The Mediating Effects of Science Classroom Talk on the Understanding of Earth-Sun-Moon Concepts with Middle School Students Who are Deaf or Hard of Hearing

Dissertation

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By

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ABSTRACT

The purpose of this study was to describe middle school DHH students’ understandings (and/or misconceptions) of the Earth-Sun-Moon relationship before and after completion of a 10-day instructional unit and to examine the change in understandings from pre- to post-instruction. Analysis focused on students’ conceptual understandings both before and after participation in an instructional unit on the Earth-Sun-Moon relationship. Data from classroom observations conducted during instruction were analyzed to determine the influence of classroom talk on students’ understanding of concepts. The influence of teacher perceptions was also addressed as a potential factor in student learning.

Prior to receiving instruction, the majority of students possessed an alternative or fragmented understanding of the Earth-Moon-Sun relationship and lunar concepts. Results from the measure of students’ knowledge of the Earth-Moon-Sun relationship on the three component questions (Earth-Moon-Sun relationship, gravity, patterns of orbit) indicated a moderate degree of conceptual change. Results from the measure of students’ understanding of lunar concepts showed a greater gain in conceptual understanding than was shown on the Earth-Moon-Sun relationship measure.

Consistent with the findings of previous research by Molander et al. (2007, 2010), ambiguity in the scientific meaning of the classroom dialogue or misconceptions arising from the use or omission of a particular term in sign language were found to have an
effect on students’ learning. Analysis of the scientific classroom talk that occurred during instruction showed that the teacher maintained a high level of control over the discourse. Data from pre- and post-instruction interviews with the teacher provided insight into her perceptions of her students’ abilities. The teacher expressed her perception of her students as largely dependent learners, which seemed to have an effect on how she delivered instruction. The teacher’s perception of her students’ ability to engage in a productive dialogue may have resulted in a greater level of teacher control over classroom talk.
Dedicated to my teachers, students, friends, and family of choice in the Deaf World.

Your imprint is forever on my heart and in my work.
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CHAPTER 1
INTRODUCTION

The pursuit of scientific knowledge has propelled humanity to levels of understanding, innovation, and invention once never thought possible (International Space Exploration Coordination Group, 2013). Yet, the learning of science topics and advancements is a complex endeavor, and has been described as a process of apprenticeship into the ideas and language of the scientific community (Lemke, 1990).

The exploration and understanding of the phenomena of our solar system is one area of strong scientific focus. The topic of the solar system is an integral component of the science curriculum, and the focus of state and national achievement standards (National Research Council, 2012; Ohio Department of Education, 2011). Students in kindergarten through high school learn about our planet and how it fits into the solar system.

Wertsch (1991) defined official science as the language of science “explicitly taught in the formal curriculum” (p. 135). In the science classroom, students are expected to shift from using informal, everyday language to academic, scientific language which includes the use of specialized scientific vocabulary and procedural explanations (Gee, 2004; Lemke, 1990; Wallace, 2004). It is often assumed that students will acquire this specialized discourse through interactions and experiences with teachers and peers in the classroom (Gee, 2004; Lemke, 1990, 2004; Wallace, 2004; Wellington & Osborne, 2001). However, for students whose sociocultural or language backgrounds
diverge from that of “traditional” students, such as for students with disabilities, students from language backgrounds other than English (LBOTE), or students who are deaf or hard of hearing (DHH), the acquisition and skilled use of scientific discourse is a more complex endeavor.

Learning the science classroom discourse for students who are DHH is equally if not more complex than that for other underrepresented student populations. Many students who are DHH experience restricted access to language from birth as a result of their hearing loss; therefore, language acquisition and the subsequent learning and cognitive development that are mediated by language are profoundly affected. Students who are DHH have been frequently characterized as dependent learners (Lang et al., 1999; Marschark, Lang, & Albertini, 2002), e.g., individuals who rely on explicit directions and guidance without taking ownership of their own learning (Kahn, Feldman, & Cooke, 2013; Lang et al., 1999). Further discussion on the dependent learning style versus other learning styles is included later in this paper.

A substantial body of literature documents that students with disabilities in middle school science classes often perform at levels significantly lower than those of their non-disabled peers (Mastropieri et al., 2006; National Transition Study 2 [NLTS2], 2010). According to publically available data from one important study of student achievements (NLTS2, 2010), of the national sample of 5,222 secondary special education students, nearly 61% were performing in the lowest 25th percentile of science assessment achievement test scores. Approximately 34% of students’ scores were in the 26th to 75th percentile range, while only 5.5% of secondary special education students’ performance was in the 76th percentile or above.
Although many improvements have been made in the area of accountability and equity for special education, achievement gaps persist between the science proficiency of students in special education and the science proficiency of students without disabilities (NRC, 2012). Cawley, Hayden, Cade, and Baker-Krooczynski (2002) emphasized the need to align the science curriculum more closely with the needs of students with disabilities. Moreover, the reading level of science textbooks is often beyond the comprehension abilities of students with special needs, making these materials inaccessible and ineffective tools for learning (Mastropieri, Scruggs, & Graetz, 2005).

Students who are DHH do not fare much better in science achievement compared to those receiving other special education services. The achievement test scores of students who are DHH are consistently lower than the scores of their hearing peers in all academic areas, including science (Mitchell & Kartchmer, 2008; Moon, Todd, Morton, & Ivey, 2012; Qi & Mitchell, 2012). Of the 5,222 special education students represented in the National Longitudinal Transition Study 2 (NLTS2, 2010) cited above, 573 students’ primary disability categorization was deafness. Of these 573 students, nearly 71 had science achievement test scores in the 25th percentile or below, which is notably higher than the 61% reported for the whole special education cohort. Only 4.9% scored in the 76th percentile or higher, which is notably lower than the 5.5% for the larger cohort and thus completes a picture of much poorer performance for the DHH student population. It has been suggested that DHH students’ difficulties with science learning are a result of limitations with scientific vocabulary and discourse (Molander, Hallden, & Lindahl, 2007, 2010), vast gaps and differences in individual prior knowledge (Molander,
Pedersen, & Norell, 2001), and a lack of consistency in the vocabulary of science in sign language (Lang et al., 2007).

**Purpose of the Study**

The purpose of this study was to describe middle school DHH students’ understandings (and/or misconceptions) of the Earth-Sun-Moon relationship before and after completion of a 10-day instructional unit, and to examine the change in understanding from pre- to post-instruction. Data from classroom observations conducted during instruction were analyzed to determine the influence of classroom talk on students’ understanding of concepts. The influence of the teacher’s perceptions of her students on the structure and content of the classroom discourse is also addressed as a potential factor in student learning.

The goal of the present study is to build an evidence-base for effective practices in the science education of students who are DHH, and to provide insights into the ways classroom talk and teacher perceptions affect learning outcomes. The application of conceptual change theory to instructional practices has been shown to facilitate learning of scientific concepts by addressing and correcting students’ misconceptions. No previous research has been found which was conducted in the area of conceptual change with students who are DHH. The application of conceptual change theory to the science learning of students who are DHH is a starting point from which to begin building an evidence base for effective practices.

**Rationale for the Study**

Research in the area of science education has become increasingly driven by standards-based reform (NRC, 2012). According to the U.S. Department of Education,
many schools previously adopted experimental lessons and materials that were later proven effective rather than relying on available evidence-based instructional practices (U.S. Department of Education, 2003). Accordingly, empirically-supported, scientifically-based teaching methods are now required under the most recent legislation. Teachers must provide instruction that addresses the learning objectives and benchmarks outlined in their state’s academic content standards.

Research on the education of students who are DHH has historically focused on the topics of language and literacy development (Marschark & Hauser, 2008; McIntosh, Sulzen, Reeder, & Kidd, 1994). As such, there is a dearth of research on teaching and learning outcomes in science, technology, engineering, and mathematics (STEM) education. According to a literature review by Wang (2011), research investigating the science learning of DHH students is sparse. In fact, Wang (2011) was only able to identify 12 empirical studies since the 1970s that investigated the impact of inquiry-based instruction on the science learning of students who are DHH that have been conducted since the 1970s.

There are several barriers to providing teachers of students who are DHH with evidence-based practices in science education. One of these barriers is the difficulty in conducting rigorous experimental research with this population due to the low incidence of deafness/hearing loss in the overall student population (Lang & Albertini, 2001). According to the U.S. Department of Education (2011) statistical data, approximately 78,000 DHH students were served under the Individual with Disabilities Education Act (IDEA) during the 2008-2009 school year, which is only 1.2% of the total number of students receiving special education services. As Lang and Albertini (2001) noted,
obtaining large sample sizes and utilizing traditional quantitative methodologies can be very difficult when conducting research with students who have low-incidence disabilities.

Deafness is a low incidence disability, occurring in approximately one to three infants per 1,000 born in the United States (Anderson, 2005). There is a great deal of heterogeneity within this small population across characteristics such as degree of hearing loss, primary language, and parental hearing status (Mayne Yoshinaga-Itano, Seedey, & Carey, 1998). An individual’s degree of hearing loss can be categorized into one of five audiological categories (Paul, 2009): slight (27-40 dB); mild (41-55 dB); moderate (56-70 dB); severe (71-90 dB); and profound (>91 dB). As Paul (2009) explained, “the term hard of hearing is also used to represent individuals with degrees of impairment from slight to severe, whereas deaf is used for individuals in the severe to profound range” (p. 13, italics original).

The term deaf or hard of hearing, DHH, as used here, is used to mean a hearing loss in the mild to profound range; a student who is DHH is one whose hearing loss must be considered as a factor in educational planning and instructional design. Additionally, because the participants in this study are all sign language users, and because their instruction is conducted in American Sign Language, the research reviewed here predominantly focuses on DHH students who use sign language. This is not to suggest that other methodologies and communication modalities within deaf education research are irrelevant; however, a review of such is outside the scope of the present study.

To date, no science curriculum materials have been published that specifically address the unique learning needs of students who are DHH (Jones, 2014). The lack of
research into the science learning of students who are DHH prevents the teachers of these students from providing evidence-based instruction. Teachers often adapt curriculum materials to meet the perceived linguistic and conceptual needs of their DHH students, resulting in a lack of consistency across grade levels and conceptual domains, and the creation of materials that are too watered-down or simplified (Lang, 1994). Students who are DHH often cannot meaningfully and successfully understand the science curriculum; therefore, they cannot learn science concepts at a level commensurate with their hearing peers.

The theoretical framework of this study combines constructivist and sociocultural approaches; the research questions draw from theories of conceptual change and mediated learning. The conceptual framework of this study utilizes the constructs of classroom talk, described here as a mediator of learning, and teacher perceptions, specifically, how these relate to instructional decisions and learning outcomes. For these reasons, the main line of inquiry for the study is the role of science talk and the information contained within this talk—which occurs both in the classroom during instruction, and in student and teacher interviews—in the conceptual change of middle school students who are DHH.

Constructivism is the dominant learning theory that has guided the development of science teaching and learning standards in the United States since the beginning of standards-based reform in the late 1990s (Naylor & Keogh, 1999). The central principle of constructivism is that "learners can only make sense of new situations in terms of their existing understanding" (Naylor & Keogh, 1999, p. 93). Grounded in the Piagetian tradition, constructivist theories of education reflect the belief that learning takes place
when new knowledge is actively assimilated and accommodated into existing knowledge. Piaget (1970) stated, "...one sees no ground why it should be unreasonable to think it is ultimate nature of reality to be in continual construction instead of consisting of an accumulation of ready-made structures" (pp. 57-58).

Conceptual change theory is naturally embedded in the constructivist belief that knowledge construction, or the learning of new ideas, involves building new concepts onto existing conceptual structures (Duit, 1999). From this perspective, an individual’s understanding of reality is constantly being revised and re-constructed through time and with exposure to new experiences. Conceptual change theory holds that certain aspects of learning and development are domain-specific and theory-based, and proponents view learning as a process of either enriching or restructuring existing knowledge (Vosniadou, 2007; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001). The process of conceptual change is gradual and is influenced by both the internal cognitive processes of the individual learner as well as the socio-cultural context in which learning occurs (Vosniadou, 2007).

Within the framework of constructivist philosophy, the primary goal of science instruction is to instantiate conceptual change. Morton (2012) asserted that the multidimensional view of conceptual change that combines epistemological, ontological, and social/affective elements suggested in previous research (e.g., Duit, Treagust, & Widodo, 2008; Treagust & Duit, 2008; Venville & Treagust, 1998) does not account for “the critical role of discourse and dialogue in bringing about changes in learners’ understandings” (Morton, 2012, p. 102). According to Morton (2012), dialogic interaction between teacher and student is a necessary step in “mediating shifts in
students’ understandings of natural phenomena from more ‘everyday’ to more scientific conceptions” (p. 102). The research of Morton (2012) and others (Mercer, 2008; Mortimer & Scott, 2003) highlights the role of classroom talk in the process of conceptual change, both as a way to elucidate students’ existing conceptions (or misconceptions) and as a means for teachers to facilitate a shift toward correct conceptions through dialogic interactions with students.

The contribution of teacher-related variables to student achievement outcomes has been the focus in a considerable body of research. Such studies have evaluated the nature and influence of teachers’ perceptions and beliefs, such as their view of the pedagogical philosophies that shape instructional design (Minor, Onwuegbuzie, Witcher, & James, 2002). The two philosophies or views of teaching that are discussed most often in the literature are transmissive and progressive. As the term suggests, transmissive educators are primarily concerned with knowledge transmission and tend to provide sequenced, subject-centered instruction that is focused on the mastery of discrete skills and knowledge (Minor et al., 2002). Conversely, progressive educators tend to provide instruction that is holistic and student-centered, and that aims to help students develop independent problem-solving and critical-thinking skills. Students in a progressive teaching environment are likely to be engaged in active learning that links their everyday experiences with curricular content and concepts (Minor et al., 2002). Progressive teaching is often associated with constructivist theories of education.

In order to support students’ acquisition of the language of science, teachers need to be aware that the domain-specific language of science contains specialized vocabulary and ways of speaking that are difficult for some students to master. The language of
science is comprised of more than just vocabulary, however; it involves the “concepts, conventions, laws, theories, principles, and ways of working of science” (Mortimer & Scott, 2003, p. 12). The laws and theories that form the basis for science and scientific understanding are products of the work of the scientific community and have been established over time through a process of social validation. Accordingly, it is the responsibility of the science teacher to be aware of the existing and emerging understandings of students, to attend to the ways students are talking about these understandings, and to incorporate students’ lived experiences as part of this apprenticeship (Mortimer & Scott, 2003).

**Research Questions**

The following research questions were the focus of inquiry and analysis for the present study:

1) What are seventh-grade DHH students’ pre-instruction conceptions of the relationship between the Earth, Moon, and Sun?

2) How do seventh-grade DHH students’ post-instruction conceptions of the Earth-Sun-Moon relationship differ from their pre-instruction conceptions?

3) How does classroom talk influence changes in seventh-grade DHH students’ understanding of Earth-Sun-Moon concepts?

4) How does the teacher perceive the effectiveness of her instruction?

**Significance of the Study**

The academic achievement of students who are DHH is consistently delayed compared to that of hearing students in all academic areas, including content-area subjects such as science (Mitchell & Kartchmer, 2008; Moon et al., Todd, Morton, &
Ivey, 2012; Qi & Mitchell, 2012). Teachers of students who are DHH must possess an impressive array of abilities in order to effectively address the needs of their students. Teachers are faced with what often seems to be an insurmountable task—creating an environment that facilitates the development of a first language (sign language) for many of their students, while simultaneously addressing the individual needs of each student and providing instruction on grade-level curriculum standards. Implicit to the instruction of academic content is the expectation of science literacy skill development. Science literacy is a necessary and fundamental part of the education and intellectual development of students who are DHH; however, because many students who are DHH have limited to no prior knowledge or understanding of basic scientific concepts or vocabulary, the efforts of teachers typically produce minimal gains (Lang, 1983, 1994; Vosnagoff, Patsch, & Toe, 2011).

