrument to assess 1,400 secondary students' understanding of basic astronomy. Project STAR contained 60 questions, of which eight questions were about the moon including lunar phases. Prior to instruction, 88% of students believed the phases occurred because of either the Earth's shadow (41%) or the Sun's shadow (27%). 26% of students answered the question correctly. Also of interest in this study, 37% of the students correctly believed that the Moon orbits the Earth in about one month. However, another 37% of students believed this orbit occurs in a 24-hour period. Students with this belief performed poorly on all portions of the instrument.

Understanding the cause of lunar phases is difficult for students (Abell, Martini & George, 2001; Baxter, 1989; Lightman & Sadler, 1993; Zeilik & Bisard, 2000). Students must grasp multiple concepts such as perspective, light, and angles as well as the motion of the Earth and Moon to adequately comprehend how Moon phases occur. To complicate matters, students bring their own conceptions of how Moon phases occur to the classroom.

Although empirical evidence is not available to support this claim, anecdotally, people assume students with a visual impairment have limited access to astronomy. This may be because astronomy often is called an observational science, in contrast to experimental sciences, such as biology and physics; however, the term observational science does not imply the need for sight. An observational science is a science where it is not possible to design and conduct controlled experiments. For the most part, the universe is not observable to the human eye. Studies of invisible light (e.g. infrared radiation and gamma rays) in the universe are used to provide astronomers valuable insights; far beyond the information provided through observations of visible light. While optical telescopes collect visible light and allow astronomers to see stars and glowing gas, this information can provide only a small part of the story of the universe. Astronomers must use methods and tools to explore areas of space that they cannot directly see to develop their understanding of the universe. Similarly, as those experiencing a seemingly invisible universe, students with a visual impairment may well have more proficiency and knowledge in exploring the unknown than anyone else on Earth.

As previously stated, no studies describing preconceptions or conceptual growth about the topic of lunar phases have been conducted with students with visual impairment. However, studies have been conducted about the way students with visual impairment learn and researchers acknowledge that observation is key to learning (Barraga & Erin, 2001). Yet children with visual impairment often miss the subtle, untaught information that provides the basis for concept development (Ferrell, 1996). These potential gaps in concept development can later affect the child’s ability to infer, predict, and comprehend during learning activities. For example, in addition to personal observations, children with vision receive information and reinforcement about the concept of lunar phases through visual images, books, and weather related television shows. These children are more likely to provide accurate descriptions about lunar phases. However, because of incomplete observations and lack of personal experience (i.e., not being able to touch the moon), children with visual impairment may not be able to infer, predict, or explain lunar phases.

Of interest in this study was examining the previous knowledge and theories of students with visual impairment about how lunar phases occur and to compare these to the alternative frameworks of sighted peers. Additionally, the use of student-constructed synthetic models and whether these models seemingly helped to shape students' understanding were examined. Observational data including student interviews, video recordings, and participant observations were used in providing a rich description of the students' alternate conceptions of lunar phases prior to instruction, construction of scientific knowledge during instruction and conceptions of lunar phases following instruction. The present study was designed to determine how students with visual impairment might think about astronomy concepts, to create opportunities for students to deepen their understanding of astronomy concepts and to promote conceptual growth of students.

## Research Questions

1. What was the nature of students' pre-existing knowledge of lunar phases?

2. What model (i.e, eclipse model) of how lunar phases occur did students possess prior to inquiry-based instruction?
3. How do these pre-inquiry instruction models compare to those of sighted peers?
4. How did the use of physical models (i.e, varied sizes of styrofoam balls to represent the sun, earth and moon) influence the development of scientific frameworks of students?
5. What evidence, if any, exists to support students' growth in conceptual change?

## Design and Procedure

### Setting

A state specialized school for the visually impaired in the southwestern United States was chosen as the site for this study. The school enrolls children with a visual impairment, and children with a visual impairment and additional disabilities. Students representative of diverse cultures from various regions of Arizona attend the residential school. Class sizes generally range from 6 to 8 students and include a classroom teacher specially trained in the education of students with visual impairments, and often a paraprofessional to assist as needed. Students in grades 5-8 were taught science as a collective group.

### *Students*

A middle school level, multiethnic classroom including one boy and four girls of primarily Hispanic culture participated in this project. The students' visual impairments can be characterized as moderately low vision (2 students, large print readers), legal blindness (2 students, braille readers), and total blindness (1 student, braille reader). Additionally, one child with legal blindness and one child with moderately low vision had physical disabilities and all students were identified with a learning disability. The mean age of students was 13 years, 2 months (see Table 5.1). Although five students participated in the inquiry-based instruction, only four of the students were able to obtain parental permission to be included in the study. The classroom teacher, with 5+ years teaching students with visual impairment, participated by observing and assisting students and providing feedback to the researcher-instructor. The classroom teacher had a Doctor of Philosophy (Ph.D.) degree in special education with a major in the education of children with visual impairment.

Table 5.1: Characteristics of Participating Students

| Name | Gender | Visual Impairment | Visual Acuity | Age |
|---|---|---|---|---|
| Kyle | Male | Optic nerve hypoplasia | 10/225 OD<br>Hand motion OS | 15.7 |
| Aspen | Female | Retinopathy of prematurity – retinal detachment | No light perception | 11.9 |
| Camille | Female | Retinopathy of prematurity | 10/80 OU | 12.1 |
| Carrie | Female | Optic nerve atrophy | 1/225 OU | 12.9 |

Based on observations and interview responses, the four participating students were characterized in the following ways:

- Kyle was very social, often gaining the attention of others through his jokes and laughter. Kyle maintained a leadership role in the group and readily voiced his opinions or knowledge about the topic. Kyle volunteered during discussions and openly talked about his enjoyment of the hands-on approach to science instruction. Other students depended on his ability to" know something" about the topic and often waited for Kyle to first speak about the subject before joining in the discussion. Kyle was proficient at both reading and writing Braille. Kyle's science notebook entries were detailed and reflected his confidence about his knowledge of the topics. Prior to instruction, Kyle reported that he was a successful student at school in the area of science and enjoyed science activities at home as well. Kyle had Optic Nerve Hypoplasia with a visual acuity of 10/225 (OD, right eye) and hand motion (OS, left eye). Kyle self-reported that he was able to see the moon in the sky during both day and night.

- Camille was quiet initially, but then became more social as the projects continued. Camille tended to keep her ideas to herself unless asked directly to share with the group. Camille had low vision (retinopathy of prematurity with visual acuity of 10/80 OU, both eyes) and was able to read regular print. Camille enjoyed writing in her science notebook and her responses were thoughtful and often accompanied by drawings or illustrations. Prior to the study, Camille reported that science was not something she thought about when she was not at school and that she did not like reading science books.
- Carrie was shy and quiet. Carrie had recently moved to the United States from Mexico and was still acquiring the English language. Because she was learning a second language, Carrie often shared her thoughts and opinions in Spanish, translated by the teacher or by another student. Carrie was learning to read and write Braille and had difficulty independently writing in her science notebook. Therefore, Carrie dictated many of her entries to the classroom teacher who would Braille the

response for Carrie. Prior to instruction, Carrie reported that she did not particularly like science because she did had difficulty reading the (text) book and did not always understand what she was reading. Carrie had optic nerve atrophy with a visual acuity reported as 1/225 OU, both eyes. Carrie self-reported that she could see the moon in the sky when it was large and full.

- Aspen was popular and animated. Aspen was active in classroom discussions and did not hesitate to ask questions about the topic. Aspen was social and interacted well with her peers. A Braille reader and writer, Aspen preferred to share her opinions and understandings orally; therefore, science notebook writing proved a difficult task and her responses were limited. Prior to this study, Aspen reported that she did not like science and she felt science was only "done in school." Aspen had retinal detachment resulting in total blindness.

## Methods of Data Collection

### *Procedures*

An hour each day for 10 weeks, students participated in an inquiry-based approach to instruction of astronomy. Topics included the relationship between the sun, moon, and earth; day and night; and the phases of the moon. Because the students were novices to inquiry-based processes, a guided approach to inquiry instruction (Palincsar, Collins, Marano, & Magnusson, 2000) was chosen to deliver content material.

The classroom teacher had limited experience as a facilitator of an inquiry-based approach to instruction; therefore, the role of the researcher was that of instructor. Content materials, lesson planning, necessary adaptations, and accommodations were discussed with the classroom teacher to ensure an appropriate level of instruction for all students. Additionally, the classroom teacher contributed by helping students during construction of models (i.e., hold components), during journal writing (i.e., occasional dictation), and one-to-one assistance as needed (e.g., student involved demonstrations).

### *Inquiry-based Instructional Unit*

A project-based Full Option Science System (FOSS) unit, Planetary Science (version 2008) was adapted and implemented using a guided approach to instruction. The unit is designed to help students use knowledge and evidence to construct explanations for the structure and motions of objects in the Solar System. The FOSS program has roots in the multi-sensory approach developed in the Science Activities for the Visually Impaired/Science Enrichment for Learners with Physical Handicaps (SAVI/SELPH; 1976,1980). SAVI/SELPH was originally developed to meet the learning needs of students with disabilities. Because of the hands-on approach, the program found application with general education students. Developed by the Lawrence Hall of Science, the procedures and features of the SAVI/SELPH program were incorporated into the materials and procedures used with all students in the FOSS program. The FOSS units were chosen for this study because the units were designed to maximize the science learning opportunities for students with disabilities.

The content of the class sessions was designed to address the findings of previous research, specifically that deep-seeded beliefs must be addressed in order for students to accept scientific explanations (Vosniadou & Brewer, 1992). To make learning more efficient, students' preliminary knowledge about the causes of lunar phases was discussed, the inconsistencies between different experiences were pointed out, and models were constructed to facilitate understanding. Each lesson was an hour in length and instruction occurred four days each week for 10 weeks.

*Assessments*

To measure student learning, a pre- and post assessment of the students' knowledge of the astronomy topics were used. The assessment was comprised of multiple choice questions and open-response questions. Examples of multiple-choice items included the following:

1. *Why does the moon appear to move across the sky during the night? (a) the moon travels around Earth every day, (b) the Earth rotates on its axis, (c) the moon is extremely far away* or *(d) all objects in space are moving.*
2. *What happens when you see the moon's "phases" change? The moon appears to change (a) color, (b) location, (c) shape* or *(d) distance.*

Examples of open-response questions included the following:

1. *Why does the air temperature rise in the summer?*
2. *Explain in your own words what causes day and night?*

### *Classroom Observations*

Video records were used to provide a view of classroom processes and to capture the complexity inherent in an inquiry-based classroom. One advantage to using video was that classroom activity could be slowed down and viewed multiple times, allowing for detailed descriptions of instructional interactions. To capture students' experiences, video recordings were collected each instructional period of the 10 week study for a total of 40 lessons. Video records were captured with the use of a tripod. In the event that students were sharing or presenting information to the class, the researcher-instructor positioned the video camera to record individuals. Otherwise, the video camera was set to capture the class as a whole group. Video records were transcribed immediately following instruction.

### *Student Artifacts*

Students' written work was collected and photo-copied throughout implementation of the unit. Writings included the students' science notebooks entries and group-constructed writing tasks such as technical drawings. During the four-day instructional week, students recorded in their science notebooks twice per week for a possible 20 entries per student or 80 total entries. However, because of student absences, 52 science notebook entries were collected. Science notebooks were written in student's medium of choice, including Braille writer, electronic Braille writer or spiral bound notebook. Braille entries were transcribed by the researcher-instructor. Because science notebook writing was a new experience for these students, verbal prompts were used to spark student response. For example, the students were asked to *Describe what you observed about the moon last night. Think about what your classmates observed. How is this different or similar to your observations?* or *Write about something you discovered today. How is this different from what you were thinking before?*

### *Student Interviews*

Two purposes existed for conducting student interviews. First, informal interviews with students were designed to probe students' understandings of the science content, the role of writing in learning science, and the students' ways of participating in a science learning community. Interviews were captured by video record and were intended to be short in duration (5 to 10 minutes). Students were asked the following questions: (a) What happened in class today? (b) What did *you* do today? (c) What did you learn about [topic under study]? (d) What did you write about today? (e) How did writing about what you learned help you today? and (f) What else would you like to tell us? Engaging the students as informants served the following purposes: (a) to ascertain the student's perspective on the day's events, and (b) to provide elaboration upon the field notes for the day.

Additionally, each participating student completed a pre and post interview. Pre-interviews were conducted prior to instruction and examined the ability of students to articulate and explain their understanding of moon phases and to identify the prevalence of alternative frameworks. The post-interviews were conducted after the final week of instruction. Students were asked to express their understandings of lunar phases verbally or by drawing in their science notebook. Student interviews were video recorded and transcribed immediately.

## Constructing the Case Study

The challenge of creating the case studies followed data collection. The goal was to represent the experiences of each learner in a way that captured the students' thinking and changes in thinking as the students participated in the inquiry-based activities about lunar phases. There were many possible foci for each case study. To guide the construction of the cases, the researcher examined the supporting evidence for each research question posed. This evidence was then used to inform the design of the individual case studies. The case of Kyle, presented in the following section, illustrates the challenges and successes experienced by many of the students during the inquiry-based instruction. Although the case of Kyle is an example of one student's participation in the inquiry-based instruction about lunar phases, this case demonstrates how these students were able to participate more fully and reveal more about their conceptual understanding when they (a) were supported in their science notebook writing, (b) participated in the construction of models, and (c) actively engaged in discussion with the instructor and with peers. The overall goal in construction of the individual case was to use them in conversations with general educators, special educators and science educators to identify the kinds of strategies that should be implemented with students with visual impairment.

## The Case of Kyle

The following case description examines Kyle's alternative frameworks prior to instruction, his engagement in the inquiry-based lessons, the types of assistance provided to him, the challenges and successes, and his conceptual growth as demonstrated during the post-interview and the post-assessment results. As previously stated, this case illustrates the pattern demonstrated by the four students who participated in this study, documenting students' thinking in the course of guided inquiry instruction about lunar phases. A description of Kyle was presented in the *Students* section of this paper.

### *Pre-Instruction*

Kyle was asked to share what he knew about the moon to obtain information about his prior knowledge.

*Instructor: What can you tell me about the moon?*

> Kyle: It has craters. And a bunch of dents because asteroids have hit it. The dents are the craters. The moon lights up but you can't see it during the day because it's across the earth. It's sucking up the sun's light like a big glow-in-the-dark toy.

Additionally, Kyle identified and talked about the shapes of the moon that had been described to him or that he had seen; however, Kyle held incomplete or confused understandings of the causes of the moon's phases. Kyle also was unable to describe the relational position of the earth, the moon and the sun as the moon progressed through the phases.

> Kyle: I think the moon makes shapes because of the craters hitting it. The half moon is when the craters burn the other side and we only see half.

*Instruction*

As part of the instructional unit, students were asked to observe the moon each night (or day) and to discuss their observations during each class period. Observations could include but were not limited to size, shape and color. Two of the four participating students had enough vision to see the moon in the night sky; however, discerning subtle changes of the moon might be difficult for all of the students. Therefore, students were asked to involve their friends and family when observing the moon and to ask clarifying questions about what the friend or family member was describing. After observing the moon for a week, crafting dough into the shape observed, recording observations in science notebooks, and recording the information on a class chart, students were asked the following question to elicit their knowledge of how lunar phases occur: "What change have you seen in the moon over the last week? Tell me why you think those changes are happening?" Kyle self-reported his ability to see the moon in the night sky and to identify the observed changes without the help of a sighted observer. The following excerpt from Kyle's class discussion is presented:

> Instructor to class: What change have you seen in the moon over the last week? Tell me why you think those changes are happening.
>
> Kyle: I saw that sometimes the moon will be full but not bright at night b/c it looks like it's further away from the earth but it's still a full moon. Sometimes when it is winter time, the moon will get really close to the earth so you can see it better and it will be a full moon and light up everything.
>
> Instructor to Kyle: Can you explain that more to me?
>
> Kyle: The summer is over and it's fall and the leaves are falling off the trees and stuff. And it's winter so the moon is going to be closer to the earth.
>
> Instructor to Kyle: So the reason the moon looks like it is changing is because the moon is coming closer to the earth?
>
> Kyle: Yeah. The moon is taking a different position on the earth. The reason why some parts of the moon are dark and some parts aren't is because there's little craters and stuff – when you burn rocks they are black and the craters in space that are burning are burning at a higher temperature – the crater will hit the moon and the crater will make a black spot – it will burn the lighted area – the moon is lit up and it will burn that

area. The full moon – the moon is not only orbiting but it's flipping. So the burnt part you can't see.

Instructor to Kyle: So how have you learned all of these ideas about the moon?

Kyle: I don't know.

Instructor to Kyle: Did you come up with these ideas from reading books? Or did your parents talk to you about the moon?

Kyle: I was watching the Discovery Channel and they were talking about craters – it showed the craters flying through space and hit the moon – and they would burn all the light.

Kyle's contributions to the class discussion were plentiful, revealing his leadership role in the class structure. This was problematic at times because the other students often adopted Kyle's ideas as their own without attempting to compare the ideas to their own beliefs.

Instructor to class: Do you have other questions about how moon phases happen? We will make a list of all of our questions and find ways to answer them.