Deaf education, as a whole, has yielded little significant progress in the improvement of science achievement outcomes in the last 40 years (Lang, 1983, 1994; Mitchell, 2008; Qi & Mitchell, 2012; Vosnagoff et al., 2011). Moreover, minimal research has been conducted in this area. For example, Wang (2011) presented a review of the empirical research conducted between 1970 and 2010 that addressed science instruction with DHH students, focusing on studies that emphasized inquiry-based instructional approaches. The studies that were included in the Wang (2011) review were chosen if they: (a) examined the science instruction, learning, or performance of kindergarten through high school (K-12) DHH students; and (b) were empirical in nature. In the 40 years of research reviewed, only 12 studies were identified that met these criteria.
As such, the goals of this study are to: (a) begin to build an evidence-base for effective practices in science education of students who are DHH by describing students’ misconceptions; (b) provide insights into the ways classroom talk and teacher perceptions affect student conceptual change; and (c) provide recommendations for ways classroom teachers can most effectively utilize classroom talk to maximize the learning of their students.
Definition of Terms

**Alternative conception** – an understanding of a concept that does not align with scientifically accepted norms (Atwood & Atwood, 1996; Trundle, Atwood, & Christopher, 2007a; Trundle, Atwood, & Christopher, 2007b; Trundle et al., 2006; Wild, 2008)

**Classroom talk** – dialogic interaction that contributes to the development of meaning in the classroom context (Mortimer & Scott, 2003)

**Conceptual change** – a shift in understanding that occurs as a result of the “gradual modification of one’s mental models of the physical world” (Vosniadou, 1994, p. 46)

**Construction of meaning** – the “use of language and experience to come to an understanding of an abstract principle” (Lang & Albertini, 2001, p. 262)

**Deaf or hard of hearing (DHH)** – a hearing loss in the mild to profound range of measurement

**Everyday (e.g., knowledge, talk)** – commonly denotes qualities of human activity or thought including informality, subjectivity, ambiguity, and improvisation; often considered the opposite of “scientific” (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001, p. 530)
**Mediated learning** – a reciprocal and meaningful interaction between a learner and a mediator (e.g., teacher, parent) during which the mediator shows the learner how to assimilate new information by drawing the learner’s attention to specific stimuli and by modeling cognitive processes (Feuerstein, 1980; Presseisen & Kozulin, 1992; Vygotsky, 1986)

**Misconception** – “pre-instructional conceptions and ideas about the phenomena and concepts to be learned that are not in harmony with science views” (Duit et al., 2008, p. 1). These conceptions and ideas are often robust and resistant to change

**Scientific (e.g., knowledge, talk)** – commonly denotes qualities of human activity or thought including formality, objectivity, precision, rationality, and detachment; often considered the opposite of “everyday” (Warren et al., 2001, p. 530)

**Scientific understanding** – an understanding of a concept that reflects all elements of its accepted scientific definition (Trundle, Atwood, & Christopher, 2002; Wild, 2008)

**Student who is deaf or hard of hearing (DHH)** – one whose hearing loss must be considered as a factor in educational planning and instructional design
Organization of the Study

This study is presented in five chapters. Chapter 1 contains the introduction, purpose, and rationale of the study, and presents the research questions, significance of the study, and definitions of key terms. Chapter 2 contains a review of the research literature relevant to the study. In Chapter 3, the research methodology and procedures utilized in the study are presented. Data are presented and analyzed in Chapter 4. Finally, Chapter 5 presents a discussion of the findings and the conclusions of the study, limitations of the study, and implications and recommendations for future research.
CHAPTER 2

REVIEW OF THE LITERATURE

Every time we communicate, new concepts compete with preconceived ideas…All students hold these ideas, but are unaware of their private theories. We must make them aware. Only then can we enable them to learn, and free them from their private universe. (Sadler, Schneps, & Woll, 1987, in Gooding & Metz, 2011)

The review of the literature begins with a discussion of conceptual change theory from three theoretical perspectives: epistemological, ontological, and motivational. Reviewed next is the literature on classroom talk and mediated learning, including a discussion of a framework for the analysis of classroom talk. Finally, a review of the research on teacher perceptions is presented, specifically detailing how teacher perceptions relate to instructional decisions and learning outcomes.

Conceptual Change Theory

Conceptual change theory originated from the study of students’ scientific misconceptions, or “alternative frameworks,” conducted by Posner, Strike, Hewson, and Gertzog (1982), who believed learning is a process of inquiry that requires students to assimilate new knowledge on the basis of available evidence. Posner and colleagues’ (1982) description of the process of learning provides a particularly valuable introduction to the fundamental underpinnings of conceptual change theory:
Learning is concerned with ideas, their structure and the evidence for them. It is not simply the acquisition of a set of correct responses, a verbal repertoire or a set of behaviors. We believe it follows that learning, like inquiry, is best viewed as a process of conceptual change. The basic question concerns how students’ conceptions change under the impact of new ideas and evidence. (Posner et al., 1982, p. 212)

Misconceptions, or “alternative conceptions,” are “pre-instructional conceptions and ideas about the phenomena and concepts to be learned that are not in harmony with science views” (Duit et al., 2008, p. 1); these conceptions and ideas are often robust and resistant to change. Identifying students’ misconceptions about a given concept and facilitating the correction of this to reflect an accurate, scientific understanding is the central instructional objective of conceptual change.

According to Duit et al. (2008), conceptual change theory has been studied under several theoretical perspectives including epistemological, ontological, and motivational views. In the following sections, the fundamental principles underlying each perspective and their implications on the teaching and learning of science concepts are reviewed.

**The epistemological view of conceptual change.** Epistemology is a cognitive construct concerned with the nature and conceptualization of knowledge and knowing (Hofer & Pintrich, 1997). Epistemological beliefs refer to “how individuals come to know, the theories and beliefs they hold about knowing, and the manner in which such epistemological premises are a part of and an influence on the cognitive processes of thinking and reasoning” (Hofer & Pintrich, 1997, p. 88). The epistemic beliefs of both students and teachers are critical determinants of instructional effectiveness. More highly
sophisticated epistemological beliefs have been shown to correlate with an increase in academic achievement (Parasnis, 2012), and to directly and indirectly influence students’ conceptual change (Vosniadou, 2007).

The way a student approaches learning is directly influenced by his or her personal epistemological beliefs. Research has demonstrated that students who approach learning with the belief that knowledge is static—or that learning simply involves an accumulation of discrete, concrete bits of information—have more difficulty with learning and comprehension tasks (Stathopoulou & Vosniadou, 2007). Similar research shows that these students may also be less receptive to learning new information that conflicts with their established beliefs (Vosniadou, 2007). Conversely, students who approach learning with the belief that knowledge is complex, dynamic, and constantly evolving (based on the integration of ideas and active construction) “may be willing to ‘open up the grammatical space’ and allow new paradigms/theories to be seriously entertained” (Vosniadou, 2007, p. 10). This type of personal epistemology has been positively related in previous studies to comprehension, learning, academic performance, and conceptual change (Stathopoulou & Vosniadou, 2007).

In their seminal work on conceptual change in science learning, Posner and colleagues (1982) proposed that conceptual change occurs under four conditions: (1) one experiences dissatisfaction with a prior conception; (2) a new conception is offered that is intelligible; (3) the new conception is plausible, or, in other words, it is consistent with the individual’s prior knowledge and understanding; and (4) the new concept is accepted as a fruitful alternative to the competing conception (p. 214).
According to Posner et al. (1982), one’s “conceptual ecology” is the cognitive framework of concepts held by an individual; the structure and contents of this cumulative framework influences the probability of successful conceptual change. Vosniadou (1994) posed an epistemological, theory-based model of conceptual change that incorporates the conceptual ecology premise to describe how students acquire knowledge about the physical world. The underlying assumption of the Vosniadou (1994) model is that one’s conceptual ecology “operates on the basis of a small number of domain-specific constraints” (p. 46). Domain-specific constraints, or framework theories, are the innate presuppositions one holds about the physical world (e.g., gravity, solidity, inertia). These constraints relate to a specific theory, which, for the individual, “consists of a set of interrelated propositions or beliefs that describe the properties and behavior of physical objects” (Vosniadou, 1994, p. 47). Specific theories are developed through observation or upon encountering new information, under the constraints of the superordinate Vosniadou (1994) framework theory.

According to the Vosniadou (1994) theory, conceptual change occurs as a result of the “gradual modification of one’s mental models of the physical world” (p. 46) and is achieved either by enrichment or revision. Enrichment, the simplest form of conceptual change, occurs when one assimilates newly accumulated knowledge into an existing conceptual structure. Revision is required when new information is in conflict with existing knowledge. Revision, at the level of a framework theory, is more resistant to change as compared to that at the level of a specific theory. Therefore, misconceptions that are the result of “entrenched presuppositions” (Vosniadou, 1994, p. 63) within one’s framework theory are the most robust and require more time and instructional support to
correct than misconceptions at the simple theory level, which is before a conceptualization is formed.

Vosniadou and colleagues conducted a series of research studies focused on understanding the process of knowledge acquisition in the area of astronomy (Samarapungavan, Vosniadou, & Brewer, 1996; Vosniadou, 1991, 1992; Vosniadou & Brewer, 1992, 1994). In the context of these studies, conceptual change is seen as the product of a revision of students’ mental models; the aims of the research conducted by Vosniadou and Brewer (1994) were to define mental model processes and study how they are revised during the process of knowledge acquisition. In their study of elementary students’ mental models of the relationship of Earth and the Moon as related to the day/night cycle, Vosniadou and Brewer (1994) found that the majority of students’ mental models were coherent and well-defined, and that the number of models constructed by students was limited and predictive of other beliefs. They defined a mental model as “the kinds of mental representations we think individuals construct when they reason about the physical world” (p. 125).

Vosniadou and Brewer suggested students’ mental models can be grouped into three categories: “(a) initial models—models consistent with the observations based on everyday experience; (b) synthetic models—representing attempts to reconcile the culturally accepted, scientific explanation of the day/night cycle with observations based on experience; and (c) scientific models—models which agree with the scientific view” (Vosniadou & Brewer, 1994, pp. 168-9, italics original). Based on the results of this study, they concluded that students’ mental models are constrained by epistemological
and ontological presuppositions, and that the mental models operate simultaneously throughout the process of knowledge acquisition (Vosniadou & Brewer, 1994).

Recent research, however, has challenged the mental model theory of conceptual change. Fréde et al., (2011), for example, challenged the methods of mental model research (e.g., Vosanidou & Brewer, 1992, 1994), suggesting that flaws in the interview measure and in the analysis of data undermine the validity of this theory. Fréde et al. (2011) claimed that mental model theorists “have underestimated children’s knowledge of the Earth, and overestimated the coherence of their non-scientific concepts” (p. 443). Hannust and Kikas (2010) came to a similar conclusion after conducting a longitudinal study of young children’s conceptions of the Earth and gravity. Their results indicated that in most cases, the children’s knowledge was fragmented, and scientific knowledge was often coexistent with alternative conceptions (Hannust & Kikas, 2010). They did not find strong support for the claim that young children possessed naive mental models of Earth and gravity concepts (Hannust & Kikas, 2010).

The ontological view of conceptual change. Ontological beliefs were described as being concerned with “the fundamental categories and properties of the world” by Chinn and Brewer (1993, p. 17, in Duit et al., p. 632). According to Pauen (1999), conceptual knowledge from an ontological perspective is based on the process of categorization and is a product of an “interconnected set of causal beliefs about the nature of a given object” that results in “stable knowledge structures that include a coherent set of causal beliefs” (p. 15).

Ontological conceptual change is based on the postulate that an individual’s knowledge is organized in a hierarchical taxonomy of categories. In this view,
Ontological categories are the most general, abstract groupings; subsequent categories become more specified as these are continually sub-divided to the singular, concrete concept level. A concept is said to be “ontologically distinct” when an attribute of one category cannot be applied to any other category (Chi, Slotta, & de Leeuw, 1994). Categories within different trees differ on the ontological level, and categories within branches of an ontological tree are called “lateral,” or in “kind” (Chi, 2008). Conceptual change from an ontological perspective can be interpreted as “a continuous process of enriching knowledge about different classes of objects and re-evaluating the importance of specific aspects for determining category membership in a given situation” (Pauen, 1999, p. 31).

Chi (2008) suggested that eliciting conceptual change at the categorical level requires two instructional steps: (1) students must be made aware of their categorization error; and (2) students need to be supported in the creation of a correct category to which the new knowledge can be assigned. According to Chi (2008), there are three possible conditions of prior knowledge within which the process of learning a new concept can occur: (1) prior knowledge that is necessary for the learning of a new concept is missing, and thus, necessitates adding new knowledge; (2) prior knowledge about a to-be-learned concept is incomplete, requiring gap filling; and (3) existing prior knowledge conflicts with new knowledge, which requires changing the misconception to a correct conception. This third condition requires instruction geared toward learning of the “conceptual change kind” (Chi, 2008, p. 61). The nature of the conflict between misconceived knowledge and to-be-learned material should determine the course of instruction needed to trigger conceptual change (Chi, 2008). Robust misconceptions can be viewed on a
continuum with individual ideas or “false beliefs” at the lowest level and ontological or
categorical conflicts at the highest (Chi, 2008).

In this context, a “belief” is defined as a single idea. A false belief is an idea that
is in conflict with new knowledge. If a student’s idea is identified as a false belief,
instruction should aim to refute this belief and provide correct information in order to
create a “belief revision” (Chi, 2008, p. 66). This type of misconception is the most
readily addressed and revised. A “mental model” is a cognitive representation organized
to reflect individual ideas or interrelated concepts that correspond to the structure of an
external construct (Chi, 2008; Vosniadou, 1994). A “flawed mental model” is an
individual’s coherent but incorrect representation of a scientific model (Chi, 2008). The
underlying knowledge structures and beliefs that may be contributing to misconceptions
become apparent when a student is using a flawed mental model with which to assimilate
new information. Instruction that refutes false beliefs often results in belief revision
when a student is made aware of the contradictions in his or her model.

Misconceptions on the categorical, or ontological, level are almost always the
most resistant to change. As discussed previously, categorization is a critical factor in
conceptual understanding: if the nature of a misconception is related to a mistake in
categorization, conceptual change requires a shift across lateral or ontological categories
(Chi, 2008). “In contrast to incorrect hierarchical categorization, category mistakes are
damaging in that categorical inferences and attributions will be erroneous, creating a
barrier to correct learning with deep understanding” (Chi, 2008, p. 65). Integrating
conceptual change theory into classroom practice requires a great deal of attention and
planning on the part of the teacher and the active engagement of the student. In order to
identify and successfully change misconceptions, teachers must identify how the prior knowledge is misconceived and why the misconceived knowledge is resistant to change (Chi, 2008).

The motivational/contextual view of conceptual change. A growing number of researchers have advocated the importance of integrating the social and contextual aspects of conceptual change in addition to the cognitive characteristics central to the epistemological and ontological perspectives (Pintrich, Marx, & Boyle, 1993; Sinatra & Mason, 2008). From this perspective, factors such as student motivation and the social context of learning are equally critical to the attainment of conceptual change (Sinatra & Mason, 2008). Pintrich and colleagues asserted that, although there was merit to the original model of conceptual change of Posner and colleagues (1982), the absence of motivational and contextual factors diminished its utility and relevance to learning in the classroom context. They deemed the original model of conceptual change “cold” in reference to its “overly rational” (Pintrich et al., 1993, p. 167) view of student cognition. Pintrich (1999) stressed the crucial role of motivational beliefs “about the self as a learner” (p. 34) in deeper cognitive engagement.

According to Sinatra and Mason (2008), cognitive engagement (i.e., learning) can be viewed on a continuum, beginning with algorithmic processing (i.e., effortless or automatic knowledge acquisition) at the lowest level and ending with intentional conceptual change at the highest. Intentional conceptual change is the “goal-directed and conscious initiation and regulation of cognitive, metacognitive, and motivational processes to bring about a change in knowledge” (Sinatra & Pintrich, 2003, in Sinatra & Mason, 2008, p. 562) and requires an understanding that the nature of learning is a
multifaceted, interactive, and complex process (Sinatra & Mason, 2008). Intentional conceptual change involves a concerted effort on the part of students to be actively engaged in learning, which implies the need for a high level of motivation in order to succeed. Pintrich and colleagues (Pintrich, 1994, 1999; Sinatra & Pintrich, 2003; Sinatra & Mason, 2008) have suggested motivational beliefs can either facilitate or constrain conceptual change at the intentional level; these beliefs include students’ achievement goals, self-efficacy beliefs, and belief in personal control of learning.

Saçkes (2010) examined the ways motivational, cognitive, and metacognitive factors supported conceptual change in students who had preservice early childhood education teachers. Specifically, he investigated the effects of an intentional conceptual change learning model in relation to the use of metacognitive strategies, and the level of metaconceptual awareness, on participants’ conceptual understandings while they studied the scientific cause of lunar phases (Saçkes, 2010). The results of Saçkes’ (2010) study indicated that the use of deep-level cognitive strategies, such as those which facilitate the use of elaboration and organization strategies, facilitated participants’ conceptual change. Additionally, Saçkes found that participants in the study who demonstrated high levels of metaconceptual awareness were more likely to have coherent conceptual understandings, and were more likely to retain their scientific conceptual understandings long-term. Finally, Saçkes found that participants’ motivational beliefs, such as their belief in their ability to learn course content, their focus on understanding content, and the value they placed on mastery of course content, were significant predictors of the participants’ usage of cognitive and metacognitive strategies.
**Classroom Talk**

From the time they are born, children gather information from their environment through direct experience with stimuli (e.g., objects, events) as well as through interaction with others who use language and other semiotic tools to attribute meaning to objects, events, and emotions. When the convergence of language and activity occur at the individual level, language is used as a tool to mediate and contextualize learning (Vygotsky, 1978; Wertsch, 1991).

Vygotsky (1978) argued that the reciprocal relationship between early language development and everyday experience has one of the most significant influences on a child’s intellectual development. Mediated learning experiences involve the learner and the stimulus, along with a third party who essentially teaches the child *how* to assimilate the new information by drawing the child’s attention to specific stimuli and by modeling cognitive processes. The mediator—in many cases, the classroom instructor—helps the child make connections between concepts and properties, and teaches the child how to acquire meaning from the environment (Pagliaro & Kritzer, 2010). Effective classroom instruction thus depends on a teacher’s ability to successfully mediate the learning of their students. As Mercer and Littleton (2007) aptly stated,

> …language is without doubt the most ubiquitous, flexible and creative of the meaning-making tools available, and it is the one most intimately connected to the creation and pursuit of reasoned argument. Becoming an educated person necessarily involves learning some special ways of using language: and language is also a teacher's main pedagogic tool. (p. 2)
The acquisition of classroom language skills is a key part of students’ learning and requires students to become socialized into the ways of speaking that are associated with literacy in a given subject (e.g., science, mathematics, history) through participation in classroom talk. Wells (1996) suggested teachers serve a “transformative” (p. 83) role as they fulfill the role of apprenticing students into language practices on both a macro and micro level. On the macro level, the teacher’s role is to organize the curriculum according to the government’s required content, but also to suit students’ interests and levels of participation so that students are engaged in opportunities to master learning goals through genuine participation. At the micro level, Wells stated, “It is in the moment-by-moment co-construction of meaning, in the sequences and episodes of discourse through which these activities are realized, that the craft of teaching is found” (1996, p. 84).