Kyle: My question is – are the craters – my theory is - are the craters burning patches into the moon? Are these making the half moon or are they just shadows and clouds?

The following observation occurred during instruction about the movement of the earth and moon:

> Using student-crafted models of the moon and earth, Kyle describes the path of the moon around the earth as a treadmill with bands, one band moving clockwise and the other band moving counterclockwise. Although the rotation of the earth and moon were described as moving in the same direction, Kyle has difficulty grasping this idea. He continues to move the earth clockwise and the moon counterclockwise on his desk. Kyle is reminded that all things in space rotate counterclockwise and a hand over hand demonstration is given to assist him with his thinking. Kyle appears to accept the movement and demonstrates the movement to a partner, using the same description presented to the class.

Although Kyle is able to demonstrate the movement of the earth and moon to a peer, his understanding of the concept is not clear. Kyle repeats the instructor's description to another student, rather than using his own description of the concept.

Two weeks into instruction, the following occurred during a discussion of the students' moon observations and the changes they were seeing each night.

> Kyle places the dough moon flat on his desk and inserts the dowel of the moon model into the dough. He begins to rotate the moon counterclockwise until the dark side (i.e., the painted, tactile side) is facing away from him. Kyle uses the term "full moon" to describe the side of the model he sees. "This is the full moon when the moon's light is very bright." Kyle continues to rotate the moon model and stops when the

> moon model appears half full. "Now the moon is half lit and half not lit. This happens because the moon is turning and we only see part of the moon from Tucson. The shape of the moon will always be round, but we only see the lit side."

Kyle demonstrates his understanding that the moon appears to change during the month, that the shape of the moon remains constant, and that he can only see the lit side of the moon from his place on Earth. Noticeable change from Kyle's pre-instruction ideas is evident: (1) Kyle is moving the moon model counterclockwise, (2) Kyle understands the shape of the moon is round although he cannot see the entire shape, and (3) Kyle is beginning to process the idea of the moon being lit, although he has not yet explained why or how this happens.

Students responded to a prompt in their science notebooks 2-3 times per week. During the third week of instruction, the following observation occurred.

> The writing prompt was given to students "Predict what you think the moon will look like next. What change might you see?" Kyle uses a notetaker to record his response. With ease, Kyle opens the science folder and creates a new document titled "I Predict." Kyle begins to write but struggles with the spelling of predict. Kyle calls out "how do you spell predict?" The classroom teacher assists him with spelling this word and several other words as Kyle continues to record his response.

This observation indicated that, although independent writing and spelling may be challenging to Kyle, his final product is accurate and descriptive and reflects his conceptual growth. The final response was as follows: I predict that I will not see the moon in the sky. I predict this because I have seen that the lit side looks like it's getting smaller. It is a tiny crescent so it should go away tonight or tomorrow and I won't see the moon.

By the sixth week of instruction, students had observed the full cycle of the lunar phases. Using the charts created in class illustrating the students' observations, students were asked to think about what they had observed and to describe what they saw on the chart.

> Instructor: (Following discussion about the students' observations from the previous night) Let's take a look at our class observation chart. What do you see?
>
> Kyle: (Listens to others responses.) I see a pattern – like how we – like the same shapes.
>
> Instructor: Can you explain what you mean, Kyle?
>
> Kyle: Uh…there's a half moon (points) and there's a half moon (points). This one is a banana and this one is a banana (points to two different days).
>
> Instructor to class following further discussion about patterns observed on the chart: Using your moon models, show me the phases of the moon that we have observed. Using his moon model, Kyle chooses to say what he is thinking out loud but to no one in particular.
>
> Kyle: (Touches his nose) This is Tucson… so I first saw this.

> Kyle looks at the chart and then positions his moon to show the waning crescent. Although the terms have been introduced, Kyle does not use the scientific terms for each of the lunar phases, rather he describes the shape instead. Kyle continues to move the moon model and stops when the model represents the full moon. Kyle refers to the chart again and counts the number of days between the waning crescent and the full moon.

This observation was interesting for several reasons. First, Kyle demonstrated his ability to accurately portray the recorded observations using a model. Next, Kyle considered the time frame between phases, an important skill needed to understand lunar phases. Also, Kyle used himself as a referent (i.e., touches his nose to represent Tucson) to help him gain perspective of the Earth view of the moon.

*Post-Instruction*

Following the 10 weeks of instruction, students were interviewed individually to determine their understanding of the science concepts. Kyle's interview is presented.

> Instructor: I'm going to ask you some questions and you can use any of the models you crafted to explain your answer.
>
> Instructor: Can you tell me about the moon phases you saw this month?
>
> Kyle: The moon phases I saw this month… (pauses) A half moon, a full moon – I saw the full moon twice this month.
>
> Instructor: Do you think there is a pattern?

> Kyle: I think the moon, you know how humans are used to everyday habits? I think that the moon is used to patterns so when it comes time for the moon to change, then it changes – that's why it's a pattern.

Kyle exhibited difficulty with sequencing of phases into patterns (i.e., waxing and waning patterns). For example, Kyle was asked to draw the phases of the moon in the order he remembered from his observations. Although the eight phases were represented, no discernable order existed in Kyle's drawing.

> Instructor: Can you expand on your idea of the moon phases happening in a pattern using your drawing? You can use the model if you want.
>
> Kyle: The moon phases happen in a pattern – like full moon, new moon, crescent moon.
>
> Instructor: Using your drawing, explain the order to the pattern that happens each month.
>
> Kyle: The order? (pauses) I don't know if there's an order – it just happens. The moon is used to changing so it just does it.

This entry was significant. Kyle demonstrated his understanding that the moon moves through phases that occurs in patterns; however, Kyle does not yet accept these patterns are predictable.

> Instructor: One of your ideas about the causes of the moon phases was that maybe clouds were making the phases of the moon... Can you explain how you think about this now?

Kyle: The clouds don't make the phases of the moon but they do hide the moon…

Instructor: So what is causing the moon phases?

Kyle: It's the orbit and the turning of the earth on its axis… (pauses)

Instructor: Explain that a little more.

Kyle: I think the earth is doing its thing and moving in circles and the moon is doing the same thing – the moon basically isn't really moving but it's like turning from the full moon to the half moon and new moon…

Instructor: Thinking about what you know about the earth spinning on its axis – what can you tell me about the moon spinning?

Kyle: I don't think the moon has an axis – but the moon does orbit the earth like the earth orbits the sun so I think the moon does spin along with the earth and – the moon is over here and it's night time – and the earth spins and it's day time. So basically when Tucson is over here (points on the globe), it's nighttime for us.

Instructor: What is that called?

Kyle: That's day and night – this works because the sun stays in one area – the earth orbits and the moon orbits the earth and the earth orbits the sun – the earth changes it's direction and another country points to the sun so our country is pointed to the moon so we're not getting any sun and it's nighttime.

Instructor: Can you show me only the movement of the earth to make day and night?

Kyle uses the earth to go around the sun –

Instructor: So the earth has to go around the sun to make day and night?

Kyle: (begins spinning the globe on the axis) No – the spinning on the axis makes day and night. For the earth to spin one turn on it's axis takes 24 hours and that's day and night.

Instructor: You also had the idea that asteroids might be making the half moon. What do you think now?

Kyle: (points) This side isn't lit – you're seeing this (points) the side that isn't lit is because of asteroids and they collide – they are going so fast they are on fire – when they hit the moon it burns and leaves a dent in the moon.

Instructor: What causes the lit side of the moon?

Kyle: I think it's the mirror effect – the sun shines on the moon and this side is lit – this side isn't because of the asteroids. So the sun is shining and lighting this side of the moon.

Instructor: Is there anything else you want to tell me about the things we've learned this month?

Kyle: I've learned to observe the moon and I've learned that the moon… When I was little I thought the moon was losing the rocks – that they were disconnecting themselves – but now I've learned that the sun shines on

> the moon to make the moon look like that. I learned that the moon is always round – so when it takes a shape like a banana, its not that it is a banana it's just what we see – because of the sun shining.

Through his responses, Kyle demonstrated that although he continued to grapple with some basic astronomy concepts (i.e., viewing the full moon twice in one month), he recognized his existing ideas (i.e., the clouds causing the moon phases and the asteroids making the half moon) and chose to reconstruct his alternative frameworks to accommodate the new knowledge and evidence he had discovered. For conceptual change to occur students must recognize their own beliefs, consider worth of these beliefs, and compare their beliefs with the new information. Although Kyle has not completely let go of his alternate conceptions, cognitive conflict is apparent as he described his developing understanding of lunar phases.

During the post-instruction interview, Kyle was asked about his science notebook writing and the models he constructed.