Mediated learning. In his seminal works on the sociocultural nature of intellectual development, Vygotsky (1962, 1978) argued that mediated learning in the classroom is most fruitful when it occurs within a child’s zone of proximal development, or ZPD. The ZPD is marked by the difference between the child’s initial independent understanding or ability of a subject, and what the child is able to understand or achieve in that subject with support from others. Similarly, Vygotsky (1962, 1978) suggested that intellectual development begins with mediated learning and apprenticeship into ways of thinking and reasoning at the intermental (social) level, and then later through internalization and integration of this learning on the individual (intramental) level. In other words, “discussion, interaction and argument become internalized as the basis for intramental reflection and logical reasoning” (Mercer & Littleton, 2007, p. 12).
Building on Vygotsky’s works, Mercer (2002) hypothesized an “intermental development zone” (IDZ) in which mediated learning occurs. Mercer (2002) described the IDZ as “a dynamic frame of reference which is reconstituted constantly as the dialogue continues, so enabling the teacher and learner to think together through the activity in which they are involved” (p. 143). Mercer (2002) postulated that the creation and maintenance of the IDZ are dependent on a teacher’s ability to “create and maintain connections between the curriculum-based goals of activity and a learner's existing knowledge, capabilities and motivations” (p. 143).

Mercer and Littleton (2007) extended the original application of the IDZ to teacher-student mediated learning situations with their studies on collaborative learning and joint production of knowledge at the classroom level. Teaching that occurs within a collective IDZ, according to the authors (Mercer & Littleton, 2007), creates a community of inquiry that allows individual students to participate actively while also learning to work, think, and problem-solve collaboratively with others. This is critical, Mercer and Littleton reasoned, because “the cultural tool of language does not just mediate teaching and learning, it mediates the broader culture too. Thus careful consideration needs to be given to how children are inducted into ways of talking and working together” (Mercer & Littleton, 2007, p. 59).

**Critical moments in classroom talk.** Myhill and Warren (2005) studied the relationship between talking and learning during “‘critical moments’ in whole-class teaching contexts” (p. 55). Building on the Vygotskian view of language as a tool for creating meaning and scaffolding knowledge, Myhill and Warren (2005) defined a *critical moment* of classroom talk as “a discourse unit where the teacher’s utterance is
significant either in supporting the development of a child’s understanding or hindering it, or where an opportunity to build on a child’s response was missed” (p. 59). As previously discussed, one goal of this study is to assess the ways classroom talk can either restrict and control, or support and scaffold, students’ learning. Toward that end, Myhill and Warren’s (2005) analysis of 54 lesson episodes from primary and middle school classrooms in order to determine the effects of critical moments in classroom talk on student learning is of particular interest.

Analysis conducted by Myhill and Warren (2005) elicited three types of critical moments: (1) those which created confusion in learning; (2) those that carefully steered the discourse along a predetermined path; and (3) those that were responsive to student learning (p. 60). They (Myhill & Warren, 2005) found that the first two types were, by far, the most common in classroom discourse, and were indicative of a product/knowledge orientation to learning rather than to a process/understanding view. Myhill and Warren (2005) concluded that many teachers had “a teaching agenda, not a learning agenda” (p. 67) and that classroom talk was very often structured to “enable children to achieve a correct answer, to meet a particular curriculum objective” (p. 68). When teachers focus classroom talk on discrete concepts or ideas to the exclusion of students’ alternative views or knowledge, the control exerted by the teacher restricts their students’ ability to engage in independent learning and authentic meaning-making.

Science classroom talk. Sutton (1996) claimed that teachers use scientific language in two ways: as a labeling system, or as an interpretive system. According to Sutton (1996), language used as a labeling system is employed for describing, reporting and informing, and is “definite, precise, needing the right word for the right thing” (p. 6).
Conversely, language as an interpretive system is used to make sense of a new experience and is “tentative, imprecise at first, and flexible in trying different ways to capture the same idea” (Sutton, 1996, p. 6).

It was Sutton’s (1996) assertion that teachers who predominantly use scientific language as a labeling system are operating under the false belief that scientific language is absolute; this belief conveys to students an incorrect assumption about the nature of science. Portraying scientific knowledge as fact, according to Sutton (1996), reflects the assumption that words have fixed meanings and these meanings simply exist without the influence of human effort or an ongoing construction of meaning. On the other hand, when teachers use scientific language as an interpretive system, it models for students the “theory-constitutive” (Sutton, 1996, p. 6) properties of language. Language used in this way, as theory-constitutive, is “an active, flexible tool of thought” (Sutton, 1996, p. 6) that is able to shape one’s attention and intention in scientific investigation and reasoning.

Glen and Dotger’s (2009) findings were consistent with Sutton’s (1996) theories. They found that the three teacher participants in their study (Glen & Dotger, 2009) used the labeling system of language far more often than they used scientific vocabulary in an interpretive context. All three teachers in the Glen and Dotger (2009) study provided a similar rationale for their approach with regard to student learning goals: they felt it was important for students to know the meaning of science vocabulary in order to read textbooks and pass state-mandated standardized assessments. Glen and Dotger (2009) offered a counterpoint to this reasoning, stating, “Students must be provided with multiple exposures to both definitional and contextual information about vocabulary in order to truly learn it and use it in their reading, writing, and speaking” (p. 80). To
achieve learning, the authors suggested a balanced use of scientific vocabulary by both a labeling and an interpretive system so that students can be prepared to use the language of science in multiple contexts and for multiple purposes (Glen & Dotger, 2009).

**Classroom talk and language development.** Gibbons (2003) utilized the theoretical constructs of mediation (e.g., Vygotsky, 1981) and mode continuum (e.g., Halliday, 1993) to investigate the ways teacher-student talk in the science classroom contributes to students’ language development. She was primarily concerned with identifying the ways teachers’ interactions with students bridged the students’ current language abilities and commonsense or established science understandings with the desired level of academic discourse and specialist understandings of to-be-learned concepts (Gibbons, 2003).

The construct of a “mode continuum” conceptualizes language as a semiotic system of tools wherein students are expected to choose the appropriate register for the context of a given situation (Gibbons, 2003). Gibbons (2003) examined how mediation influenced learners’ ability to shift along a mode continuum, defining and measuring students’ learning as a shift in academic register along this continuum. It was hypothesized by Gibbons (2003) that an increase in learning would be indicated when the learning became less context-dependent.

Gibbons (2003) suggested that the success of mediation was predicated upon the presence of a contingency, described as a “closeness of fit” between teacher and student contributions. She concluded that successful mediation is more likely to occur when contingent interactions are challenging enough that students are exposed to new language
and learning contexts, but not so distal from the students’ base of understanding that they will not understand any of the teacher’s discourse.

**A framework for the analysis of classroom talk.** Mortimer and Scott (2003) developed an analytical framework for “capturing and characterizing the talk of school science” (p. 4). The authors researched how concepts are developed through language in the science classroom and, more specifically, determining how teachers make scientific concepts available while also identifying and exploring students’ ideas and guiding them towards scientific understandings (Mortimer & Scott, 2003). Four topics are relevant for consideration while planning for, engaging in, and analyzing science classroom talk: (1) teaching purposes; (2) content; (3) communicative approach; and (4) patterns of discourse (Mortimer & Scott, 2003). A discussion of each topic follows, below.

First, the teaching purposes identified by Mortimer and Scott (2003) are: (a) opening up the problem; (b) exploring and working on students’ views; (c) introducing and developing the scientific story; (d) guiding students to work with scientific ideas and supporting internalization; (e) guiding students to apply and expand on the use of the scientific view; and (f) maintaining the development of the scientific story.

The aspect of analysis concerned with the content of classroom talk, of second interest in Mortimer and Scott (2003), attends to the variety of ways concepts are discussed. According to the research (Mortimer & Scott, 2003), ideas expressed between students and teachers can be classified as toward either an everyday understanding or a scientific understanding of a given concept. Scientific statements can be categorized as descriptions, explanations, or generalizations, which are further distinguished as being either empirical or theoretical (Mortimer & Scott, 2003).
Third, the communicative approach identifies the ways in which students’ ideas are developed through their interactions with the teacher. Mortimer and Scott (2003) suggest that this aspect of the framework consists of four fundamental classes that indicate whether the approach is dialogic or authoritative, and interactive or non-interactive. (Figure 2.1)

<table>
<thead>
<tr>
<th></th>
<th>INTERACTIVE</th>
<th>NON-INTERACTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIALOGIC</td>
<td>A. Interactive/dialogic</td>
<td>B. Non-interactive/dialogic</td>
</tr>
<tr>
<td>AUTHORITATIVE</td>
<td>C. Interactive/authoritative</td>
<td>D. Non-interactive/authoritative</td>
</tr>
</tbody>
</table>

Figure 2.1. Four classes of the communicative approach based on dialogic, authoritative, interactive, and non-interactive factors. Reprinted from Mortimer, E. F., & Scott, P. H. (2003). *Meaning making in the science classroom*, p. 35. Copyright 2003 by Open University Press

The pattern of discourse refers to the pattern of interaction within the classroom talk that is established by the teacher. The most common pattern of classroom discourse is the three-part initiation-response-evaluation (IRE) sequence: teacher initiation, student response, and teacher evaluation (Cazden, 1987). This type of interaction occurs when the teacher controls the classroom discourse and the interaction tends to be authoritative in nature. Other possible patterns include the initiation-response-follow-up (IRF; teacher initiation, student response, and teacher follow-up) and initiation-response-follow-up-
response-follow-up (IRFRF; also known as elaborative feedback) sequences, which are discussed in more detail below.

**Teacher Perceptions**

Teachers are responsible for determining the structure of classroom talk, and the structure of classroom discourse inevitably influences the way it is “taken up” by students (i.e., if the instruction is effective). Lemke (1990) proposed that there are two patterns of science dialogue: an organizational pattern, and a thematic pattern. The organizational pattern of science dialogue is represented by its activity structure; in other words, “the structure within which teachers and students talk science in the classroom” (Lemke, 1990, p. 11). Thematic patterns are connections among the meanings of words in a particular scientific discipline and rely on an understanding of the semantic relationships between words and concepts (Lemke, 1990).

The most common pattern of classroom discourse, according to Cazden (1987), is the three-part IRE sequence mentioned in the previous section. This type of interaction occurs when the teacher controls classroom discourse, including what topic is being discussed and who gets the floor during the discussion (Cazden, 1987). Other types of interaction include IRF (teacher initiation, student response, and teacher feedback/follow-up) (Sinclair & Coulthard, 1975; Wells, 1993) and IRFRF (elaborative feedback) (Mortimer & Scott, 2003) sequences. Several researchers have suggested that the nature of the follow-up aspect in the IRF sequence either supports or restricts the co-construction of meaning (Chin, 2006). The decisions made by a teacher with respect to how control of discourse occurs and what it facilitates have a great deal of influence on how students access and assimilate knowledge.
**Teacher questioning and feedback.** Chin (2006) investigated the “communicative and cognitive functions” (p. 1320) of the follow-up aspect in the IRF sequence during science instruction. Extending the work of Mortimer and Scott (2003) and others (Carlsen, 1991; Wells, 1993), Chin developed an analytical framework to examine the ways teachers use questioning to foster thinking and support knowledge construction in science learning. The Questioning-based Discourse (Chin, 2006) analytical framework consists of four elements: content, type of utterance, thinking elicited, and interaction pattern (p. 1322). Chin’s (2006) analysis elicited a typology of teacher feedback to students’ responses that correspond to those that are correct, both correct and incorrect, or incorrect. The four types of feedback are: (1) Affirmation-Direct Instruction, which involves the teacher affirming and reinforcing the response, and then following up with further explanation and direct instruction; (2) Focusing and Zooming, or “extension by responsive questioning” (p. 1326) in which the teacher accepts the response and follows with a series of related questions to probe or extend conceptual thinking; (3) Explicit Correction-Direct Instruction, which involves an explicit correction of an incorrect response, followed by an elaboration on the correct scientific viewpoint; and (4) Constructive Challenge, in which the teacher responds with an evaluative or neutral comment followed by rephrasing of the same question or posing a more challenging question (Chin, 2006). See Table 2.1. Chin (2006) emphasized the importance of “teacher-led but not teacher-dominated” (p. 1343) discourse in science instruction that aims to foster inquiry and conceptual change.
Table 2.1.

*Types of Feedback to Students’ Responses (Chin, 2006, p. 1326)*

<table>
<thead>
<tr>
<th>Nature of student’s response</th>
<th>Type of feedback</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct</td>
<td>(a) Affirmation-Direct Instruction</td>
<td>Affirm and reinforce response followed by further exposition and direct instruction</td>
</tr>
<tr>
<td>Mixture of correct and incorrect</td>
<td>(b) Extension by responsive questioning: Focusing and Zooming</td>
<td>Accept response followed by a series of related questions that build on previous ones to probe or extend conceptual thinking</td>
</tr>
<tr>
<td>Incorrect</td>
<td>(c) Explicit correction-Direct instruction</td>
<td>Explicit correction followed by further expounding of the normative ideas</td>
</tr>
<tr>
<td></td>
<td>(d) Constructive challenge</td>
<td>Evaluative or neutral comment followed by reformulating the question or issuing a challenge via another question</td>
</tr>
</tbody>
</table>

Teacher-controlled science classroom talk can support or constrain the ways students respond to questions designed to assess their understanding. The two studies that follow serve as examples of the influence of teacher control on students’ ability to adequately represent their knowledge. First, a study by Edwards (1993) is offered as an illustration of the restrictive potential of teacher-controlled classroom dialogue on student learning. The second study, conducted by Crawford (2005), demonstrates how presenting science language in multiple ways can be a great benefit to students, particularly those who are outside of the mainstream norm.
**Teacher-controlled classroom talk that restricts student learning.** Concerned by the ways overly structured patterns of classroom discourse, controlled by the teacher, constrain students’ concept formation, Edwards (1993) argued for attention to *how* students think rather than to *what* they think when assessing scientific learning. Edwards presented an analysis of the functions of classroom talk in a kindergarten science classroom, examining how “patterns of discourse, of turn-taking between children and teachers, may play an important part not only in the social organization of talk but also in the nature of the conceptual understandings that are the content of talk” (p. 214).

Edwards (1993) emphasized the importance of viewing classroom talk as “situated action” (p. 217); in other words, in view of how the context of students’ responses to teacher-controlled discourse bears influence on how student cognition is validated.

To elucidate his point, Edwards (1993) provided the following example of the “dominant discursive orientation” (p. 214) (i.e., the level of teacher control) that was typical of the classroom in this study. After visiting a greenhouse and observing the activities of the gardener working there, students were asked to share what they had learned. Their responses, which were expected to follow the teacher’s predetermined structure, were recorded in a special book for the students about what had been observed. Students were not given the opportunity to engage in any discussion or other co-construction of understanding, but rather were explicitly forbidden from doing so.

When asked to provide her rationale for sanctioning students’ attempts to engage in authentic discussion, the teacher explained that everyone needed to have a turn, make a contribution, and hear what the others were saying (Edwards, 1993). This resulted in what Edwards called “a sequential accumulation of separate bits of knowledge” (p. 215).
for the students in the service of “the need for social orderliness, coherence, and discipline” (p. 215). This account illustrates a “divorcing of content and process” (p. 217) wherein variability in response, or a response that goes off-script, is not valued.

Edwards (1993) concluded with the assertion that, regardless of the structure of the student’s contribution (i.e., its adherence to the teacher’s pre-determined script), attention must be paid to the content and context in order to find evidence of underlying cognitive representations, developmental change, and conceptual growth.

**Teacher-controlled classroom talk that supports student learning.** The study of teacher-constructed discourse effects on student learning conducted by Crawford (2005) offers an illustration of how Edwards’ (1993) recommendations can be put into practice. Crawford (2005) examined the ways science students demonstrated their knowledge through the construction of communicative repertoire in grades four and five. In the context of this study, students’ learning is evidenced by the communicative competence they demonstrate. Crawford (2005) described communicative competence as “the ways students select from the communicative repertoire within a particular classroom to participate in appropriate ways” (p. 146). This study was primarily concerned with identifying opportunities that the classroom teacher constructed for students to demonstrate their knowledge across curricular content areas through the use of multiple discourses.

In a preliminary observation of a classroom, Crawford (2005) identified three types of discourse that were most commonly incorporated by the teacher: oral, visual, and written. Crawford (2005) concluded that, depending on the mode of discourse a student is engaged in, his or her knowledge may or may not be adequately represented. In a
comparative analysis of one student’s demonstration of his knowledge in two modes, Crawford (2005) examined the differences between the oral and written discourse production to determine if either provided a more accurate portrayal. She found that the oral mode allowed the student to demonstrate his “scientific competence through literate action” (Crawford, 2005, p. 160). In contrast, the written mode constrained the student’s ability, and “the representation of his knowledge and skills to function as a scientist remained questionable” (Crawford, 2005, p. 160).

**Teacher perceptions and classroom talk.** Morton (2012) analyzed one teacher’s use of classroom talk to address her students’ misconceptions, utilizing the Mortimer and Scott (2003) framework. The goal of the Morton (2012) study was to investigate how a bilingual science teacher’s perceptions of her students’ conceptual issues influenced the way she utilized classroom talk and, upon post-instruction reflection, how she perceived the effectiveness of her instruction during two classroom periods of instruction.

Prior to instruction, Morton (2012) asked the teacher to describe the conceptual issues and problems she expected her students to have with the material. Morton (2012) asked the teacher to describe the content of the lesson she planned to teach and her purpose for teaching the content as planned, and to reflect on the conceptions the students may or may not have prior to instruction. The teacher expressed the belief that the students did not have any conceptions about the topic, a determination which Morton (2012) found somewhat valid based on the students’ long silences and short answers during the subsequent lesson.
Classroom observation video data of the instructional activities were collected to evaluate how the teacher used classroom talk to address learners’ conceptions. These data were also used in a post-instruction interview in which Morton (2012) asked the teacher to reflect on the outcome of her instructional practices as she dealt with students’ conceptual issues.