> Instructor: How did writing help you learn?
>
> Kyle: It helped me think about my answer and made me think that I should look at the moon before I say anything else – it didn't help me learn about my answer – it made me want to find out more.
>
> Instructor: Did the models help you in any way?

> Kyle: It helped me explain my ideas about the way the earth looks in space and where the moon and sun are in space – it helped me think about it more – and come up with my own theory.

Table 5.2 presents Kyle's understanding of lunar phases before, during and after inquiry-based instruction about lunar phases. This table demonstrates the nuanced changes in Kyle's thinking.

Table 5.2: Kyle's Understanding about Moon Phases During the Course of Instruction

| Pre-instruction: Kyle's understanding |
|---|
| The moon lights up but you can't see it during the day because it's across the Earth. It's sucking up the sun's light like a big glow-in-the-dark toy.<br>I think the moon makes shapes because of the craters hitting it. The half moon is when the craters burn the other side and we only see half. Also, clouds might make the phases. |
| Beginning of instruction |
| Sometimes when it is winter time, the moon will get really close to the Earth so you can see it better and it will be a full moon and light up everything |
| Two weeks into instruction |
| The reason some parts of the moon are dark and some parts aren't is because there's little craters and stuff – the crater will hit the moon and will burn the lighted area… The moon is not only orbiting but it's flipping so the burnt part you can't see. |
| Four weeks into instruction |
| Using a model of the moon, Kyle rotates the model and stops to describe the phases he has observed: The moon is half lit and half not lit. This happens because the moon is turning and we only see part of the moon from Tucson. The shape of the moon will always be round, but we only see the lit side. |

Table 5.2 continued

Six weeks into instruction

Kyle counts the number of days between similar lunar phases using the class constructed chart. I see a pattern…like the same shapes.

Post-instruction: Changes in Kyle's understanding of lunar phases

I think the moon is used to patterns so when it comes time for the moon to change, then it changes. I don't know if there's an order – it just happens.

The clouds don't make the phases of the moon but they do hide the moon. It's the orbit and the turning of the Earth on it's axis (that makes the phases).

I think it's the mirror effect (that causes the lit side of the moon). The sun shines on the moon and this side is lit – this side isn't because of the asteroids.

When I was little I thought the moon was losing rocks – that they were disconnecting themselves – but now I've learned that the sun shines on the moon to make the moon look like that. I learned the moon is always round – so when it takes a shape like a banana it's not that it is a banana it's just what we see – because of the sun shining.

This case features a student who has significant visual impairment. Nonetheless, with appropriate supports, Kyle was actively engaged in the guided inquiry-based classroom. Kyle shared his observations and conducted analysis of scientific phenomena. Kyle was successful in crafting models to illustrate lunar phases. Kyle was attentive during discussions, contributed to the discourse of the learning community, and expressed his ideas, even when his beliefs were challenged. Kyle also capably met the cognitive demands of inquiry-based instruction, such as thinking about the relationship between his pre-instruction ideas and the evidence observed (i.e., observing the moon daily). Additionally, with minimal assistance, Kyle was able to express his thinking more fully, engage in revision, and elaborate on his thinking when writing in his science notebook.

This article concludes with a discussion of the implications of these findings.

## Discussion

Analyses of Kyle's interview dialogue and dialogue during instruction suggested that Kyle had personally meaningful preconceptions about the cause of the moon phases. These preconceptions apparently came from prior experiences, although not necessarily from prior school experiences. Some thoughts such as "asteroids have hit it – the dents are the craters" reflect the recollections of television programs. Other ideas such as "it's sucking up the sun's light like a big glow in the dark toy" reflect Kyle's personal experiences with specific types of toys. Kyle also connected his ideas of day and night and related these understandings to his new knowledge about the changes he was observing in the moon. Overall, Kyle brought a wealth of relevant information into the instructional context, derived from a variety of previous experiences. Nevertheless, Kyle's beginning knowledge of moon phases was fragmented, incomplete, and sometimes contradictory. Although Kyle had a visual impairment defined as legal blindness (IDEA, 2004), Kyle's preconceptions and reasoning about the cause of the moon's phases were not qualitatively different from the preconceptions and reasoning of peers with sight (Stahly, et al., 1999; Baxter, 1989; Bisard, 1994, Trundle, et al., 2007).

Although conceptual change has long been an important feature of science education literature, such ideas have not been carefully explored with students with visual impairment. Vosniadou (2003) identified significant characteristics of effective instruction targeting conceptual change. The guided approach to inquiry instruction used in this study was consistent with these characteristics. Vosniadou stated that instructors First, students observed the moon daily for five weeks, analyzed the information and compared observations to pre-instruction concepts of lunar phases. Next, using the guided inquiry approach to instruction, the researcher-instructor assisted students as they identified lunar shapes and patterns and began to develop an explanation for these observed changes. Additionally, model construction (i.e., models of the moon, models of the relationship between the sun, moon and earth), demonstrations (i.e., self-referent "your nose is Tucson – what lunar phase is seen now?"), and instructional activities (i.e., graphing lunar observations, using dough rather than flat shapes) provided students ways to further assimilate and accommodate this new knowledge of lunar phases. Additionally, students demonstrated metacognitive awareness by reviewing science notebook entries for clarity and coherence, and revising responses when they recognized limitations in initial attempts.

This is the first documentation of conceptual understanding about the cause of lunar phases for middle school students with a visual impairment. I postulate that students' with visual impairment conceptual understanding would not have been possible using traditional instruction on astronomy concepts (i.e., lecture, text-book based approach to instruction). With appropriate and decidedly non-traditional instruction, students with visual impairment can achieve conceptual understanding about the cause of lunar phases. Additionally, these results contribute to the literature base for understanding the characteristics of inquiry-based instruction associated with conceptual development for students with visual impairment.

The researcher-instructor examined the conceptual understanding of students with visual impairment following guided inquiry-based instruction about lunar phases. As a result of this study, questions emerged that could be addressed by further research. The students in this study exhibited alternative conceptions about lunar phases before inquiry-based instruction. Driver (1981) emphasized the importance of recognizing students' preconceived notions of science concepts. Therefore, knowing and acknowledging the alternative conceptions of students with visual impairment in other astronomy topics and science domains is imperative. Furthermore, although the findings illustrated positive conceptual change in scientific understandings about lunar phases for students with visual impairment, additional measures (i.e., longitudinal follow-up student interviews) could be conducted to determine students' retention of knowledge about lunar phases.

Results of this study should not be seen as representative of all students with visual impairment. The students attended a residential school for the blind and visually impaired and only four students participated in the study. To extend the findings of this study, replication of the study should be considered in multiple residential schools for students with visual impairment and blindness, inclusive classrooms in public school systems, and with larger populations of students with visual impairment.

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# CHAPTER VI

# CONCLUSION

Science education reform necessitates purposeful and planned instruction for all students, emphasizing instruction aligned with the current thinking found in empirical research grounded in theory (National Research Council, 1996; Singer, Marx, Krajcik, & Clay-Chambers, 2000). Knowledge of science pedagogy for children with disabilities is continuing to increase (Mastopieri, Scruggs, & Butcher, 1997; Palincsar, Collins, Marano, & Magnussen, 2000; Palincsar, Magnusson, Collins, & Cutter, 2001; McCarthy, 2005). However, literature in science methodology for learners with a visual impairment is sparse (Erwin, Perkins, Ayala, Fine, & Rubin, 2001; DeLucci & Malone, 1982; Hadary, 1977). Using a three-manuscript format to the dissertation, the purpose of this mixed-methods study was to examine the experiences and outcomes of students with visual impairment as they participated in a guided inquiry-based unit about astronomy.

This dissertation represents the first study of this kind to examine how guided inquiry-based instruction may best support students' with visual impairment learning and understanding in the context of science instruction. A middle school classroom of five students participated in the guided inquiry-based instruction, and results are reported for the four students who obtained parental permissions. A modified project-based Full Option Science System (FOSS) unit Planetary Science (version 2008) was used to best meet the needs of the learner with visual impairment. The adapted unit was designed to help students use knowledge and evidence to construct explanations for the structure and motions of objects in the Solar System (i.e., lunar phases, sun-moon-earth system, seasonal change) and content was delivered through a guided inquiry approach. Additionally, students participated in assessments to measure student learning and attitudes toward science, and informal interviews designed to probe students' understanding of content and ways students' ways of participating in the learning community. Classroom interactions were captured with video recording each day of instruction and student artifacts (i.e., models, science notebook entries) were collected. Student interviews, classroom observations, video records, and assessments were analyzed and used to construct case studies about each student.