Morton (2012) then analyzed the communicative approaches utilized by the teacher during the two lessons observed and found that the teacher used a variety of communicative approaches to position her students in different ways: as having no prior conceptions of the topic being discussed, and in the same lesson, as reporters of personal experience with the concept, and as being able to provide a definition of the concept. Referring back to the Mortimer and Scott (2003) framework, Morton (2012) noted that, within the course of one lesson, the teacher moved from an interactive/dialogic approach (see Figure 2.1) to the “intervening stages of authoritative and dialogic talk, culminating in a spate of clearly non-interactive/authoritative discourse” (p. 107).

Morton (2012) analyzed the patterns of discourse that occurred in the classroom and, in the post-instruction reflection interview with the teacher, attempted to ascertain the teacher’s rationale for the shifts she made between communicative approaches, and whether she felt that these shifts had supported student learning. Lastly, Morton (2012) utilized the classroom observation video footage during the post-instruction interview to support the teacher’s reflection on her decisions.

Morton (2012) found that, while the teacher’s goal during the lesson was to uncover student misconceptions, she had exclusively focused on the “deconstruction” (p. 108) of these misconceptions, and thus missed several important opportunities to allow
students to construct conceptions of their own. Morton (2012) concluded that the teacher perceived the purpose of classroom talk as “uncovering misconceptions and then replacing them with the correct ones, without an intervening stage of open reflection and exploration of the students’ conceptions” (p. 108). Morton (2012) believed that this approach may actually be a detriment to student conceptual change, stating, “Using ‘misconceptions’ as an interactional resource may be related to closing down opportunities for exploring students’ ideas rather than opening them up” (p. 108).

**Discrepancies in student and teacher perceptions.** Tasker and Freyberg (1985) found that students’ experiences in activity-based science classrooms are often characterized by “major discrepancies between the teacher’s intent for the lesson, and the pupils’ actual involvement” (p. 68). Tasker and Freyberg (1985) suggested these mismatches occur when teachers design instructional activities from their own scientific perspective, which results in “a range of mistaken assumptions about how the learner will respond to, and what the learner will learn from, such tasks” (p. 77). They outlined eight types of potential discrepancies between teacher and student perceptions, grouped into three categories: (1) discrepancies in intent (of the context, purpose, or design of an activity); (2) discrepancies in action (for the expectations, results, or consideration of findings of an activity); and (3) discrepancies in views of the world (regarding the impact of the experience or relationship on pre-determined outcomes).

Tasker and Freyberg (1985) suggested three scenarios that address and eliminate discrepancies between teacher intentions and student responses in activity-oriented instruction: (1) the teacher’s purpose for the activity becomes the students’ understood purpose; (2) the activity designed to achieve a purpose is established in advance by the
teacher and understood by the students as a “sensible and straightforward method to accomplish it” (p. 77); and (3) the students’ conclusions are “valued, discussed, and related to the teacher’s hoped-for conclusion” (p. 77).

**Lunar Concepts: Curriculum and Research**

Science education in the United States has undergone a significant transformation with the implementation of standards-based reforms. These reforms were prompted by the realization that American students were falling behind their international peers on assessments of science knowledge. Results from these assessments indicated that, while “most students have some grasp of basic scientific facts and principles by the end of high school, they are not able to apply scientific knowledge to a new situation, design an original experiment, or explain the reasoning behind their answers” (National Research Council, 1998, p. 4).

In order to address these gaps in performance, both researchers and policymakers have investigated the ways core ideas of science and the conceptual progression of these ideas can be accessed by students in the classroom. The resultant curriculum framework and body of literature is reviewed below.

**Lunar concepts curriculum framework.** In *A Framework for K-12 Science Education* (NRC, 2012), the National Research Council outlines major practices, crosscutting concepts, and disciplinary core ideas for all students in kindergarten through twelfth grade. The framework also details the ways practices, concepts, and ideas develop over the course of a student’s schooling. The following quote reflects the application of conceptual change theory to the design of these national standards:
[The framework] is built on the notion of learning as a developmental progression. It is designed to help children continually build on and revise their knowledge and abilities, starting from their curiosity about what they see around them and their initial conceptions about how the world works. The goal is to guide their knowledge toward a more scientifically based and coherent view of the sciences and engineering, as well as of the ways in which they are pursued and their results can be used. (NRC, 2012, p. 10-11)

Embedded in the core disciplinary ideas of the content standards designed by the NRC are the core and component ideas of earth and space sciences. The core and component ideas provide the learning framework from which science instruction is to be designed.

According to the NRC (2012), a scientific understanding of the Earth and its solar system supports the following concepts:

- The solar system consists of the Sun and a collection of objects of varying sizes and conditions—including planets and their moons—that are held in orbit around the Sun by its gravitational pull on them. (NRC, 2012, p. 175)
- The Earth and the Moon, Sun, and planets have predictable patterns of movement. (NRC, 2012, p. 175)
- Gravity holds the Earth in orbit around the Sun, and it holds the Moon in orbit around the Earth. (NRC, 2012, p. 175)
- The Moon’s and Sun’s positions relative to the Earth cause lunar and solar eclipses to occur. (NRC, 2012, p. 175)
- The Moon’s monthly orbit around the Earth, the relative positions of the Sun, the
Moon, and the observer, and the fact that the Moon shines by reflected sunlight explain the observed phases of the Moon. (NRC, 2012, p. 175)

Consequently, students completing middle school should know that the solar system consists of the Sun, planets and their moons, and other objects such as asteroids, and that these are held in orbit around the Sun by gravitational pull (National Science Teachers Association, 2012). Additionally, by the end of middle school, students should be able to identify patterns in the changing positions of the Moon and Earth as they orbit the Sun and understand that these phenomena are predictable due to the nature of the solar system (Ohio Department of Education, 2011). Students should also understand how these patterns and cycles relate to the seasons, lunar and solar eclipses, and lunar phases (NSTA, 2012).

**Lunar concepts and misconceptions research.** Concepts related to patterns of the Sun, the Moon, and the Earth are abstract and can be difficult to understand, even after being observed regularly (Stahly, Krockover, & Shepardson, 1999; Trundle, Atwood, & Christopher, 2007). The body of literature on individuals’ understanding of lunar concepts indicates there are persistent and common misconceptions present in individuals of all ages (e.g., K-12 students, university students, teachers) (Baxter, 1989; Dunlop, 2000; Saçkes, 2010; Trundle et al., 2002, 2006, 2007a, 2007b, 2010). Students often have preconceptions about the solar system and its patterns and cycles that are reinforced by their everyday experiences and observations (Trundle et al., 2010). Instructional approaches that account for these preconceptions have been found to be a critical factor in students’ development of scientifically accurate understandings (Stahly et al., 1999; Trumper, 2001; Trundle et al., 2002, 2006, 2007a, 2007b, 2010).
Piaget (1929) found that children often have misconceptions about the movement and appearance of the Moon and the cause of moon phases. Piaget was the first of many to identify the common misconception that moon phases are caused by the Earth’s shadow, a view often referred to as the “eclipse model” (Trundle et al., 2007b, p. 596). The eclipse model is the most commonly held alternative conception among students across all ages, elementary school through college, including those in middle school (Baxter, 1989; Saçkes, 2010; Trundle et al., 2010). Variations of the eclipse model also include the belief that clouds, other planets, or the Sun itself are the cause of the Moon’s phases (Barnett & Morran, 2002; Dunlop, 2000; Roald & Mikalsen, 2001; Trundle et al., 2010). Za’rour (1976) found that some children believe that a change in the Moon’s appearance is caused by a change in its size.

Trundle and colleagues have conducted a series of studies examining the conceptual development of lunar cycle concepts with students in fourth grade (Trundle et al., 2007b), middle school (Trundle et al., 2010), and with pre-service elementary school teachers (Trundle et al., 2002, 2007a; Trundle et al., 2006). The results of this body of research have provided robust evidence of the pre-instructional misconceptions of students regarding lunar phases across a wide range of ages, along with instructional factors and interventions that positively contribute to conceptual change, and also have provided the theoretical and methodological framework for the present study.

The series of studies conducted by Trundle and colleagues (2002, 2006, 2007a, 2007b, 2010) all utilized the same inquiry-based instructional sequence with participants. The instruction was modeled after Physics by Inquiry (McDermott, 1996) and involved
three phases: (1) gathering, recording, and sharing moon data based on observations; (2) analyzing moon data, looking for patterns; and (3) modeling the causes of moon phases.

The first phase, gathering, recording, and sharing moon data, was conducted over a period of 9 weeks. Students were taught how to make and record moon observations and asked to record daily observations as frequently as possible over the subsequent 9-week period. During this time, students were given 15 minutes, once each week, to share their observation data with classmates. During the next phase, students analyzed their data and looked for patterns. This phase of instruction involved five steps: (1) identifying observable shapes and patterns; (2) determining the length of the cycle of changes; (3) sequencing the observed shapes; (4) applying new concepts and scientific labels; and (5) modeling the cause of moon phases. Finally, to help students interpret their data and resolve possible inconsistencies in their understanding versus a scientific understanding, students engaged in a psychomotor modeling activity of the lunar cycle.

Trundle et al. (2007b) studied the ability of fourth grade students to identify observable moon phases and patterns of change, a National Science Education Standards (NRC, 1996) K-4 benchmark. The researchers noted the gap in intervention research studies addressing the instructional methods that may successfully support the learning of these concepts by students at this grade level (Trundle et al., 2007b). In order to address this need, Trundle et al. (2007b) utilized the same instructional methodology that had been employed in their previous studies with pre-service elementary school teachers, detailed above (2002, 2006, 2007a).

Of the 63 fourth grade students who received instruction, 48 participated in the pre- and post-instruction tasks of drawing and sequencing moon phases (Trundle et al.,
During the first of two drawing tasks, the pre-instruction drawing task (Task 1), participants were asked to draw all the moon phases they expected to see, and for the post-instruction task, they were asked to draw the moon phases they had observed. During the first of two sequencing tasks, the pre-instruction sequencing task (Task 2), students were asked whether the moon shapes they expected to see would appear in a predictable pattern, and in the post instruction task, they were asked if the shapes they observed had, in fact, appeared in a predictable pattern. Finally, if students responded affirmatively to the questions asked in Task 2, they were asked to draw the moon shapes in the sequence they expected to (pre-instruction) or had (post-instruction) observed; this was the last task (Task 3).

The results from Task 1 showed that, prior to instruction, 38% of students’ drawings were of non-scientific moon shapes (Trundle et al., 2007b). Of the students who drew the moon phases in sequence, 42% drew non-scientific moon shapes during the pretest; following instruction, 92% of students’ responses on the drawing task reflected a scientific understanding in both Tasks 1 and 3 (Trundle et al., 2007b).

Of the 48 students who participated in the initial tasks, seven students were selected to participate in an in-depth post-instruction interview, along with three students from special education classrooms, in order to create sample of 10 students. This post-instruction interview probed students’ understandings of the cause of the moon phases. Students were asked to use models to demonstrate what happens when the Moon cycles through its phases and verbally explain why each change in the arrangement of the Sun, Moon, and Earth caused each of the phases.
Of the 10 students who participated in the additional interview tasks, eight provided responses that were judged to be scientifically accurate explanations for the causes of the seasons. A scientifically accurate explanation included four components: (1) one-half of the moon is always lit; (2) the Moon orbits Earth; as the Moon orbits Earth, the illumination pattern changes; (3) the change in illumination causes us to see different portions of the lighted half of the Moon from the Earth (p. 610-611). Two of the students, one from the original sample and one special education student, provided responses that were deemed “scientific fragments” (Trundle et al., 2007b, p. 611) meaning they included one to three of the four components of the scientific explanation.

Trundle et al. (2010) investigated the effect of guided inquiry instruction on middle school students’ development of lunar concepts, specifically addressing: (a) the shapes or phases of the moon; (b) the sequence of moon phases; and (c) the cause of moon phases. The first and second components of the research question (shapes or phases, and phase sequence) were evaluated in 20 eighth grade students (Trundle et al., 2010). These students received 10 weeks of specialized, guided inquiry instruction, and completed a pre-instruction interview as well as a pre- and post-instruction drawing task immediately before and again three weeks after instruction.

During the pre-instruction drawing task, participants in the Trundle et al. (2010) study were asked to draw all the moon phases they expected to see, and for the post-instruction task, they were asked to draw the moon phases they had observed. Researchers evaluated whether the shapes drawn by students in response to this question included all of the moon phases (waning gibbous, third quarter, waning crescent, waxing
crescent, first quarter, waxing gibbous) and if the shapes were “scientific” or “non-scientific” (i.e., if the waxing and waning phases were over- or under-articulated).

Prior to instruction, all but one of the participants’ drawings included specific moon phase drawings that were non-scientific; that is, 95% of students’ drawings reflected alternative understandings of the shape and sequence of the moon phases (Trundle et al., 2010). After instruction, 85% of students’ responses on the drawing task reflected a scientific understanding, while 15% still exhibited an alternative understanding (Trundle et al., 2010).

Participants’ understanding of the cause of moon phases was evaluated using in-depth post-instruction interview data collected from a sample of 11 of the 20 students. The post-instruction interviews were conducted in order to evaluate conceptions regarding the third component of the research question (the cause of moon phases) both before and after instruction. Purposeful sampling was used to ensure that the chosen students would represent those who perform at average, above average, and below average levels. Before instruction, none of the students who participated held a scientific understanding of the cause of moon phases. After instruction, however, 8 out of the 11 students (72.7%) interviewed provided explanations that could be considered scientific, while 3 students (27.3%) still held a non-scientific, alternative understanding (Trundle et al., 2010).

**Science Learning in Special Education**

Science instruction has traditionally been designed as a lecture-based, textbook-driven endeavor, which requires a strong command of the language of instruction (Scruggs & Mastropieri, 2007; Therrien, Taylor, Hosp, Kaldenberg, & Gorsh, 2011).
This emphasis on language in science is a barrier to learning for many students, including students with learning disabilities, students from language backgrounds other than English, and students who are DHH (Lang et al., 2007; Therrien et al., 2011). The achievement scores of special education students may provide evidence of these barriers.

In the area of science, students with disabilities often perform at levels significantly lower than those of their typical peers (Mastropieri et al., 2006; NLTS2, 2010). As discussed in the beginning of this paper, in a national sample of 5,222 secondary special education students, over 60% of students were performing in the lowest 25th percentile of science assessment achievement test scores (NLTS2, 2010). Approximately 34% of these students’ scores were in the 26th to 75th percentile range of achievement, while only 5.5% of secondary special education students’ performance was in the 76th percentile or above (NLTS2, 2010).

Scruggs and Mastropieri (2007) emphasized the need for concrete, hands-on presentations of science concepts in their review of research in science education for students with disabilities. They suggested that students with disabilities may experience difficulties with tasks requiring “substantial learner insight or formal construction of knowledge” (Scruggs & Mastropieri, 2007, p. 68), particularly when the students are asked to independently complete learning tasks that require such abilities. Scruggs and Mastropieri (2007) also emphasized that, when asking students with disabilities to engage in inductive thinking during science tasks, teachers need to actively support the process of scientific reasoning and present material in a highly structured manner. The authors concluded that students with disabilities learn vocabulary and general facts most effectively via direct instruction, while science concepts are learned best when
information is presented in a structured manner that includes multiple opportunities to engage in hands-on activities (Scruggs & Matropieri, 2007).

Therrien et al. (2011) drew similar conclusions in their review of 12 studies that evaluated the effectiveness of instructional strategies in science for students with learning disabilities (LD). The results of their meta-analysis indicated that students with LD are most successful in science when concepts are presented in a structured manner and when instruction follows an inquiry-based approach (Thierren et al., 2011). According to Therrien et al. (2011), the instructional components that have been shown to promote successful learning in students with LD include: (a) focusing on overall concepts/big ideas; (b) hands-on, concrete learning experiences that are teacher-directed; and (c) opportunities for additional practice and review of core concepts and vocabulary (p. 201).

Science education and students with visual impairments. Wild and Trundle (2010) investigated the effects of an inquiry-based instructional approach on the learning of seasonal change concepts of seventh grade students with visual impairments. There were a total of six participants in the Wild and Trundle (2010) study: three from a class receiving inquiry-based instruction, and three from a class receiving traditional instruction. Students in the inquiry group received instruction that facilitated their active participation in knowledge construction (Wild & Trundle, 2010). Students in the comparison group received traditional instruction that was predominantly lecture-based and depended on information from textbooks.

Students from each group participated in pre- and post-instruction interviews with the researcher. The interview questions were designed to assess students’ level of understanding of the causes of seasons on earth. With the exception of one student from
the inquiry group, all of the students held alternative conceptions about the causes of seasons prior to instruction (Wild & Trundle, 2010). Following the unit of instruction, both groups of students participated in a post-interview which was coded to determine the degree to which conceptual change was experienced. Data indicated that students in the inquiry group performed much better than their peers in the comparison group (Wild & Trundle, 2010). Whereas the alternative understandings of the three students in the comparison group remained unchanged after instruction, the students in the inquiry group all developed a degree of scientific understanding of the causes of the seasons during the unit (Wild & Trundle, 2010). The results of this study provide additional empirical support for the use of hands-on, inquiry-based learning for students with disabilities.