In this final chapter, I discuss the findings reported in the manuscript chapters and situate these findings within the context of previous teaching and learning research and specifically examine the literature about best practices for instruction for students with visual impairment. Additionally, I consider the relevance of this study and discuss how this work will inform current understanding of instructional practices for students with visual impairment. Implications for professional development for both science educators and special educators are discussed. Finally, I highlight limitations of this study and consider how future directions will further contribute to the literature base about instructional approaches for students with visual impairment.

## Opportunities Provided to Students in an Inquiry-based Classroom

Social constructivist theories of learning have implications for instruction for all students, including students with disabilities. Within this paradigm, student learning takes place when surrounded by a collaborative environment that supports the sharing of tasks and the exchanging of ideas for the purpose of actively building new knowledge (National Research Council [NRC], 2000; Vygotsky, 1986). One purpose of this study was to examine the opportunities provided to students with visual impairment in an inquiry-based learning environment. This study represents the first to examine science methodology for students with visual impairment and a comparison between the results of this study and the results of previous studies about instructional approaches with learners with disabilities is warranted. To frame this next section, I refer back to the four salient features fundamental to the social constructivist perspective and considered common ground between the much needed collaborative endeavors of special education researchers and science education researchers discussed in the first chapter: (a) active construction of knowledge, (b) situated learning, (c) community of learners, and (d) discourse.

### *Active construction of knowledge*

Although previous knowledge and experiences are the starting point of new learning for all students, active participation in learning is believed to lead to students' deeper understanding and use of knowledge, thereby supporting students' application of what they have learned (Krajcik et al., 1998; Driver et al., 1994; Brooks & Brooks, 1993). When students actively reason through scientific content, they are likely to learn, remember, and comprehend more than when they are directly provided with the same information (Scuggs et al., 1994; Palincsar et al., 2000, 2001). Similar to the findings of previous studies with students with disabilities (Erwin et al., 2001; Palincsar et al., 2000; Mastropieri et al., 1998), active involvement with authentic tasks was essential for students with visual impairment to successfully participate in the inquiry-based learning environment. Active exploration by students facilitated knowledge construction by enhancing the meaningfulness and concreteness of the experiences (e.g., observations of lunar phases, model construction) and helped students build these experiences into their existing knowledge system.

### *Situated learning*

Learners with disabilities must be provided opportunities to acquire complex cognitive skills through participation in social interaction within purposeful contexts (Palincsar et al., 2001). The guided approach to inquiry instruction used in this study was designed to engage students as they participated in authentic observations, recorded observations, analyzed data, and communicated findings. By the very nature of the instructional activities, students were encouraged to actively use science investigative skills within a collaborative learning environment. The instruction was not traditional in the sense that the instructor provided students the information. Rather the students actively found lunar data, shared findings, recorded and tracked observations, made predictions based on observations, and participated in discussions about their findings. In this study, the guided inquiry-based approach to instruction was used to encourage students to assume responsibility, challenge other's observations and findings, compare observations to current understandings, make sense of their understandings and continue to build upon existing knowledge. In this way, students are acculturated into the cognitive practices and strategies of science (Lave & Wenger, 1991).

### *Community of learners*

In the context of the social constructivist framework, student learning takes place within a collaborative environment that supports the sharing of tasks and the exchanging and critiquing of ideas for the purpose of building new knowledge (Magnusson & Palincsar, 1995; Wenger, 1998). The findings of this study point to three important factors that influenced the learning community: (1) the importance of the instructor's role in supporting students in the inquiry-based environment, (2) the importance of appropriate verbal and written prompts in contributing to the discourse of the learning community, and (3) the importance of students engaging in authentic tasks to support learning and understanding of science phenomena.

Findings in this study revealed that the instructor's role was to guide students' construction of scientific knowledge and reasoning through the process of inquiry about the physical world. Students began with engagement around a question and worked together, with the instructor, to answer the question by making observations, collecting data, and analyzing results. Additionally, the role of the instructor was to introduce students to the language of science including science-specific terms, standards for model construction and graphic representations, and inquiry-based methods (i.e., data collection, recording data). Positive student outcomes (e.g., engaging in problem-solving, active participation in discussions, seeking assistance with inquiry-based tasks) were reported in other studies when guided inquiry was used to help students construct knowledge and understanding (Palincsar et al., 2001); however, this study elaborates on the types of support and guidance needed to establish a community of learners (i.e., reciprocal teaching strategies; functional, metagcognitive and interpersonal supports).

### *Discourse*

Discursive practices in the science classroom included discussions, questioning, and science notebook writing. Students with visual impairment participated in discussions with appropriate verbal prompting (i.e., asking a question, asking student to expand or tell more). Additionally, students discussed ways to "prove" their observations were accurate and used student-crafted models to make sense of the data and negotiate shared understandings. Similar to these results, Palincsar et al. (2000, 2001) and Scruggs et al. (1993) stated student discussions were an important factor to inquiry-based instruction and enhanced the learning of students with disabilities. This study contributes to the literature about discursive practices in the science classroom by expanding on the types of supports needed by students to successfully participate in the inquiry-based learning environment. For example, students initially had difficulty when writing about their observations and findings in their science notebooks. Reflection prompts (White & Frederiksen, 1998; Davis, 2003; McNeil et al., 2006) were purposefully crafted to help students articulate their thoughts about how and why something occurs (i.e., the cause of lunar phases, the cause of seasons, day and night). Metacognitive supports (i.e., claim, evidence, reasoning) helped students be aware of their own thinking and learning by reflecting in a logical sequence. Additionally, functional supports were provided to assist students' understanding about how to complete a task (i.e., Braille contractions, format for science notebook entries), and interpersonal supports helped students facilitate social interactions such as turn taking and peer interaction (Kekelis, 1992; Kekelis & Sacks, 1992; McGaha & Farran, 2001). Students were able to fully participate in writing activities and their writing evidenced the importance of using these types of prompts. Educational researchers (NRC, 1996; Rivard & Straw, 2001) identified the importance of writing in science; however, this study represents the first to examine students' with visual impairment writing in science. In the present study, writing practices are demonstrated in the context of the inquiry-based classroom and the types of instructional supports needed by students with visual impairment to actively participate in science writing are identified, defined and applied.

## Challenges Faced by Students in an Inquiry-based Classroom

Engaging in inquiry is purported to deepen students' learning of science content and broaden their understanding of the nature of science (Krajcik et al., 2006); therefore, providing all students with opportunities for learning through inquiry-based instruction is imperative. However, learners in inquiry-based learning environments are presented with many cognitive challenges. For example, students must organize knowledge in new ways (NRC, 2000). To successfully engage in scientific practices such as collecting data, generating evidence, and reporting results, learners need to use reading, writing and speaking skills and draw from knowledge across content areas (Bybee, 2002). In this way, learners are expected to integrate knowledge, and use and apply this knowledge as they reason through inquiry investigations (NRC, 2000). Despite these challenges, students with disabilities are successful in inquiry-based learning environments (see Literature Review chapter for complete review). Another purpose of this study was to examine the challenges faced by students in the guided inquiry classroom. In this next section, I discuss three areas that were most challenging for students and the supports provided to assist student learning and understanding of scientific phenomena: (1) student-generated questions, (2) science notebook writing, and (3) analyzing data to draw conclusions.

### *Student-generated Questions*

For the student with a visual impairment, questions are important tools for communication and ultimately for learning. Initially, the task of generating questions proved difficult for students in this study. However, with the instructor's use of reciprocal teaching, modeling questions, and anticipating students' non-scientific questions, students were able to generate authentic and personally meaningful science questions. Students with visual impairment typically use questions for three purposes: (1) to seek new information (Burlingham,1961), (2) to keep in contact with and oriented to others (Balikov & Feinstein, 1979), and (3) to maintain conversational control; allowing the children to choose the topic, specify the information needed, and override the absence of nonverbal cues (Kekelis & Anderson, 1982). Arguably, these three functions of questions are vitally important for the learner with visual impairment in the science classroom. However, within the context of the inquiry-based classroom, the results of this study revealed that students used questions for more than obtaining information or establishing verbal contact. By watching and listening to their peers ask questions and by watching and listening to the instructor's response, students learned through observation that asking questions would help them to elaborate on their own thinking and expand or explain others' thinking. Additionally, the instructor's question modeling supports were vital to students' ability to construct questions. By asking questions, students focused and clarified ideas, demonstrating personal investment in the discussions and full participation in the context of the learning community.

Through the course of instruction during this study, students generated a total of 220 questions, 147 questions generated by students with blindness and 73 questions generated by students with low vision. This relationship between question frequency and visual impairment confirms the frequency differences noted by Erin (1986). However, this finding was presented with caution. In a collection of case studies related to this research, two students with blindness were characterized as social and outgoing and the two students with low vision were described as shy and quiet. The number of student-generated questions in this study may be directly related to the students' personalities and not to their level of vision.

Initially, student generated questions were of a low cognitive level; however, with instructor modeling and class discussion about authentic questions, coupled with the components of guided inquiry instruction, students produced questions at a higher level of thought during the course of instruction. Students asked eight analyzing type questions, all occurring during the final two weeks of instruction. This finding is consistent with results reported about students without disabilities in science classrooms. Scardamalia and Bereiter (1992) showed that students initially asked low-level factual questions and that the level of the questions improved as students gained more background knowledge; however, the researchers did not discuss the types of supports needed or used to assist students in generating higher cognitive questions. In the present study, students' abilities to generate authentic questions were fostered through active engagement, instructor modeling of authentic question formats, and analysis of students' non-scientific questions. Students also received timely and informative feedback from the instructor and were given opportunities to revise their questions and generate new ones. Although students' initial questions were considered to be factual and low-level cognitive questions, the fact that students' were generating higher-level cognitive questions at the conclusion of this study is a positive result.

### *Supporting Student Writing*

Writing in science can promote "the intellectual and cultural traditions that characterize the practice of contemporary science" (NRC, 1996, p. 21). Participating in discipline specific writing practices will help students develop a personal ownership of ideas conveyed in the classroom, and students involved in inquiry-based approaches to science instruction have authentic purposes for writing (e.g., recording observations, procedures, and data; technical drawings, and reflecting on findings). The present study makes a significant contribution to the literature about writing in the disciplines (see Rivard, 1994 for a complete review) and is the first to examine the writing practices of students with visual impairment. Written communication has been anecdotally documented as difficult for students with visual impairment and the results of this study demonstrate the challenges students have with writing. For example, students used multiple tools to participate in written communication (i.e., Braille writer, electronic notetaker, large print, and regular print). Written tasks were dependent upon the students' skills and efficiency with these tools. Additionally, students' preferred means of communication was oral communication, meaning they preferred to verbally explain their thinking rather than write about their thinking. Although these challenges were evident, instructor support provided students opportunities to overcome these challenges. For example, three categories of supports needed by students during writing instruction were revealed in this study: (1) functional – to help the learner understand how to do something, (2) metacognitive – to help the learner be aware of his/her own thinking and learning by reflection, and (3) interpersonal – to help the learner facilitate social interaction such as turn taking and interaction with peers. Although attempts were made over time to fade the three types of supports, students were more successful in their writing tasks when the prompts were used, and students' written entries evidenced the value of the repeated prompts in assisting students to fully explain their thinking and to participate in writing activities.

Students with a visual impairment need more opportunities for educationally meaningful interaction (Hoben & Lindstrom, 1980; Kekelis, 1992; Kekelis & Sacks, 1992; McGaha & Farran, 2001). To facilitate the social interaction within the context of the learning community, students participated in peer sharing about science notebook entries and whole class sharing about responses to reflection prompts. Engaging in peer interaction around written communication provided students with opportunities to share their own thinking and to value, or at the very least, consider others' thinking. Results of this study indicate that with appropriate supports (i.e., reflective prompts, functional prompts), students with visual impairment can engage in authentic writing about science concepts. Additionally, results documented in this study demonstrate the necessity of discursive practices for students with visual impairment in the science classroom to build connections, to think critically, to bridge learning and understanding of content, and to engage in meaningful participation with others. The results of this study serve to inform teachers of the impact that language and forms of communication have on student learning and the importance of knowing and understanding the language of science to effectively communicate about observations and evidence with others.

### *Analyzing Data to Draw Conclusions*

The students participating in this study were novices to inquiry-based instructional approaches to learning. Similar to novices in other science studies (Palincsar et al., 1999, 1993; Krajcik et al., 1998), students did not develop logical arguments using evidence to support their claims and tended to present information and draw conclusions without explicitly linking the two. For example, students participated daily in the construction of a class chart about their observed lunar phases; however, when asked to predict the next phase, students did not refer to the chart or to their written science notebook entries. One reason for this difficulty was that students had limited prior experiences in organizing and analyzing data and in drawing conclusions about the data. The implication of this difficulty faced by students to conclude findings based on evidence and observations demonstrates the need for teachers to provide multiple opportunities for students to engage in this scientific process and to participate in the science classroom by doing science much like that of practicing scientists (Minstrell & van Zee, 2000).

## Conceptual Change

Although conceptual change has long been an important feature of science education literature (Pfundt & Duit, 1991; Trundle et al., 2007), such ideas have not been carefully explored with students with visual impairment. A third purpose of this study was to provide descriptive information on the prior understandings students with visual impairment have about lunar phases and how they respond when an event is discrepant with, or consistent with, their stated preconceptions. Vosniadou (2003) identified significant characteristics of effective instruction targeting conceptual change. The guided approach to inquiry instruction used in this study was consistent with these characteristics. Vosniadou stated that instructors must (a) involve students in evaluating evidence that differs from their beliefs, (b) present clear explanations of scientific concepts using models and analogies, (c) demonstrate how scientific models and explanations are superior to non-scientific conceptions, and (d) encourage purposeful student learning characterized by a high level of metacognitive awareness. First, students observed the moon daily for five weeks, analyzed the information and compared observations to pre-instruction concepts of lunar phases. Next, using the guided inquiry approach to instruction, the researcher-instructor assisted students as they identified lunar shapes and patterns and began to develop an explanation for these observed changes. Additionally, model construction (i.e., models of the moon, models of the relationship between the sun, moon and earth), demonstrations (i.e., self-referent "your nose is Tucson – what lunar phase is seen now?"), and instructional activities (i.e., graphing lunar observations, using dough rather than flat shapes) provided students ways to further assimilate and accommodate this new knowledge of lunar phases. Additionally, students demonstrated metacognitive awareness by reviewing science notebook entries for clarity and coherence, and revising responses when they recognized limitations in initial attempts.

This is the first documentation of conceptual understanding about the cause of lunar phases for middle school students with a visual impairment. I postulate that students' with visual impairment conceptual understanding would not have been possible using traditional instruction about astronomy concepts (i.e., lecture, text-book based approach to instruction). With appropriate and decidedly non-traditional instruction, students with visual impairment achieved conceptual understanding about the cause of lunar phases. Additionally, these results contribute to the literature base for understanding the characteristics of inquiry-based instruction associated with conceptual development for students with visual impairment.

## Recommendations for Professional Development

Collectively, these studies can provide educators important information regarding inquiry-oriented approaches to science instruction for students with visual impairment. Support for the value of inquiry-based approaches is evident. Knowledge construction was facilitated by the meaningfulness of materials presented, by active participation and exploration, and by building these experiences into the students' prior knowledge. Structured questioning techniques were used to guide and facilitate students' thinking, demonstrating that the student with visual impairment can exhibit higher-level thinking skills and cognitive processes needed to solve problems. Guided coaching strategies were used to provide students with opportunities to build upon prior knowledge and experiences and to construct new knowledge and understanding. Additionally, inquiry-oriented approaches facilitated the development of students' with visual impairment social skills because peer interaction was encouraged in the learner-centered environment. Participation in a science classroom in which the instructor promoted peer interaction, the sharing of information, and discussions of findings encouraged the learner with visual impairment to be socially aware and to practice social negotiation in problem solving. Interestingly, students in this study expressed a preference for inquiry-oriented activities rather than text-book based instruction, indicating *I learned more when I did my own observations of the moon, I had fun learning, I think science is fun now,* and *I wish science class was like this all the time.*

Implementing guided inquiry practices often requires substantial changes made by the teacher and students (Crawford, 2007), and teacher change may be more challenging when students with visual impairment and additional disabilities are involved. Anecdotally, educators of students with disabilities report use of traditional teaching strategies (i.e., text-book based, lecture format) more often than inquiry-based approaches to instruction (Scruggs et al., 1993) and this traditional format is assumed to be the preferred instructional technique of educators of students with visual impairment. An inquiry-based learning environment involves both a change in teaching practice and a change in traditional teaching roles. Therefore, professional development is essential for assisting educators in moving from traditional roles and practices to inquiry-based roles and practices.

Based on the results of this study, professional development opportunities are suggested in the following areas: (1) guiding students in the practices of inquiry (i.e., observing, collecting data, keeping records, sharing information), (2) how to develop appropriate verbal and written supports to facilitate student learning and understanding, (3) the use of discursive practices (i.e., discussions, science notebook writing), and (4) appropriate accommodations and adaptations for students with visual impairment and additional disabilities to fully participate in the learning community.

## Limitations of the Study

Results of the collective studies are limited by the sample of students involved and should not be seen as representative of all students with visual impairment. Demographic information presented in the first manuscript along with supporting descriptions of the participating students should assist in determining the applicability of the findings to similar contexts.