**Deaf Education and Science Instruction**

Approximately 95% of DHH children are born to hearing parents who typically are not fluent in the use of sign language (Mitchell & Karchmer, 2004). Accordingly, approximately five percent of deaf children have parents who are also deaf. Deaf children of deaf parents (DCDP) typically acquire language at a pace more closely matched to that of their hearing peers (Anderson & Reilly, 2002; Mohay, 2000; Swisher, 2000; Tomaszewski, 2008). The academic achievement of DCDP has been a topic of great interest to researchers, as these children often perform significantly better than their DHH peers with hearing parents (deaf children of hearing parents [DCHP]) across subjects (Anderson & Reilly, 2002; Mohay, 2000; Swisher, 2000). This difference is typically attributed to the benefit of early language exposure DCDP experience as a result of being born into families who are familiar with their needs and who already know sign language (Mohay, 2000; Swisher, 2000; Tomaszewski, 2008).
Anderson and Reilly (2002) conducted a study to establish normative data for vocabulary development in young DHH children. Until the time of this study, a normed assessment of the early sign language development of DHH children did not exist. Data were collected from 69 children between the ages of eight and 35 months who were all DCDP (Anderson & Reilly, 2002). Both cross-sectional and longitudinal data were discussed, providing a parallel comparison with the spoken language acquisition of hearing children of the same age.

The findings of this study indicated that the median vocabulary scores for children at 24 months of age were comparable to the scores of same-age typically hearing children assessed with the original version of the same instrument (Anderson, 2005; Anderson & Reilly, 2002; Fenson et al., 1993). Notably, however, the average vocabulary size for deaf children at 30-33 months (n = 12) was 367 words (Anderson & Reilly, 2002), while the normative average score of a typically hearing 30-month-old is 530 words (Fenson et al., 1993, in Mayne et al., 1998). Although the authors acknowledged that the small sample size of children was a potential limitation to the study, data from 69 children is at least moderately representative given that the total number of DCDP is incredibly small (only five percent of the low incidence population of deaf children).

**Academic achievement.** The academic achievement of students who are DHH is consistently delayed compared to that of students with typical hearing in all academic areas, including content-area subjects such as science (Moon et al., 2012; Mitchell & Kartchmer, 2008; Qi & Mitchell, 2012). Research findings have indicated that DHH students’ difficulties with science learning are a result of limitations in scientific vocabulary and discourse (Molander et al., 2007, 2010), vast gaps and differences in
individual prior knowledge, and a lack of consistency in the vocabulary of science in sign language (Lang et al., 2007).

Vosganoff, Paatsch, and Toe (2011) conducted a study examining the science and mathematics achievements of 16 ninth grade DHH high school students from Western Australia. This study compared the achievement scores from compulsory state tests (Monitoring Standards in Education, or, MSE) with the state and class averages for students with typical hearing. Twelve of the 16 students who participated were fully mainstreamed with peers, while four were partially mainstreamed. When compared with school and state averages on the MSE, all DHH students performed below their school cohort and 14 out of 16 (88%) performed below the state average (Vosganoff et al., 2011).

An additional analysis of performance on the science assessment separated questions that required a written explanation from those which were multiple choice. Findings indicated that DHH students performed significantly higher on those questions that did not require a written response (Vosganoff et al., 2011). Finally, researchers compared the performance of DHH students on the MSE science assessment to that of LBOTE peers. They found little difference between LBOTE students’ scores and scores of students with typical hearing, and determined that students who are DHH appeared to face greater challenges in accessing and achieving the assessments at the same level as their typical peers than do their LBOTE peers (Vosganoff et al., 2011). Vosnagoff and colleagues (2011) concluded that the DHH students’ poor experiences with language and development of foundational reading and writing skills contributed to their low performance in the area of science.
Language and prior knowledge. Many students who are DHH experience restricted access to language from birth as a result of their hearing loss; therefore, language acquisition and the subsequent learning and cognitive development that are necessarily mediated by language are profoundly affected. As mentioned previously in this paper, approximately 95% of DHH children are born to hearing parents who typically are not fluent in sign language (Mitchell & Karchmer, 2004). If the child’s degree of hearing loss is severe enough to limit his or her access to spoken language, and if visually accessible language (i.e., sign language) is not consistently available, DHH children often do not encounter adequate language models until they begin early intervention services, or, in some cases, until they begin kindergarten (Strong & Prinz, 1997). As such, the early language development of children who are DHH is often delayed compared to that of their hearing peers (Anderson & Reilly, 2002; Mayne et al., 1998; Moeller, 2000).

Because students who are DHH often arrive to school with language that is already significantly delayed, the mode and quality of the language in the school environment needs to be as accessible as possible in order for the child to have the best chance possible at minimizing the effects of any deficit (Johnson, Liddell, & Erting, 1989). Wang (2011) asserted, “It is unreasonable to assume that children who are struggling with the language of communication and instruction (e.g., English) will be able to access and understand the language of science” (p. 251).

Types of sign language. There are several varieties of sign language that are used by students who are DHH and the school personnel they come into contact with. Three primary methods of sign language are used in the United States: American Sign Language (ASL), Signed English, and Pidgin Sign Language (PSE)/Contact Sign.
American Sign Language is considered a language in its own right, with a vocabulary and grammatical structure that is independent of that of English. Signed English is a manual (signed) representation of the English language. Pidgin Sign Language is a creolization of English and ASL that resulted from a sustained mixing or contact between these two languages among users. Fingerspelling is a manual representation of English orthography, and is used in conjunction with the three aforementioned sign languages.

*American Sign Language.* ASL has all of the features of a unique, natural language (Padden & Humphries, 1988; Valli & Lucas, 2000): it is comprised of unique grammar, vocabulary, and linguistic features (such as facial expressions and mouth movements) (Siple & Fischer, 1991). In the bilingual-bicultural model of deaf education, ASL is the primary mode of instruction, and English is acquired as a second language through the use of signed English and English in-print.

*Signed English.* There are several invented sign systems used to manually represent English. Initially, these were proposed by educators of the deaf who, in an attempt to convey spoken English to deaf students visually, assumed that “signing in English word order will eventually make sense to deaf students” (La Bue, 1995, p. 199). Signed systems use English grammar and modified versions of ASL signs, and often sacrifice conceptual clarity in an attempt to approximate English.

*Pidgin Sign English (PSE)/Contact Sign.* There is some disagreement by researchers on the definitions and use of the terms “contact signing” and “Pidgin Sign English” (PSE), which are frequently used interchangeably or incorrectly (see Berent, 2008, for further discussion). Contact signing is defined as “a kind of signing which results from the contact between American Sign Language (ASL) and English and
exhibits features of both languages” (Lucas & Valli, 1989, p. 458). In other words, this type of signing falls somewhere in between ASL and English signing on the spectrum of so-called pure language forms. The mixing of sign languages has also been called Pidgin Sign English (PSE), and this term has become commonly used in the literature.

Fingerspelling. Fingerspelling is described as an alphabetic representation of English orthography, or a “manual system for representing the alphabet” (Padden, 2006, p. 189). Fingerspelling is incorporated into each of the communication modes presented above as a way to express verbatim representations of English words, phrases, or sentences; proper nouns such as the name of a person or place; words for which no conventional signs exist such as technical English vocabulary; slang expressions; or acronyms or other abbreviations (Wilcox, 1992). In the classroom, fingerspelling is often used by teachers in a number of ways to capitalize on the bridge it creates between sign language and English. In the case of science instruction, fingerspelling is often used to represent vocabulary that is more specialized, or for words that do not have equivalent representations in sign language.

“Chaining” is the use of fingerspelling to help convey the meaning of words and link the known (signed) word to the unknown (printed) word, and is thus an intermediary mode. Padden (2006) explained the sequence teachers often follow when chaining: “[The teacher will] fingerspell a word, immediately point to the word printed on the blackboard next to her, and fingerspell the word again; or sign a word and immediately fingerspell it as well” (p. 90). This method gives students access to the specialized vocabulary required for all content areas and at all ages, and is one way to provide access to the vocabulary necessary for learning. Future research to investigate the ways
fingerspelling is used for instruction in the science classroom for DHH students would contribute to the understanding of how science language and discourse is (or is not) taken up, and how this contributes to students’ ability to “talk science” (Lemke, 1990).

**Classroom placement.** Currently, more than 86% of students who are DHH are reported to be integrated in the general education setting, at least to some degree, with hearing peers (Mitchell & Karchmer, 2011), with 43% of these students spending most of their school day in the general education setting (Reed, Antia, & Kreimeyer, 2008). Classroom placement options for students who are DHH are on a continuum from complete inclusion (with or without additional services such as an interpreter) to placement in a separate school (Stinson & Kluwin, 2011). Separate school placements, including residential and day school programs, are self-contained classes of students who are DHH with instruction by a teacher of the deaf (Stinson & Kluwin, 2011). As of 2006, 12.4% of DHH students were placed in a residential setting (National Center for Education Statistics, 2008, in Stinson & Kluwin, 2011).

Resource rooms and separate classes are located in public schools where the majority of students are hearing. Separate classes are self-contained classrooms with a teacher of the deaf and students who are all DHH. Apart from lunch, recess, and possibly extracurricular classes (e.g. gym, art), students in these placements spend most, if not all, of their instructional time in the separate classroom (Stinson & Kluwin, 2011). Resource room placements allow students who are DHH to be integrated into general education classes for some or most academic subjects, and come to the resource room for instruction in subjects for which they need more support (Stinson & Kluwin, 2011). General education placements are those in which a DHH student is fully included with
hearing peers, and where instruction is provided by a general education teacher. Support is available as needed for students in these settings, including classroom interpreters, itinerant teachers (a teacher of the deaf who provides consultation or academic support), or speech-language pathologists (Stinson & Kluwin, 2011).

**Sign language in the science classroom.** In their study of the standardization and use of conceptually correct technical science signs, Lang et al. (2007) found that approximately 60% of the science terms selected for analysis did not have corresponding signs that had been recorded or otherwise agreed upon. Furthermore, the science teachers interviewed for the Lang et al. (2007) study demonstrated highly variable and often conceptually inaccurate uses of science signs. For example, when provided with three possible signs for the word “shark,” almost half of the teacher participants chose the sign depicting a fin on the shark’s head (see Appendix A, Image 1), while the other half chose the more conceptually correct sign (see Appendix A, Image 2). The authors asserted that the lack of standardized vocabulary in ASL must be addressed within the fields of education and classroom interpreting for students who are DHH.

The findings reported by Lang and colleagues (2007) demonstrate the problematic nature of the intersection of ASL and English science terms. Although ASL is a true, natural language, as evidenced by the research of Stokoe (1960) and others, a lack of standardization in sign vocabulary remains (Lucas, Bayley, & Valli, 2003). The variability of signs has been attributed to regional dialectal differences as well as to differences in socioeconomic status, gender, and age (Lucas et al., 2003). However, as Lang et al. (2007) reported, the variability among teachers of the deaf (many of whom are
not native sign users) is an issue that needs to be addressed in teacher preparation programs as well as in future research.

The need for standardization in the sign language used in science instruction of students who are DHH has been addressed by Lang and other researchers from the National Technological Institute for the Deaf (NTID) at the Rochester Institute of Technology through the development of the NTID Science Signs Lexicon (Rochester Institute of Technology, n.d.). This web-based database allows users to contribute videos of signs used in their community, discuss alternatives, and rate the contributions made by other users.

DHH students who rely on sign language to access information and learning are those most affected by the consequences of the lack of standardization of science signs. According to Lang and colleagues (2007), incorrect sign language use can contribute to, or is evidence of, misconceptions in science. Exposure to multiple variations of the same sign for the same concept causes an increase in the cognitive demand for students, particularly for those whose language foundation is tenuous at best. With respect to the instructional practices that may address the problem of language standardization, Lang et al. (2007) recommended embedding explanations about the etymology of signs when introducing students to new signs. This practice will contribute to students’ overall understanding of the concept and may serve as extra information that supports semantic categorization and conceptual structuring.

*Construction of meaning in science classroom sign language.* Molander, Hallden, and Lindahl (2007, 2010) investigated the implications of science learning in a bilingual-bimodal Swedish Sign Language (SSL), and spoken Swedish, class of 13-
15-year-old DHH students. The authors were particularly interested in the ways that ambiguity between signs and their spoken language counterparts impacted meaning construction and understanding in the “joint productive activity” (Molander et al., 2007, p. 327) of classroom dialogue. Both studies (2007, 2010) compared DHH students with same-age, typically hearing peers. Interviews were conducted with each group of students, and probes were used to initiate discussion about the meaning of science vocabulary words and their related concepts.

Results indicated that the use of SSL to mediate conceptual understanding was a factor in the science learning difficulties of DHH students. In both studies, findings indicated that the ambiguity between the Swedish word and the SSL sign created confusion (Molander et al., 2007, 2010). Students showed difficulty connecting their prior knowledge to the newly learned concepts being taught in class (Molander et al., 2007). The authors asserted that DHH students faced a doubly difficult task when learning scientific concepts, as they must “cross not only the border to a scientific culture, but also a border between SSL and scientific words expressed in their second language, Swedish, and possible differences with regards to what the different languages might mediate” (Molander et al., 2007, p. 328).

Findings from Molander et al.’s (2007) study indicated that DHH students experienced incongruence between the meaning most often associated with the SSL sign and the other, more specialized meaning used in the scientific context. This not only led to misconceptions or underdeveloped conceptions, but also led to “uncertainty and unproductive lines of reasoning” (Molander et al., 2007, p. 337) during group discussions. As such, Molander et al. (2007) recommended teachers of students who are
DHH “consider the possible connection between students’ initial ideas, what meaning the language might carry and possible conflicts between Swedish words and signs in SSL” (p. 339).

**Incongruity of meaning between spoken and signed languages.** Molander et al. (2010) presented similar findings to their 2007 study regarding the incongruence between signed and spoken language (specifically with respect to scientific language). Translating scientific vocabulary into sign language often leads to misconceptions, as the metaphorical value of words that would be common sense to a hearing person is lost in translation and can make learning even more difficult. Molander et al. (2010) found that the representational nature of some scientific vocabulary makes it less understandable to students who do not have a full command of or who do not have unrestricted access to the auditory/aural language being used. The language of science often borrows words from other disciplines or contexts and uses the “metaphorical value” (Molander et al., 2010, p. 45) of these words to give meaning to models and phenomena within the scientific context. For typically hearing students, the connotations between words from different contexts are more easily made, and thus facilitate productive meaning-making and conceptual development. Students who are DHH must not only learn new concepts, but also must learn the words for these concepts in the second language.

Molander and colleagues (2010) argued that “the problems encountered in grasping and using scientific reasoning can be partly understood in terms of how familiar connotations of words and signs direct students’ reasoning” (p. 46), and that teachers must take a more active role in facilitating students’ understanding of scientific language. The authors concluded that teachers need to elicit information from students about their
mental models of the concepts, be aware of the potential conflicts and alternate meanings that may be embedded in a particular sign or word, and actively participate in providing redirection or correction of students’ misconceptions or incorrect language usage (Molander et al., 2010).

Learning styles of students who are DHH. A student’s “learning style” has been defined as the “individual differences in approaches to tasks that can make a difference in the way in which and, potentially, in the efficacy with which a person perceives, learns, or thinks” (Sternberg, Grigorenko, & Zhang, 2008, p. 486). Riechmann and Grasha (1974) outlined six primary learning styles based on their study of students’ attitudes toward learning, their view of teachers and/or peers, and their response to classroom activities: competitive, collaborative, participative, dependent, independent, and avoidant.

Students who are DHH have been frequently characterized as exhibiting dependent learning styles (Lang et al., 1999; Marschark et al., 2002). A person who has a dependent learning style is characterized as one who relies on explicit direction and guidance without taking ownership of his or her own learning (Kahn et al., 2013; Lang et al., 1999). A study of 110 college-age DHH students’ learning styles by Lang et al. (1999) found that the dependent learning style was the most common style preference among participants. Lang et al. (1999) described dependent learners as those who “do not show much intellectual curiosity, often learn only what is required of them, prefer teacher-centered approaches, strong guidance, outlines, (and) notes on the board” (p. 18).

Kahn, Feldman, and Cooke (2013) presented research findings that challenge the characterization of DHH students as primarily dependent learners. The authors studied DHH high school students’ autonomy in science learning, particularly looking at the
relationship between DHH student autonomy and inquiry-based instruction. Three classrooms were chosen to participate in a video-taped observation of one class period in which each class carried out the same hands-on, interactive learning task.

The researchers analyzed data through the frameworks for learner dependency and scientific inquiry to find evidence of students’ autonomy and teachers’ facilitation of inquiry. In Classroom 1, the teacher alternated between providing highly structured instruction and encouraging collaboration and independence; however, as the authors noted, the structured approach taken by the teacher was appropriate in providing scaffolding to emphasize the importance of precision in science experiments (Kahn et al., 2013). All but one of the seven students in the Classroom 1 exhibited “tremendous autonomy and collaboration,” according to Kahn et al. (2013, p. 18).

In Classroom 2, the teacher provided a high level of structure and explicit instruction to his students. While the teacher in the first classroom observed allowed time for her students to independently engage in the activity before providing explicit instruction, the Classroom 2 teacher began the class with an extensive lecture that outlined for the students what they should expect to observe. The teacher also continually made anticipatory comments that “may have diminished opportunities for greater inquiry on the part of the students” (Kahn et al., 2013, p. 20). One of the five students in this classroom exhibited signs of autonomy in her learning and participation. She was persistent in communicating her observations during the experiment, even when they were corrected or rebuffed by the teacher (Kahn et al., 2013).

In Classroom 3, the teacher strongly supported her students’ engagement in inquiry learning. She asked open-ended questions and responded to students’ questions
in a higher order manner, and she “cue[d] her students to attend and engage, and equally importantly, appeared to intentionally remain silent at times” (Kahn et al., 2013, p. 21). Similar to the first classroom, students in Classroom 3 engaged in debate, collaboration, and made observations and predictions. When they were presented with discrepancies in the data they had collected, the teacher facilitated a debate between two students and helped them come to the conclusion that both of them were correct. In allowing for, and then mediating, this exchange, the teacher provided the opportunity for the students to see the open-ended nature of scientific inquiry for themselves (Kahn et al., 2013).

The authors (Kahn et al., 2013) concluded that autonomy and scientific inquiry are, by definition, entwined. Scientific inquiry requires ownership of one’s learning, decision making skills, and the ability to advocate for one’s position, which are all evidence of autonomy. It appears that, in an attempt to accommodate their students’ perceived dependent learning styles, teachers who provide explicit instruction and guidance without allowing for inquiry experiences and autonomy in science learning may actually undermine their students’ ability to develop inquiry skills such as those to hypothesize, describe, question, and self-direction, according to Kahn et al. (2013). Kahn et al. (2013) proposed five key elements of teacher facilitation to promote autonomy and inquiry in DHH students: “1) asking open-ended questions, 2) scaffolding student responses to higher levels of inquiry; 3) refraining from suggesting what “should” happen or why a student’s prediction would not; 4) encouraging students to advocate for their ideas; and 5) fostering interdependence among students” (p. 24).

**Instructional modifications.** Several authors have addressed the need for instructional modifications that address the unique learning needs of students who are
DHH in science. Many students who are DHH do not have the reading skills necessary to access and understand complex scientific language in print, such as the information presented in traditional science textbooks. Some researchers have suggested that this barrier to learning might be mitigated by giving students a way to receive and communicate information in the performance mode, or via performance literacy (Paul, 1998, 2009, 2012; Paul & Wang, 2006; Wang, 2011). As the communication mode relates to the discussion of science teaching and learning of students who are DHH, performance literacy materials present information in a through-the-air (i.e., non-script-based) form that closely resembles the vocabulary and grammar of the same information that would otherwise be captured in print (Paul, 2009). Providing this type of access to the information, suggested Paul (2009), allows students opportunities to develop cognitive and metacognitive abilities independent of their ability to access and interpret information in print form.

Wang (2011) suggested the integration of an inquiry-based science program with the use of performance literacy during science instruction with students who are DHH. She cautioned, however, that performance literacy should not be used to the exclusion of print and that performance literacy usage is meaningful only for those students who possess the cognitive and linguistic prerequisites needed to understand the information presented orally (Wang, 2011). Wang suggested that students who are DHH benefit most from science instruction that combines inquiry-based practices, performance literacy materials, print materials, fingerspelling of target science vocabulary, and teacher scaffolding of information (2011).
Lang and Albertini (2001) examined the ways DHH students in sixth to eleventh grades constructed meaning through writing in a study on the use of write-to-learn activities in science instruction. Lang and Albertini (2001) found that limitations in technical and nontechnical vocabulary knowledge, along with ambiguity in the associations between the sign and printed word for given concepts, contribute to students’ misconceptions in science. They also found that teachers needed to frequently intervene and provide support for students during writing tasks (Lang & Albertini, 2001). Teacher support must be present in order for the students to be able to accurately construct meaning using English until students develop the requisite skills for more independent comprehension. In the study, not only did teachers need to mediate the language students were using in order to achieve conceptual understanding, they also needed to have extensive knowledge of the science principles being discussed—and the signs or concepts students may associate with these concepts—in order to successfully interpret DHH students’ writing (Lang & Albertini, 2001). The findings of the Lang and Albertini (2001) study support the assertions made by Molander et al. (2010) regarding the need for teacher support in mediating and facilitating the learning of scientific concepts and vocabulary.

Egelston-Dodd and Ting (2007) collaborated to develop a series of web-based video tutorials that addressed the need for additional support in the learning of science vocabulary suggested by other scholars (e.g., Lang & Albertini, 2001; Molander et al., 2010; Paul, 2009; Wang, 2011). These video tutorials were created to facilitate the learning of vocabulary and concepts for DHH post-secondary students taking a high school freshman-level astronomy course (Egelston-Dodd & Ting, 2007). The short video
tutorials provide web-based practice for students in course vocabulary and conceptual material, and give content summaries in ASL. Making the technology available via the Internet provides opportunities for students to access the content at any time during the duration of the course, which allows for frequent and repeated exposure to relevant concepts.

The authors described the sequence of instruction that incorporates the video tutorials as follows: (1) hands-on experience in a lab setting; (2) collaborating and prompting class discussion of relevant results; (3) viewing the explanation in ASL on video with media and taking notes; (4) reading mediated text and observing media on the course website; (5) writing the lab report; (6) answering questions in the textbook; and (7) taking the online content quiz (Egelston-Dodd & Ting, 2007, p. 23). This sequence presents students with information in a manner that allows for conceptual restructuring because, as the authors suggested, students who are DHH learn more readily when the organization and structure of visual components is hierarchical (Egleston-Dodd & Ting, 2007). Impressively, findings from the first iteration of the study indicated pre- to post-test gains increased by an average of 10 points for those students whose course included the web-based tutorials (Egelston-Dodd & Ting, 2007).

In the same field of instructional modifications using computer-based supplements, Diebold and Waldron (1988) investigated the effects of multimedia modifications to printed science materials. Participants in the Diebold and Waldron (1988) study were 60 DHH students from a residential school who were between the ages of 12 and 22. Researchers assigned participants four different printed science instructional formats, all focused on the same conceptual content: the water cycle. The
four formats investigated were: (1) the standard text format, (2) the simplified text format, (3) the simplified text/labeled diagram format, and (4) the labeled diagram format. Researchers found that the use of highly pictorial content and simplified English text produced significantly higher pre- to post-test gain scores compared to formats with less pictorial content and more complex English in the text (Diebold & Waldron, 1988).

Prior knowledge and the development of mental models. Molander et al. (2001) investigated the differences in reasoning about science in high school DHH students as compared to their hearing, same-age peers. This study used data from a national standardized science assessment of students against which DHH students’ responses were compared and evaluated (Molander et al., 2001). An interview methodology was utilized to elicit responses from the eight DHH participants to the selected question from the assessment: “Think about an animal in the forest. It is composed of many atoms. The animal dies and starts to rot. What will happen to the atoms as the animal rots and finally disappears?” (Molander et al., 2001, p. 201).

DHH students’ responses were transcribed and categorized according to their main line of reasoning. Of the eight participants in the study (Molander et al., 2001), only one participant met the criteria for a scientifically correct response (e.g., transferred domain-specific knowledge, transferred science concepts between subjects, evidenced a clear structure between concepts and models). A second student’s responses were suggestive of a vague conceptual structure and minimal transfer between domains (Molander et al., 2001). The remaining six of the eight students demonstrated extremely limited understanding and reasoning in their responses. These six participants demonstrated no transfer of knowledge between domains, and virtually “no reasoning
within a symbolic school-science domain” (Molander et al., 2001, p. 209). The authors concluded that, for these six students, science concepts and life-world concepts are completely separate spheres of knowledge, and as such, scientific knowledge “does not come into play in their reasoning” (Molander et al., 2001, p. 208) when they are confronted with decontextualized scientific problems.

Molander and colleagues (2007) later commented on the conflict between life-world knowledge and scientific knowledge, stating, “Deaf students bring experiences, expressed mainly in SSL, to school where they are confronted with scientific concepts in written Swedish” (Molander et al., 2007, p. 328). In other words, concepts that students originally encoded using sign language may not be readily retrieved when the same concept is presented using spoken language vocabulary (e.g., through the use of fingerspelling, when the word is presented in print form) or when the sign used by one member of the class is incomprehensible to others.

It can be concluded that the difficulty students experience in making connections between lived experiences and concepts presented in the context of the classroom may be a result of their inability to consistently use language to mediate the learning of new concepts in an academic context. Another possibility is that students’ mental models of science concepts are flawed as a result of non-standard vocabulary use or the inability to adequately add information gained during a prior experience to an existing mental model if the experience was not linguistically mediated (i.e., if it was entirely visual/experiential).

**DHH students’ misconceptions about the Earth-Sun-Moon relationship.**

Research has shown that students who are DHH possess similar misconceptions about the
Earth-Sun-Moon relationship as their peers with typical hearing. Roald and Mikalsen (2001) studied the understanding of lunar phases and cycles among DHH students aged 7, 9, 11, and 17 years and a comparison group of nine-year-old typically hearing students. The purpose of the study was to assess the conceptions of students who were DHH about moon phases and compare these conceptions with that of children with typical hearing to determine if there were any differences, and then to evaluate possible reasons for these differences.

When asked to explain the causes of moon phases, approximately half of the DHH students and half of the typically hearing students believed moon phases are caused by a reflection from the Sun (Roald & Mikalsen, 2001). One hearing student thought moon phases were relative to the point of view of the observer, while one 11-year-old DHH student believed the phases to be caused by a shadow from the Earth. Four of the typically hearing students and one DHH student thought that moon phases are caused by cloud cover. Finally, five DHH students believed moon phases to be caused by a physical change of the Moon (i.e., magical, animistic), while none of the typically hearing students shared this belief.

It is of note that DHH and typically hearing students across ages had a relatively similar explanatory power and inner coherence to their conceptions. The authors concluded that all but two of the 36 total students had synthetic conceptions, those that combined the observations and reasoning of their everyday experiences with fragments of scientific knowledge and reasoning (Roald & Mikalsen, 2001). Students demonstrated a high level of explanatory power and inner coherence in their conceptions, which, according to the authors, indicated “the non-scientific conceptions of the participants
were not caused by some deficiency in their logical capacity due to low age or to deafness, but were rather caused by the lack of scientific knowledge and the counterintuitivity of the scientific conceptions regarding these themes” (Roald & Mikalsen, 2001, p. 437).

Chapter Summary

The development of scientific discourse is a necessary and fundamental part of science learning; because many students who are DHH have little to no prior knowledge or understanding of basic scientific concepts or vocabulary (Lang, 1983, 1994; Vosnagoff et al., 2011), teachers must address these gaps while simultaneously addressing the individual needs of each student and providing instruction on grade-level curriculum standards. Analysis of the role of classroom talk in science is critical to an understanding of how concepts are developed and mediated for the student through discourse and how students integrate the concepts into their existing frameworks of understanding. Teachers are responsible for determining the nature and structure of science classroom talk, and their instructional choices can either support or constrain student learning (Crawford, 2005; Edwards, 1993). Analysis of teacher perceptions and the effects these perceptions have on the structure and content of classroom talk is an important piece in understanding how students who are DHH learn science concepts.
CHAPTER 3
METHODOLOGY

The purpose of this qualitative study is to identify and analyze the misconceptions students who are DHH may have regarding Earth-Sun-Moon concepts, and to explore the instructional techniques and classroom factors that support learning. The primary objective of this qualitative, exploratory study is to gain a more precise understanding of the ways DHH students assimilate science knowledge, and how classroom factors such as the language used during instruction and the teacher’s perceptions of student ability may influence this assimilation.

Design of the Study

Analysis focused on students’ understanding of concepts before and after an instructional unit on the Earth-Sun-Moon relationship. Data from classroom observations were analyzed to determine the influence of the language used during instruction on students’ ability to develop a scientifically accurate understanding of concepts related to the Earth-Sun-Moon relationship. Data from teacher interviews and researcher observations were used to inform the analysis of the influence that teachers’ perceptions may have on student learning.

Participants and Context

Participants were recruited from a school program that serves students who are DHH in the Midwestern United States. Participants included a middle school science teacher of students who are DHH as well as students in a seventh grade science class.
**Students.** Six students participated in this study. Purposeful criterion sampling was used to identify participants. In order to qualify for participation, student participants were required to (a) have a documented hearing loss, (b) be enrolled in the seventh grade, and (c) be able to communicate in sign language at a functional level.

Parental consent was obtained for all student participants. Parents were informed of the opportunity for their child to participate in the study via written communication from the researcher. This communication included an introduction letter and university Office of Responsible Research Practices consent documents. In addition, student assent was obtained verbally (via ASL) by the researcher prior to beginning the pre-instruction interview.

Along with consent to participate in the research study, parents were asked for permission to access their child’s cumulative school records to obtain information regarding demographic and achievement data. Demographic data obtained included: the student’s age, gender, degree of hearing loss, language(s) used in the home, family hearing status, and number of years enrolled in the current school. Achievement data obtained included, when available, scores from state standardized achievement tests and scores from assessments given as part of the students’ Evaluation Team Report (ETR), including academic skills as measured by the STAR Reading and STAR Mathematics assessments. The scores for the STAR Reading and STAR Mathematics assessments are provided as grade equivalent (GE) scores. Students were identified by randomly assigned numbers rather than by their names, and all data were kept in a secure location on a password-protected computer. See Table 3.1 for participant demographic and achievement information.
Table 3.1

**Student Demographic and Academic Achievement Data**

<table>
<thead>
<tr>
<th>Student #</th>
<th>Gender</th>
<th>Age</th>
<th>Degree of hearing loss</th>
<th>Hearing aid/CI used?</th>
<th>Primary home language</th>
<th>Parental hearing status</th>
<th>Years in current school</th>
<th>IQ</th>
<th>STAR Reading</th>
<th>STAR Math</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Male</td>
<td>14</td>
<td>n/a</td>
<td>NO</td>
<td>English</td>
<td>M/F - Hearing</td>
<td>8 yrs.</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>Sibling-Deaf</td>
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</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>13</td>
<td>R 100dB L 90dB</td>
<td>2 HA</td>
<td>English</td>
<td>Hearing</td>
<td>n/a</td>
<td>GE 2.4</td>
<td>GE 4.3</td>
<td></td>
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<tr>
<td>3</td>
<td>Male</td>
<td>14</td>
<td>R 90dB L 40dB</td>
<td>R HA L CI</td>
<td>ASL</td>
<td>M- Deaf F- Hearing Siblings-Deaf</td>
<td>3 yrs.</td>
<td>92 (PR)</td>
<td>80 (PS)</td>
<td>n/a</td>
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<tr>
<td>4</td>
<td>Male</td>
<td>12</td>
<td>R 90dB L 85dB</td>
<td>2 HA (not worn)</td>
<td>ASL</td>
<td>Deaf</td>
<td>1 mo.</td>
<td>n/a</td>
<td>GE 1.8</td>
<td>GE 3.5</td>
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<tr>
<td>5</td>
<td>Female</td>
<td>14</td>
<td>R 95dB L 90dB</td>
<td>2 HA</td>
<td>Sign language</td>
<td>Deaf</td>
<td>3 yrs.</td>
<td>n/a</td>
<td>GE 2.4</td>
<td>GE 4.2</td>
</tr>
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</tr>
<tr>
<td>6</td>
<td>Male</td>
<td>14</td>
<td>R 85dB L 80dB</td>
<td>2 HA</td>
<td>Somali &amp; English</td>
<td>M/F- Hearing</td>
<td>3 yrs.</td>
<td>72 (FSIQ)</td>
<td>GE 1.4</td>
<td>GE 3.3</td>
</tr>
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<td></td>
<td>Sibling-Deaf</td>
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</table>

*Note. HA = hearing aid; CI = cochlear implant; M = Mother; F = Father; PR = Perceptual reasoning; PS = Processing speed; FSIQ = Full-Scale IQ; GE = Grade Equivalent*

The six students were enrolled in the seventh grade class at the time this study was undertaken, and all six students had parental consent to participate in the study. Four of the students were male, and two were female. Students’ ages were between 12 and 14 years old. All of the students’ level of hearing loss was in the severe-to-profound range. Five of the students were reported to have at least one hearing aid, with one of these students having one hearing aid and one cochlear implant. Of these students, only two
participants consistently wore the hearing aid(s) or cochlear implant during school. All of the students used ASL in the classroom and as their primary mode of communication, and three of the six students were reported to use ASL to communicate in their homes. Three students had at least one parent who was deaf, and two of the students with hearing parents have a sibling who was also deaf. One of the six students was the only deaf person in her family. Five of the students had been attending the residential school for three or more years at the time of the study, while one student had enrolled just before the study began. Of the four students whose academic assessment data were on file, two had a reading score of 2.4 (GE), one had a score of 1.8 (GE), and one had a score of 1.4 (GE). Mathematics scores for these four students ranged from 3.3 (GE) to 4.3 (GE).

**Teacher.** Students received instruction from the middle school science teacher at the residential school for the deaf. The teacher has a master’s degree in deaf education, is a certified teacher of students who are DHH, and is considered “highly qualified” to teach science based on multiple state and federal criteria. The teacher has been teaching science to middle school students who are DHH for 16 years, with all of her experience in the same school where the study took place. Although she is not deaf, the teacher participant is fluent in ASL and uses this as the primary language of instruction in the science classroom.

**Participant observer.** The researcher has a background as an elementary school teacher of students who are DHH and as an ASL interpreter. The researcher has both a bachelor’s and a master’s degree in deaf Education, and held licensure to teach students for over 10 years. The researcher gained experience in conducting qualitative research studies through coursework and practicum experiences that involved designing,
conducting, analyzing, and reporting findings. She conducted a pilot study that utilized a similar methodology as the current study, which further added to her specialized experience in conducting conceptual change research with students who are DHH.

The researcher was a participant observer in the classroom during all instruction that occurred on the Earth-Sun-Moon relationship. During this time, the researcher audio- and video-recorded instruction and other classroom events. Additionally, the researcher kept field notes that documented information such as observations, events of interest, and classroom design and layout. The researcher conducted all interviews of the student and teacher participants, which were also audio- and video-recorded.

**Setting**

The data collected for this study included classroom observations, and teacher and student interviews. All data collection took place at a residential school for the deaf in the Midwestern United States. The seventh grade class had six students enrolled, all of whom were identified as deaf or hard of hearing sign language users.