The students attended a specialized school for the blind and visually impaired and four students and their teacher were purposefully selected to participate. To extend the findings of this study, replication of the study should be considered in multiple specialized schools for students with visual impairment and blindness, inclusive classrooms in public school systems, and with larger populations of students with visual impairment. Additionally, a comparison between students participating in a traditional approach to instruction (i.e., textbook; lecture format) and students participating in an inquiry-based approach to instruction would provide further support for the results of this study.

Another limitation to the studies may be that the GIsML approach to instruction (Palincsar et al. ) was modified and adapted to best meet the needs of the learner with visual impairment. However, multiple forms of data were used to assist in analyzing the effectiveness of the guided inquiry approach including classroom observations, student artifacts, and student interviews.

In reference to the second manuscript, questioning behavior of students depends largely on the particular classroom and instructor; therefore, the results reported reflect the interactions between the researcher-instructor and the students participating in this study. Another limitation is that the questions posed by the researcher-instructor and the influence of these questions on student interactions are not addressed. The questioning behavior of students should be interpreted in terms of the instructor's behavior. For example, if the instructor asks more questions of a certain type, do students ask the same types of questions?

Furthermore, student interviews were captured using video recording methods; however, the students did not review the transcribed videos for accuracy of their responses. The researcher believed that having students review their responses throughout instruction would have influenced students to modify or change their responses based on their understanding as instruction progressed. The purpose of the interviews was to capture students' thinking in the moment and to compare the students' progress before, during and after instruction. Therefore, changes made to the transcribed interviews would have influenced the results.

A further limitation is the possibility of researcher bias. The researcher-instructor was a former teacher of the visually impaired and worked with children with visual impairment for 15 years. Researcher bias is a plausible threat to validity. However, an informal description of the researcher-instructor's background in educating children with visual impairment was provided to students to help ameliorate potential researcher bias.

Despite the limitations presented, the results of the collective studies are valuable because this is the first attempt to examine how guided inquiry-based instruction may best support students' with visual impairment learning and understanding in the context of science instruction.  The findings will be of interest to educators in all fields who are concerned about how students with visual impairment learn best.

## Future Directions

This study is the first to examine the experiences and outcomes of students with visual impairment as they participated in a guided inquiry-based learning environment.  As a result, several questions emerged requiring additional investigation.  The questions are explored below in the context of the three manuscripts.

In the first manuscript, the initial experiences of students with visual impairment as they participated in a guided inquiry-based science classroom were examined.  Educational researchers necessitate the need for research-based instructional practices for all students, emphasizing inquiry-based instructional strategies (NRC, 2000).   Research about the experiences of students in general education classrooms supporting the use of inquiry-based learning environments is abundant and the literature base about inquiry-based instruction for students with disabilities continues to increase.  However, research about inquiry-based learning for students with visual impairments is extant in the literature. Additional research is needed to examine the components of inquiry-based instructional strategies and how these strategies can best support students' with visual impairment learning and understanding in the science classroom.

In the second manuscript, the researcher examined the discursive practices of students with visual impairment in the inquiry-based classroom, specifically the frequency and types of questions students generated and the instructor supports necessary to support students' written communication (i.e., science notebook entries). Further research is needed to address the influence of the instructor's behavior on the questioning behavior of students. For example, if the instructor asks more questions of a certain type, do students ask the same types of questions? Furthermore, the researcher found that students with visual impairment asked questions to focus and clarify ideas within the learning community. Research attempting to replicate these results is necessary to validate these findings and to demonstrate that students with visual impairment ask questions for more than to seek information or to establish verbal contact within the classroom context.

The written communication of students with visual impairment to support learning and understanding is extant in the literature. Further research is imperative to support educators in the writing instruction for students. For example, this researcher discovered three specific types of supports were needed to guide students in the task of writing including functional supports, metacognitive supports and interpersonal supports. What additional categories of supports may be necessary for the learner with visual impairment when participating in general writing tasks and discipline-specific writing tasks?

In the third manuscript, the researcher-instructor examined the conceptual understandings of students with visual impairment following guided inquiry-based instruction about lunar phases. Questions emerged that could be addressed by further research. The students in this study exhibited alternative conceptions about lunar phases before inquiry-based instruction. Driver (1981) emphasized the importance of recognizing students' preconceived notions of science concepts. Therefore, knowing and acknowledging the alternative conceptions of students with visual impairment in astronomy topics and other science domains is imperative for implementing effective instruction. Furthermore, although the findings illustrated positive conceptual change in scientific understandings about lunar phases for students with visual impairment, additional measures (i.e., longitudinal follow-up student interviews) could be conducted to determine students' retention of knowledge about lunar phases.

As a collective study, the researcher worked with middle school students from a specialized school for the blind and visually impaired. Additional research is needed with students with visual impairment from a variety of grade levels and instructional settings (i.e., specialized settings, public school settings, inclusive settings, resource room settings) to examine how students with visual impairment and individual differences learn best.

# Conclusion

Researchers in all fields of study have examined extensively how students learn. The general consensus is that students learn best from opportunities that actively engage them in exploring and questioning the physical world. For students with visual impairment, learning through use of the senses, exploring objects to advance understanding, questioning discoveries, and testing discoveries are assumed to be a natural occurrence. However, there are very few descriptions of inquiry-based classrooms that involve students with visual impairment and address best practices for learning. This study considered both to provide a picture of the interplay between instructional practices and student learning in a guided inquiry-based learning environment with middle school students with visual impairment. The purpose of the study was to describe the experiences and outcomes of students with visual impairment in a guided inquiry-based science classroom and to identify the opportunities presented to and the challenges faced by students. Additionally, the study characterized inquiry-based instructional strategies as best practice for students with visual impairment and connected these practices to student learning of a challenging astronomy unit.

Overall, findings contribute to the need for classroom-based information about the value of inquiry-based approaches to instruction and the learning of students with visual impairment. Findings showed that student learning was enhanced when the instructor guided students in accomplishing complex tasks and in making sense of their observations and findings.  Findings also demonstrated that active student participation, appropriate instructor accommodations for written and verbal communication, and shared understandings between peers were essential to helping students learn. As illustrated in this study, by engaging students with visual impairment in strategies that advance their learning within an authentic learning community, educators will increase students' conceptual understanding, spark further interest about the world, and provide new avenues for students' futures.

# APPENDIX A: PLANETARY SCIENCE UNIT

A. Introduction: The Planetary Science Unit will be used to help students investigate and study Earth, Moon, and Sun systems. Students will gain an understanding of the lunar phases, day and night, and causes of the seasons.

B. Student Outcomes Adapted from FOSS and National Science Education Standards

   a. Students will identify questions that can be answered through observations and use of student-created models.
   b. Students will use appropriate tools and techniques to gather, analyze, and interpret data.
   c. Students will design and craft models of the Earth, Moon, Sun systems
   d. Students will develop descriptions, explanations, predictions using evidence.
   e. Students will think critically and logically to make connections between evidence and explanations of the lunar phases.
   f. Students will communicate about their observations and understandings of scientific phenomena.
   g. Students will use mathematics in scientific inquiry.

h. Students will understand that scientific explanations emphasize evidence.
i. Students will understand the relationships between the Earth, Moon, and Sun.
j. Students will observe and record the moon’s changing appearance for at least a month.
k. Students will use models of the Sun, Moon, and Earth to explain lunar phases, day and night, and the causes of the seasons.
l. Students will recognize and analyze alternative explanations and predictions.
m. Students will develop an understanding of how people of various cultures have contributed to the advancement of science, and how major discoveries and events have advanced science.
n. Students will develop problem-solving, decision-making and inquiry skills, reflected by formulating usable questions, planning investigations, conducting observations, interpreting and analyzing data, drawing conclusions, and communicating results.

# APPENDIX B: COURSE MATRIX

| Synopsis | Science Concepts | Thinking Processes |
|---|---|---|
| | | |
| Where Am I? | *a map is a representation of a place or area<br>*frame of reference is important in describing locations on Earth | *observe the classroom and draw a map to represent the area<br>*relate information from different frames of reference |
| | | |
| Round Earth/Flat Earth | *curved surfaces create horizons which interrupt the line of sight | *use models to make observations, gather evidence, and draw conclusions about the shape of the Earth |
| | | |
| Day and Night | *the Sun is the light source in our system<br>*Earth rotates counterclockwise every 24 hours causing day and night | *use models to relate Earth's motions to the Sun<br>*describe/discuss/demonstrate the direction of the Earth's rotation |
| | | |
| Discover the Moon | *the Moon's appearance changes over the course of a 28-day period<br>*the Moon can be observed during different times of the day and night<br>*the Moon has a geography very different than that of Earth<br>*the Moon revolves around the Earth and rotates on its axis<br>*half of the moon is lit by the Sun at all times<br>*we see only a portion of the Moon from Earth | *observe and record the Moon's appearance for at least one month<br>*craft questions based on observations<br>*analyze observations<br>*create class observation chart of observed lunar phases<br>*use models to discuss observations, make predictions, and draw conclusions<br>*relate the origin of features of the Moon using Moon Myths |
| | | |

| | | |
|---|---|---|
| Seasonal change | *the Earth revolves around the Sun<br>*the Earth travels in an orbit<br>*the Earth's orbit is about the same distance from the Sun at all times | *predict and communicate questions about seasonal change<br>*describe observed seasonal changes<br>*use models to describe the Sun, Moon, Earth systems and the relationship to seasonal change |
| | | |

# APPENDIX C: ASTRONOMY PRETEST/POSTTEST

Name______________________

Date____________________

Multiple choice–– Choose the best answer.

1. Why does the moon appear to move across the sky during the night?
a. It travels around Earth every day.
b. Earth rotates on its axis.
c. It is extremely far away.
d. All objects in space are moving.

2. What happens when you see the moon’s "phases" change? The moon appears to change
a. Color
b. Location
c. Shape
d. Distance

Use this diagram to answer the next two questions.

3. What phase of the moon would you see on this night?
a. Half moon
b. Gibbous moon
c. New moon
d. Full moon

4. How many days would pass before the moon was on the other side of Earth?
a. 7
b. 14
c. 21
d. 28

5. Why do we see phases of the moon during a month?
a. We see only the lit part of the moon as it moves around Earth.
b. We see only the parts of the moon that are always in shadow.
c. We see the eclipse of the moon that occurs nightly.
d. The moon is smaller when it is farther from us.

6. Which of the following would be a way to investigate the phases of the moon?
a. Watch all night.
b. Draw it every night for a month.
c. Measure the moon with a ruler.
d. Make measurements every Wednesday for a year.

7. Which of the following correctly describes the movement of Earth, moon and sun?
a. Moon revolves around sun, Earth revolves around moon.
b. Sun revolves around moon, moon revolves around Earth.
c. Moon revolves around Earth, Earth revolves around sun.
d. Sun and moon revolve around Earth.

8. What is the movement of Earth on its axis called?
a. Phases
b. Flotation
c. Revolution
d. Rotation

9. What is the movement of Earth around the sun called?
a. Precipitation
b. Random movement
c. Revolution
d. Rotation

10. What causes the apparent movement of objects across the sky during a day or night on Earth?
a. Revolution of Earth in its orbit
b. Rotation of Earth on its axis
c. Location of Earth in space

d. Objects are moving around Earth

11. If you watched the night sky for several hours, you would notice that the stars appear to be moving around
a. the North Star.
b. the Big Dipper.
c. the moon.
d. the milky way.

Use the following diagram to answer the next two questions.
The moon’s position lags behind every night by about thirteen degrees (this is roughly the width of your fist held at arms length). This amounts to being slower by about fifty-five minutes each night. Assume each dot on the diagram is thirteen degrees, and that the moon would take twenty-nine of these dots to complete one cycle.

12. If you stand at point X and the moon is at point B, when will it be at point A?
a. 13 days ago
b. In 16 days
c. In 24 days
d. In 6 days

13. If the moon is at point D below the horizon, how many days until it is at point C?
a. 16 days
b. 5 days
c. 2 days
d. 8 days

14. If the Farmers Almanac told you that the full moon was on April 5, 2008, which day in April of the same year would you most likely see a last quarter moon?
a. April 9
b. April 13
c. April 17
d. April 21

15. Which of these things would revolve rather than rotate?
a. An electric train running on a circular track.
b. A tire rolling down the road.
c. A top spinning on the floor.
d. A fan blowing air in a room.

16. Day and night are caused by
a. the sun and the moon moving across the sky.
b. the revolution of the earth around the sun.
c. the rotation of the earth on its axis.
d. the earth moving in and out of the moon's shadow.

17. Why does the air temperature rise in the summer?
a. In the northern hemisphere we are closer to the sun in the summer.
b. The air becomes thicker and more dense as the temperature goes up.
c. The sun's rays are more direct angle and the days are longer.
d. The ratio of the hours of daylight to the hours of night is reduced.

18. Why is it summer in the Southern Hemisphere when it is winter in the Northern Hemisphere?

a. The Southern Hemisphere is closest to the sun.
b. The Southern Hemisphere is receiving the most direct rays from the sun.
c. The Southern Hemisphere is in the path of warm winds from the equator.
d. The Southern Hemisphere is balancing out the temperatures for Earth.
19. What time of year is the sun farthest from the earth?
a. Winter in the Northern Hemisphere.
b. Spring in the Northern Hemisphere.
c. Summer in the Northern Hemisphere.
d. Fall in the Northern Hemisphere.

Use the diagram below to answer the next three questions.

QuickTime™ and a
decompressor
are needed to see this picture.

20. In which positions will the day and night hours be equal?
a. A and B
b. B and C
c. C and D
d. B and D

21. What season is it at point A in the northern hemisphere? Assume the north pole is on top.
a. Winter
b. Spring
c. Summer
d. Fall

22. What season would it be at point D?
a. Winter
b. Spring
c. Summer
d. Fall

23. In what month would Arizona have the greatest number of daylight hours?
a. January
b. June
c. September
d. December

Use this drawing of a lamp and a black piece of paper to answer the next two questions.

24. Which piece of paper would be the hottest after the light had shown on it for one hour? Assume that the papers were all the same distance from the light bulb.
a. A
b. B
c. C
d. D

25. What variable changed in the experiment shown above?
a. The amount of time the light shone on the paper.
b. The amount of energy the light bulb gave off.
c. The color of the paper.
d. The angle at which the light hit the paper.

26. Which of the following images shows the most correct angle of the Earth's axis relative to the sun?

QuickTime™ and a
decompressor
are needed to see this picture.

a. A
b. B
c. C
d. D

27. In what month would the sun's light strike Arizona at the lowest angle?
a. January
b. June
c. September
d. December

Open-response questions:

1. What is the shape of the Moon?
2. Explain in your own words what causes day and night.
3. Why do you think the air temperature rises in the summer?
4. Draw the Sun, Moon, and Earth as you view them in the sky. Explain your drawing.
5. What do you think causes the moon to appear to change shapes? Explain your thinking.

# APPENDIX D: SCIENCE ATTITUDE SURVEY

Gender: male female

Student ID number: ____________________

Age: ______________________
Grade: __________________

Primary language spoken at home: English Spanish
other: __________________________

What words come to mind when you think of a scientist?
Please circle the letter of the response that best describes what you think about each statement.

| | Strongly agree | agree | neutral | disagree | Strongly disagree |
|---|---|---|---|---|---|
| 1. I think being a scientist would be exciting. | a | b | c | d | e |
| 2. I would rather listen to someone talk about science than read a science book. | a | b | c | d | e |
| 3. I like to watch TV shows about science. | a | b | c | d | e |
| 4. I think science is important only at school. | a | b | c | d | e |
| 5. I would rather use computers to learn about science than read a science book. | a | b | c | d | e |
| 6. Science tests are easier than other tests. | a | b | c | d | e |
| 7. I learn more from doing experiments than from listening to the teacher's explanations. | a | b | c | d | e |
| 8. Science is fun. | a | b | c | d | e |
| 9. I like to use science equipment to study science better than reading science books. | a | b | c | d | e |

| | | | | | |
|---|---|---|---|---|---|
| 10. I usually try my best in science class. | a | b | c | d | e |
| 11. If I don’t understand a science topic I read about it. | a | b | c | d | e |
| 12. I like to figure out something without the teacher telling me how to do it. | a | b | c | d | e |
| 13. Reading books is my favorite way to learn about science. | a | b | c | d | e |
| 14. I would do well in science if I took it next year in school. | a | b | c | d | e |
| 15. We learn about important things in science class. | a | b | c | d | e |
| 16. Science class activities are exciting. | a | b | c | d | e |
| 17. I am interested in many scientific ideas that are not taught at school. | a | b | c | d | e |
| 18. I know where to find answers about science questions. | a | b | c | d | e |
| 19. I feel comfortable asking questions about science. | a | b | c | d | e |
| 20. I know how to set up a scientific investigation. | a | b | c | d | e |

# APPENDIX E

## DATA COLLECTION FORM

*Frequency of Students' Questions, Condition Question Occurred, Level of Question*

| Date/Time | Number of Students' Questions ( / = 1 event) | Condition in which Question Occurred (L, R, GD, SG, PC) | Level of Question (to be coded following observation) |
|---|---|---|---|
| | | | |

L – Lecture
R – Recitation
GD – Guided Discussion
SG – Small Group
PC – Peer Collaboration

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