The science classroom was located in the middle school wing of the school building. Entry to the classroom was made through a door at the back of the room in the southwest corner. Just inside the classroom, the wall to the right of the door (south) was lined with cabinets and countertop space. On the counter were baskets for students to place completed assignments, small shelves where workbooks were kept, and displays of previously completed projects. Immediately inside the room, about five feet beyond the door, was a small table with three chairs placed around it.

In the center of the classroom, student lab tables were arranged in a horseshoe configuration with the open side facing the front of the room, which maximized the
visibility of the whiteboard and Smartboard situated on the front (east) wall. The
majority of instruction occurred in this space, with students seated at the lab tables and
the teacher standing at the front. The teacher’s desk was located to the left of this
instructional space in the northeast corner of the room. Behind the teacher’s desk, along
the north wall of the room, were cabinets that stored instructional and other materials. To
the left of these cabinets, and visible directly when walking into the room, were a series
of large windows. In the northwest corner of the room were two desktop computers on
tables arranged such that students seated at these tables would be sitting facing one
another. Along the back (west) wall of the room were additional cabinets that stored all
of the hands-on materials used during experiments and other activities. Posters were
hung on these cabinets, and along the back wall of the classroom, that provided
information such as the steps of the scientific method and students’ classroom duties.

Data Collection

The data collected for this study includes student interviews, teacher interviews,
classroom observations, and field notes.

Student interviews. A semi-structured protocol was used to interview students
about their understanding of concepts related to the Earth-Sun-Moon relationship, and to
lunar phases and eclipses. The interview questions were designed to assess students’
knowledge of vocabulary and concepts related to the Earth-Sun-Moon relationship, and
to lunar phases and eclipses. The interviews were conducted prior to instruction and again
at the conclusion of the unit to provide information about their understandings before and
after instruction. The student interview questions were designed to reflect the content of
the instructional unit on moon phases and eclipses, and are thus directly linked to state
and national content standards in Earth Science. The semi-structured interview protocol used was structured in a manner similar to that used in previously conducted research of students’ understanding of lunar concepts (Stahly et al., 1999; Trundle et al., 2007) (see Appendix B for Student Interview Questions).

Pre-instruction interviews were conducted approximately two weeks prior to the beginning of instruction. All students were interviewed during the same class period, and all interviews took place in a private room out of the view of the teacher or other students. Participants were not informed of the content of the interviews in advance and were not able to discuss the interview content or procedures with other students.

Post-instruction interviews were conducted approximately two weeks after participants completed the unit on the Earth-Sun-Moon relationship. The interviews took place over two class periods with three students completing their interviews the first day and three completing on the second, and all interviews took place in a private room out of the view of the teacher or other students. Participants were not informed of the content of the interviews in advance, but the questions asked during the post-instruction interview were identical to the questions asked during the pre-instruction interview.

First, in order to assess their knowledge of target vocabulary, students were asked to provide the ASL sign for each of the words that were studied during the unit: satellite, eclipse, umbra, lunar phase, penumbra, Earth, moon, sun, rotation, revolution, and axis. Each word was printed on a 3 in. x 5 in. notecard. Students were shown each card and given the opportunity to respond. If no response was given, the researcher continued to the next card. Next, students were asked a series of content-related questions (see Appendix B).
Students’ conceptual understanding of the Earth-Moon-Sun relationship was assessed in three areas: (1) movement in orbit/rotation; (2) the role of gravity; and (3) the changes seen on the Earth as it orbits. When asked to demonstrate the rotation of the Earth, the Sun, and the Moon, students were provided with a model to use to represent each of the three bodies. Students were given three different-sized Styrofoam balls that had been placed on wooden sticks and were told that a medium-sized ball represented the Earth, a large ball represented the Sun, and a small ball represented the Moon. The final set of questions probed students’ understanding of lunar concepts. Students were asked if it was possible to see all sides of the Moon from the Earth, to describe the lunar cycle and how the Moon looks different at different times, and to explain what happens during a lunar eclipse.

The focus of the student interviews was on the student responses and did not impose scientific viewpoints of the concepts in order to follow established protocol (Barbour & Schostak, 2005). Semi-structured interview questions do not offer choices from which the respondent selects an answer (i.e., multiple choice assessments) (McMillan & Schumacher, 2006), therefore, responses were not guided by any external suggestion. The researcher made every effort to avoid asking probing questions that would provide students with additional or leading information.

Pre- and post-instruction interviews were audio- and video-recorded for analysis. The researcher kept field notes during the interviews as well. All interviews were transcribed for data analysis by the researcher. A second researcher who is ASL fluent reviewed the transcripts to ensure accuracy of translation from sign language into English. Themes and patterns that emerge from the data were coded and analyzed.
regarding participants’ conceptual understanding and language use. Two additional researchers with experience in conceptual change data analysis and the coding system used in this study independently coded students’ interview data. These codes were compared to those of the researcher, and discrepancies were addressed through discussion until consensus was reached.

**Teacher interviews.** The teacher participant was interviewed before and after the completion of the unit. The pre-instruction interview was designed to gain insight into the teacher’s pedagogical approach to instruction and to identify her expectations for student learning. The teacher was also asked to demonstrate the signs she uses for the vocabulary words/concepts that were included in the unit of instruction.

The post-instruction interview questions focused on the teacher’s reflections about her instruction and the degree to which she thought students experienced a change in their understanding of the concepts taught during the unit. She was asked how she felt the students’ learning progressed through the course of the unit, and if she made modifications to her original plans to accommodate students’ preconceptions or otherwise differentiate instruction. (See Appendix C for pre- and post-instruction teacher interview questions.)

**Classroom observations.** The lesson plan for the unit on moon phases and eclipses was developed by the teacher participant, based on state content standards and with the use of the curriculum series *Science Fusion, Seventh Grade, Module G* (Houghton Mifflin Harcourt, 2012). *Science Fusion* is the curriculum series used to teach middle school science at the research site and is an inquiry-based, multi-modal
curriculum designed to align with the Next Generation Science Framework (Houghton Mifflin Harcourt, 2012).

The unit on moon phases and eclipses took place over 10, 50-minute class periods, all of which were audio- and video-recorded for their duration. Field notes were also taken by the researcher during this phase of the study. The 10 days of instruction were not concurrent; there were several days during which instruction did not occur due to school activities or inclement weather, and these instances are noted below. The following is a summary of the instruction that occurred on each day of the unit.

**Day 1.** The first day of the unit began with the teacher asking the students to answer the question, “What do you know about the moon?” in their science journals. Then, the teacher engaged the students in a discussion about the Moon, asking “does the Moon look the same every day, or does it change?” The teacher then used a model of the Moon and the Earth—a globe and a small Styrofoam ball on a pencil, to represent the Moon—to demonstrate the Moon’s orbit around the Earth. Next, the teacher asked, “What pulls the Moon? Can it float away from the Earth?” Following a brief discussion, the teacher invited two students to the front of the room to demonstrate the force of gravity. She asked the two students to hold hands, lean back, and move in a circle, and then asked, “What do you feel? Do you feel a pull? What would happen if you let go?” Next, the teacher wrote the word *satellite* on the board and asked students if they knew the meaning of the word. This led to an extensive discussion of the two different signs for *satellite*, which can be differentiated as either a communications satellite or an object that orbits another object. Finally, the teacher explained the moon phase calendar activity the students would begin working on the following day.
**Day 2.** The second lesson began with the teacher using the same models of the Moon and the Earth used during the orbit demonstration on Day 1. She first asked a student to demonstrate how the Moon orbits around the Earth. During this demonstration, it was emphasized by the teacher that only one side of the Moon is visible from the Earth. Moon phases and the moon phase calendar activity were then introduced using a moon phase simulator that the teacher projected onto the Smartboard from a United States Naval Observatory website (http://tycho.usno.navy.mil/vphase.html). From this site, one is able to view the Moon’s phase at any point in time from 1800 A.D. to 2199 A.D. at four-hour intervals. Students were each given a blank calendar and asked to each get a laptop computer to use to access the website. The students were instructed to choose a beginning date and then record the moon phase that occurred on each day thereafter for a 30-day period. Students worked on this assignment with the teacher’s support for the rest of the class period.

*Note there were three days between Day 2 and Day 3 during which instruction did not occur due to: (1) a federal holiday; (2) a snow day; (3) a teacher meeting during which the students were given work by a substitute and the unit material was not covered.*

**Day 3.** The third day of instruction began with the teacher reviewing the students’ moon phases assignment given on Day 2. One student’s completed assignment was displayed on the Smartboard using a projector, and the response given for each day on the calendar was discussed. There was confusion among many students regarding the correct manner in which to shade the Moon in each phase, particularly the full and new moon phases. This confusion seemed to be related to the sense that shading the entire moon was perceived as a full moon phase; however, the teacher emphasized that an all-
black moon would not be visible in the dark, but a white, lit moon would be visible.

Following the group’s discussion of the assignment, the class moved to the back of the room where the teacher set up a model of the Earth-Sun-Moon system. This model consisted of a globe (the Earth), a lamp (the Sun), and a volleyball (the Moon). Students were shown how moving the Moon (the volleyball) in different positions around the globe (the Earth) would change the reflection and shadow on the Moon’s (the volleyball’s) surface. Then, students manipulated the model to create each of the moon phases with the light from the Sun (the lamp) and shadow on the Moon (the volleyball).

*Note that one day of instruction was missed between Day 3 and Day 4 due to a field trip which was unrelated to the unit material.*

**Day 4.** The fourth day began with a discussion of the force of gravity and how it is exerted on the Moon by the Earth. During this discussion, the teacher referred to a bird’s-eye view diagram of the Earth-Sun-Moon system and orbits that was displayed on the Smartboard. The teacher then showed the students their next assignment—a worksheet with a diagram of the phases of the Moon, each with a blank line next to it. She explained that the students were to label each phase with the correct name (i.e., waxing gibbous, first quarter) and said that she would set up the globe/lamp/volleyball model for them to use if needed. Students were given time to work on their assignments and the teacher continued providing support. After several minutes, the teacher seemed to recognize that students were having difficulty with some of the names of the moon phases, and called their attention back to the front of the classroom. She showed a short video simulation of the Moon moving through each phase on the Smartboard, stopping at each phase to review the phase name, which was shown below each image of the
changing moon. She asked students to copy from the whiteboard into their notebooks the definitions for *waxing* (getting bigger) and *waning* (getting smaller). Students then used the information on the Smartboard video to complete the labeling assignment.

**Day 5.** Day 5 began with the teacher helping two students (S1 and S6) to complete their moon phases labeling assignment from the previous day. The teacher and two students were working at the back of the room, using the lamp/globe/volleyball model and labeled moon phase picture cards to help conceptually link the two ideas. The remaining four students worked at their seats in their workbooks, completing an assignment related to the unit. After S1 and S6 completed their work, the teacher called attention to the front of the room. She presented information on the Smartboard about the reflection of the Sun’s rays on the Earth and the Moon, and introduced the vocabulary terms *umbra* and *penumbra*.

**Day 6.** The teacher began Day 6 with the words *waxing* and *waning* written on the whiteboard. She reviewed the meaning of these words with the students, and then told the class they would be working in two groups on two different activities. She instructed one group (S1, S3, S6) to begin at the Smartboard and the second group (S2, S4, S5) to begin at the globe/lamp/volleyball model at the back of the room. Students at the Smartboard were instructed to take turns completing an interactive module in which they would order and label the phases of the Moon according to the lunar phase chart. The students at the back of the room were instructed to take turns either answering which phase the Moon was in at each point, holding the volleyball (the Moon) and moving through each phase, or checking the answers of the student whose turn it was. The teacher spent the majority of the time supporting the students who were working on the
activity with the model at the back of the room. When each group was finished with its first activity, it was asked to switch activities with the other group and complete the second assignment.

**Day 7.** Solar and lunar eclipses were introduced during this lesson. The teacher showed several online video clips to show what the Moon looks like during a lunar eclipse and what the Sun looks like during a solar eclipse. These videos were shown on the Smartboard, and students were given opportunities to ask questions while the teacher explained how these phenomena occur. Following the discussion of the videos, students were instructed to write in their journals what had happened in each of the video clips. Next, the class returned to the globe/lamp/volleyball model. The volleyball was replaced with a more accurately scale-sized Styrofoam ball on a stick to represent the Moon. The teacher explained that the Moon orbits the Earth following the equator and that the Earth is tilted rather than straight up and down. She then explained that when the Earth is tilted on its axis, the Moon can sometimes be blocked by the Earth, and the Sun’s rays can’t be seen for a short period of time.

**Day 8.** The teacher set up six independent work stations for students to rotate through and complete individually. The teacher began by passing out an answer sheet for students to mark responses on at each station. She then listed each station on the whiteboard and pointed to where it was located in the room. Each student was assigned to each begin at a particular station, and then rotate clockwise through the stations until he or she had completed all six. The six stations were labeled by their target activity and were thus called *Illustrate It, Assess It, Research It, Organize It, Watch It, and Explore It.*
The directions for the activity were printed on cards at the station. A brief summary of each follows.

At the Illustrate It station, the instructions included an outline of the lunar cycle diagram (Figure 3.1) and instructions to use the outline as a model from which the student should make a drawing on his or her answer sheet to “show the light on the moons as we would see them from the Earth in their given positions.” At the Assess It station, there were four multiple-choice questions printed on cards for students to answer on their answer sheets. Questions included, “What phase comes after a waxing crescent?” and “What is the difference between waxing and waning?”

Figure 3.1.

*Lunar cycle diagram*

![Lunar cycle diagram](image)

The Research It station was set up at one of the classroom computers. Students were to use the website that had already been loaded on the computer and complete interactive tasks such as, “Illuminate the moon and Earth with the correct light” and “Choose the correct moon phases.” The Watch It station was set up at the other
classroom computer with a video loaded and ready. Students were to watch the video and answer questions on their answer sheets including, “What phase is it when the moon is between Earth and the sun?” At the Explore It station, students were instructed to set up a model of the Sun (a flashlight), the Moon, and the Earth (two Styrofoam balls of different sizes on sticks). They were to then follow the instructions and answer questions printed on a card as follows: “1) Slowly revolve (orbit) the moon counter-clockwise around the Earth. Move behind the Earth (opposite the moon) as the moon orbits; 2) On your lab sheet discuss what happens to the light as you look at the moon from Earth. Stop when you get to the full moon.”

Students spent the remainder of the period working at each station, and the teacher moved around the room to offer support as students needed it.

**Day 9.** On this day, the class reviewed the information learned in the unit introduced during this study using a quiz designed by the teacher and presented on the Smartboard. The teacher created a practice test with a multiple choice response format to prepare for the following day’s assessment. Students used clickers to respond to questions displayed on the Smartboard, and then answers were reviewed to make sure all students understood the correct answer to each question.

**Day 10.** On the final day of the unit, students were given a written assessment to determine their level of understanding of the concepts presented in the unit. All students were given an assessment that was modified from the textbook format to present questions in a simplified format. Three of the six students were given an assessment that was further simplified, with less print. All students were given reading support by the teacher when needed.
**Data Analysis**

The recorded videos of students’ pre- and post-instruction interviews were transcribed by the primary researcher, which included the process of translating responses from ASL to English. Constant comparative analysis of this data set was then undertaken by the primary researcher and later checked for agreement with two additional researchers.

**Constant comparative analysis of conceptual change.** Data from the pre- and post-instruction interviews were analyzed using the constant comparative method (Glaser & Strauss, 1967). This methodology has been utilized in previous research (see Trundle et al., 2002, 2007a, 2007b) including research conducted with students who have sensory impairments (Hilson, Hobson, & Wild, 2016; Wild, 2008, 2011; Wild & Trundle, 2010; Wild, Hilson, & Farrand, 2013).

According to Glaser (1965), constant comparative analysis consists of four stages: “(1) comparing incidents applicable to each category, (2) integrating categories and their properties, (3) delimiting the theory, and (4) writing the theory” (p. 439). Boeije (2002) outlined three steps used in the coding of interviews that are consistent with constant comparative data analysis: (1) comparison of data within a single interview to a code framework; (2) comparison of interviews within the same group to the coded framework; and (3) comparison of interviews of different groups to the coded framework (Boeije, 2002).

This type of analysis supports theory generation in a systematic manner, using “explicit coding and analytic procedures” (Glaser, 1965, p. 437). This method of analysis allows for simultaneous coding and analysis to identify gaps, omissions, or
inconsistencies in the data (Glasser, & Strauss, 1967). Analysis of students’ conceptual change began with an established partial coding framework, detailed below, and new codes were added as they emerged during the coding process. The coding framework is designed to facilitate analysis and standardize coding, but is not intended to restrict the coding process (Trundle et al., 2002). The researcher developed the initial coding framework, and the codes were added during discussion and analysis with the researchers who participated in the data analysis.

**Development of a coding framework.** A preliminary coding framework was developed in order to answer the following research questions:

1. What are seventh grade DHH students’ pre-instruction conceptions of the relationship between the Earth, the Sun, and the Moon?
2. How do seventh-grade DHH students’ post-instruction conceptions of the Earth-Sun-Moon relationship differ from their pre-instruction conceptions?

Changes in students’ conceptual understanding were evaluated based on the seven categories of conceptual understanding established in previous research by Trundle and others (Hilson et al., 2016; Trundle et al., 2002, 2007a, 2007b; Saçkes, 2010; Wild, 2008; Wild & Trundle, 2010; Wild et al., 2013) (see Table 3.2). The seven types of conceptual understanding are as follows: (1) *scientific understanding* which includes all of the elements of a scientific conception; (2) *scientific fragment* which includes some but not all of the elements of scientific understanding, and no alternative ideas are included; (3) *scientific fragment with alternative fragment* which include a subset of the scientific conception with at least one fragment of an alternative conception; (4) *alternative fragment with a scientific fragment* which include multiple alternative conceptions and
only one scientific concept; (5) *alternative understanding* which includes misconceptions, or understandings that do not agree with scientifically correct understandings; (6) *alternative fragments* which include one or more subsets of alternative conceptual understanding; and (7) *no understanding* which includes no evidence of the understanding of concepts (Hilson et al., 2016; Trundle et al., 2002, 2007a, 2007b, 2010; Saçkes, 2010; Wild, 2008; Wild & Trundle, 2010; Wild et al., 2013).

Table 3.2.

*Categories of Conceptual Understandings and Criteria for Identification Specific to Science Study of the Earth-Sun-Moon Relationship (adapted from Trundle et al., 2002, 2007a, 2007b; Saçkes, 2010)*

<table>
<thead>
<tr>
<th>Types of Conceptual Understandings</th>
<th>Criteria for Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Understanding</td>
<td>Includes all critical elements of understanding</td>
</tr>
<tr>
<td>Scientific Fragments</td>
<td>Includes a subset, but not all of the concepts identified as scientific understanding of the Earth-Sun-Moon relationship, and no alternative ideas are included</td>
</tr>
<tr>
<td>Scientific Fragments with Alternative Fragments</td>
<td>Includes a subset of scientific conceptions of the Earth-Sun-Moon relationship with at least one fragment of alternative conceptions</td>
</tr>
<tr>
<td>Alternative Fragments with a Scientific Fragment</td>
<td>Conceptual understanding that contains multiple alternative conceptions and only one scientific concept</td>
</tr>
</tbody>
</table>

continued
Table 3.2. continued

<table>
<thead>
<tr>
<th>Types of Conceptual Understandings</th>
<th>Criteria for Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative Understanding</td>
<td>Conceptual understanding that does not agree with the scientifically accepted norms</td>
</tr>
<tr>
<td>Alternative Fragments</td>
<td>Includes a subset or subsets of alternative conceptual understanding</td>
</tr>
<tr>
<td>No Understanding</td>
<td>Exhibits no evidence of understanding of concepts</td>
</tr>
</tbody>
</table>

The content-knowledge codes (Table 3.3) are categorized as being characteristic of either a scientific understanding (SCI_) or of an alternative conception (ALT_).

Scientifically accurate concepts are the target concepts for learning and are outlined in state and national content standards and curricular materials (Houghton Mifflin Harcourt, 2012; NGSS, 2012; Ohio Department of Education, 2012). The alternative conception codes are drawn from the misconceptions literature related to moon phases and eclipses (Barnett & Morran, 2002; Dunlop, 2000; Roald & Mikalsen, 2001; Trundle et al., 2002; 2007a; 2007b; Za’rour, 1976).

**Scientific understanding: Earth-Sun-Moon relationship.** Students’ conceptual understanding of the Earth-Sun-Moon relationship was assessed in three areas: the movement in orbit/rotation, the role of gravity, and the changes seen on the Earth as it orbits. With regard to the movement in orbit/rotation, a response was considered scientific if the student demonstrated an understanding that the Earth orbits the Sun, and the Moon orbits the Earth (NGSS, 2012; ODE, 2012). A scientific understanding of the
importance of gravity to the Earth-Sun-Moon relationship holds that the Moon is held in orbit around the Earth because of the Earth’s gravity, or gravity holds the Earth and the Moon together (Houghton Mifflin Harcourt, 2012; NGSS, 2012). A response to the third component was considered scientific if the student conveyed an understanding that the Earth’s rotation and revolution produce changes that can be seen on earth (i.e., days, seasons) (Houghton Mifflin Harcourt, 2012).

**Scientific understanding: Lunar concepts.** Students’ understanding of lunar concepts was assessed in three areas. First, students were asked: (a) if it is possible to see all sides of the Moon from earth; (b) to describe the lunar cycle and how the Moon looks different at different times; and (c) to explain what happens during a lunar eclipse. A response to the question, “Is it possible to see the whole moon from earth?” was considered scientific if the student explained that only one side of the Moon is visible on earth (Houghton Mifflin Harcourt, 2012). A response to the question regarding the lunar cycle was considered scientific if the student included all of the phases of the Moon in the correct order (Houghton Mifflin Harcourt, 2012; NGSS, 2012). A response to the question regarding the lunar eclipse was considered scientific if the student explained that a lunar eclipse happens when the Earth passes between a full moon and the Sun, so the side of the Moon visible on earth travels through the Earth’s shadow (Houghton Mifflin Harcourt, 2012; ODE, 2012). SCI_CYCLE indicates a scientific understanding of the progression of the moon through a cycle; during a new moon, the Moon is between Earth and the Sun. As the Moon moves along its orbit, the sunlit side of the Moon waxes until a full moon is seen, when Earth is between the Sun and the Moon. Then, the sunlit side of the Moon wanes and a new moon is seen. Finally, SCI_SIDE is a scientific understanding
that only one side of the Moon can be seen from earth because the Moon turns once on its axis each time it orbits the Earth. See Table 3.3 for a summary of the preliminary coding framework.

Table 3.3.

*Preliminary Coding Framework with Code Definitions (Trundle et al., 2007a, 2007b, 2010)*

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition of Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI_ECLIPSE</td>
<td>A lunar eclipse happens when the entire moon passes through the Earth’s shadow. A total lunar eclipse occurs when the Moon passes through the Earth’s umbra, the darkest part of its shadow. A partial lunar eclipse occurs when part of the Moon stays sunlit (Houghton Mifflin Harcourt, 2012; ODE, 2012)</td>
</tr>
<tr>
<td>SCI_GRAVITY</td>
<td>Gravity holds the Earth in orbit around the Sun, and it holds the Moon in orbit around the Earth (Houghton Mifflin Harcourt, 2012; NGSS, 2012)</td>
</tr>
<tr>
<td>SCI_ORBIT</td>
<td>The Earth orbits the Sun, and the Moon orbits the Earth. At times, the Moon is between Earth and the Sun (NGSS, 2012; ODE, 2012)</td>
</tr>
<tr>
<td>SCI_PHASE</td>
<td>Lunar phases are the different appearances of the Moon due to its changing position relative to the Sun and the Earth (Houghton Mifflin Harcourt, 2012; NGSS, 2012)</td>
</tr>
<tr>
<td>SCI_CYCLE</td>
<td>During a new moon, the Moon is between the Earth and the Sun. As the Moon moves along its orbit, the sunlit side of the Moon waxes until a full moon is seen, when the Earth is between the Sun and the Moon. Then, the sunlit side of the Moon wanes and a new moon is seen (Houghton Mifflin Harcourt, 2012; NGSS, 2012)</td>
</tr>
</tbody>
</table>

continued
Table 3.3 continued

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition of Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCI_SIDE</td>
<td>Only one side of the moon can be seen from the Earth because the Moon turns once on its axis each time it orbits the Earth (Houghton Mifflin Harcourt, 2012)</td>
</tr>
<tr>
<td>ALT_ECLIPSE</td>
<td>Dark part of the Moon is in the Earth’s shadow; phases are caused by the Earth’s shadow (Baxter, 1989; Trundle et al., 2010)</td>
</tr>
<tr>
<td>ALT_ROT</td>
<td>The Earth’s rotation on its axis causes the moon phases (Trundle et al., 2010)</td>
</tr>
<tr>
<td>ALT_ETILT</td>
<td>The tilt of the Earth on its axis causes the moon phases (Trundle et al., 2010)</td>
</tr>
<tr>
<td>ALT_GEO</td>
<td>The moon phases are relative to the observer’s position on earth; people in different geographical positions see different moon phases (Roald &amp; Mikalsen, 2001; Trundle et al., 2010)</td>
</tr>
</tbody>
</table>

*Alternative understandings (misconceptions).* Preliminary codes for alternative understandings of moon phases and eclipses are taken from previous work of Trundle and others (Baxter, 1989; Roald & Mikalsen, 2001; Trundle et al., 2010). ALT_ECLIPSE indicates the eclipse model misconception, or the understanding that the dark part of the Moon is in Earth’s shadow and phases are caused by the Earth’s shadow. The code ALT_ROT indicates the alternative understanding that the Earth’s rotation on its axis causes phases. ALT_ETILT describes an alternative understanding that the tilt of the Earth on its axis causes moon phases. Finally, ALT_GEO indicates the alternative
understanding that moon phases are relative to the observer’s position on earth, or, that people in different geographical positions see different moon phases.

Additional codes were identified during the data collection process and were added to the framework. These codes included ALT_REV, which indicated a reversal of the movement of a sign, ALT_REVO, which indicated the response was “revolution” when asked for the sign “rotation,” ALT_COLOR which indicated a response about the Moon’s changing appearance as the changing color of the Moon rather than the changing shape, and ALT_AIR when a response to gravity included a reference to air being a factor.

**Constant comparative analysis and coding.** Each student’s interviews were coded for conceptual change using the codes defined above. Additionally, each transcript was analyzed by the researcher to determine the conceptual content of responses and to assign each response a code based on the coding scheme. New codes were added when responses did not match codes that had been established in the preliminary system. During the coding process, the researcher continually checked the assignment of codes against other determinations to maintain consistency in the coding of responses. Two additional researchers with experience in conceptual change data analysis independently coded students’ interview data with the coding system utilized in this study. These codes were compared to those of the researcher, and discrepancies were addressed through discussion until consensus was reached.

Students’ coded responses from the pre- and post-instruction interviews were compared to determine the degree to which, on an individual level, a change in understanding occurred during instruction. Each student’s change in understanding was
evaluated in each of the conceptual domains to determine the degree of conceptual change. This analysis elicited a typology of the conceptual changes that occurred during instruction.

**Analysis of Classroom Talk**

Classroom observation video data were analyzed based on the analytical framework proposed by Mortimer and Scott (2003). The purpose of this analysis was to provide qualitative, descriptive data on how classroom talk supports conceptual change in students who are DHH. To this end, four elements of instruction suggested by Mortimer and Scott (2003) were analyzed—teaching purposes, content, communicative approach, and patterns of discourse. As suggested by Mortimer and Scott (2003), the following questions were used to frame the initial analysis of instructional events in the following domains of the framework:

- **Teaching purposes**: What purpose(s) is served, with regard to the science being taught, by this phase of the lesson?
- **Content**: What is the nature of the knowledge that the teacher and students are talking about during this phase?
- **Communicative approach**: How does the teacher work with the students to address the diversity of ideas present in the class during this phase of the lesson?
- **Patterns of discourse**: What are the patterns of interaction that develop in the discourse as teacher and students take turns in classroom talk?

**Trustworthiness**

The quality and rigor of a qualitative research study can be determined by an analysis of the trustworthiness of the study’s design, data collection, and data analysis.
According to Denzin and Lincoln (1994), the trustworthiness of findings can be established by considering four factors: credibility, transferability, dependability, and confirmability. This study was evaluated for trustworthiness through checks of credibility, measured by data triangulation to address credibility and transferability concerns, and confirmability, which used inter-rater reliability as a measure. The details along each of these factors is below.

Credibility refers to “the confidence one can have in the truth of the findings” (Bowen, 2005, p. 215). For the purposes of this study, credibility was established through the use of data triangulation and member checking. Triangulation is a method for establishing credibility that involves the collection of data using multiple methods in order to cross-validate findings (Somekh & Lewin, 2005).

Data triangulation was achieved through the analysis of several pieces of data. The data analyzed in this study included student interviews, teacher interviews, classroom observations, and field notes. All data were consulted during analysis to inform findings.

Member checking is also an important determinant of credibility. According to Shenton (2004), member checking “may take place “on the spot,” in the course, and at the end, of the data collection dialogues (p. 68). During the pre-and post-instruction student and teacher interviews, “on the spot” (Shenton, 2004, p. 68) member checks were conducted by the researcher in order to confirm her understanding or interpretation of a participant’s response. This check involved the researcher rephrasing or repeating the response to confirm a correct interpretation of the response, or probing the participant to explain further if his or her response was unclear.
Confirmability has been defined as “the internal coherence of the data in relation to the findings, interpretations, and recommendations” (Bowen, 2005, p. 216). Confirmability of the findings of this study was achieved through checks of the accuracy of the ASL-English translation and transcription results and of the interrater reliability for the coding of student conceptual change data; the procedures of each are both detailed below.

**Translation and transcription.** Following data collection, the researcher transcribed and translated each students’ pre- and post-instruction interviews from ASL to English. To begin, the researcher created a verbatim gloss of the students’ ASL responses. Then, the researcher viewed each of the interviews and compared them against the glossed information. The second step further translated the gloss into conceptually accurate English, to the extent possible. A second researcher who is ASL fluent independently transcribed and translated all students’ pre- and post-instruction interviews. The two researchers then met and compared the transcripts to identify any discrepancies. When there were differences between the two researchers’ translations, the translations were discussed and a consensus was reached. The two researchers ultimately reached 100% agreement on the ASL-to-English transcript translation of all students’ pre- and post-instruction interviews.

**Coding conceptual change data.** Transcripts of the pre- and post-instruction student interviews were coded independently by the primary researcher and two additional researchers. Both of the non-primary researchers were certified science teachers with years of experience teaching science to (typically hearing) students in a K-12 setting. Additionally, they both have extensive experience in qualitative analysis,
including in the analysis of student conceptual change in science learning with the coding framework utilized in the present study.

The initial round of independent coding was followed by a meeting of all three researchers to, first, clarify portions of the data that were unclear due to translation issues between ASL and English, and then to discuss any coding discrepancies. Because neither of the researchers conducting the reliability check had experience with ASL or working with students who are ASL users, some translations did not adequately convey the true content of the student’s response. For example, when a student explained the movement of the Earth, the Sun, and the Moon in relation to one another, much of the information being expressed was gestural, and movement and location were embedded in one sign. This information was not clearly translatable to English without altering the true content of what was said.

Therefore, in the face-to-face researchers’ meeting, the discussion of code assignment and rater agreement involved the primary researcher clarifying the conceptual content of the responses that may have been unclear in translation and, in some cases, demonstrating the student’s response so the raters could more easily see the embedded information (e.g., movement, placement). Prior to a discussion and clarification of the students’ responses, the coding agreement of the three researchers was 75%. Following the discussion and clarification of all items in each student’s pre- and post-instruction interview, the three raters reached 99% agreement on the interview data codes.
CHAPTER 4

FINDINGS

Introduction

The purpose of this qualitative study was to identify and analyze the misconceptions DHH students may have regarding scientific concepts and to evaluate how instructional factors such as classroom talk and teacher perceptions of student learning support conceptual change. This study specifically addresses seventh-grade DHH students’ understandings and/or misconceptions about the Earth-Sun-Moon relationship. Analysis focused on students’ conceptual understandings both before and after participation in an instructional unit on the Earth-Sun-Moon relationship. Interview data of students’ understandings of the Earth-Sun-Moon relationship were taken approximately two weeks prior to, and then two weeks after, instruction occurred. Data from classroom observations conducted during instruction were also collected using audio- and video-recording and field notes taken by the researcher to determine the influence of classroom language on students’ understanding of concepts. The influence of teacher perceptions was also addressed as a potential factor in student learning, using data collected in pre- and post-instruction teacher interviews.

The following research questions were the focus of inquiry and analysis for the study:

1. What are seventh-grade DHH students’ pre-instruction conceptions of the relationship between the Earth, the Sun, and the Moon?
2. How do seventh-grade DHH students’ post-instruction conceptions of the Earth-Sun-Moon relationship differ from their pre-instruction conceptions?

3. How does classroom talk influence changes in seventh-grade DHH students’ understanding of Earth-Sun-Moon concepts?

4. How does the teacher perceive the effectiveness of her instruction?

The chapter is structured as follows: first, representative types of conceptual understandings are outlined along with examples of student responses in each category, the codes that were assigned to each response, and the rationale for the assignment of the code; next, the findings of the study with regard to student conceptual change are presented, including a discussion of the pre- and post-instruction student interview data; then, an analysis of the influence of classroom talk on student learning is presented; and finally, the influence of the teacher’s perceptions on her instruction and of students’ learning is reviewed and discussed in light of the findings of the conceptual change and classroom talk aspects of this study.

**Representative Types of Conceptual Understandings**

Changes in students’ conceptual understanding were analyzed using the seven categories of conceptual understanding developed by Trundle and colleagues (Trundle et al., 2002, 2006, 2007a, 2007b, 2010; Saçkes 2010): scientific, scientific fragment, scientific fragment with alternative fragment, alternative fragment with a scientific fragment, alternative understanding, alternative fragment, or no understanding, which were described in detail in Chapter 3 and can be found in Table 3.2. This framework has been used in other research on conceptual change in the science learning of students (Saçkes 2010; Trundle et al., 2002, 2006, 2007a, 2007b, 2010), including students with
sensory disabilities (Hilson et al., 2016; Wild, 2008; Wild & Trundle, 2010; Wild et al., 2013). Examples of student responses in each category are presented below, along with the codes that were assigned to each response and the rationale for the assignment of the code.

**Scientific understanding.** Scientifically accurate concepts are the target concepts for learning and are outlined in state and national content standards and curricular materials (Houghton Mifflin Harcourt, 2012; NGSS, 2012; ODE, 2012). A response that is considered *scientifically accurate* includes all of the elements of a scientific conception. Students’ scientific understanding was assessed in two areas: the Earth-Sun-Moon relationship, and lunar phases and eclipses.

**Scientific understanding: Earth-Sun-Moon relationship.** Students’ conceptual understanding of the Earth-Sun-Moon relationship was assessed in three areas. Students were asked: (1) to describe the Earth-Moon-Sun relationship using a model; (2) if gravity was important to the Earth-Sun-Moon relationship; and (3) what kinds of changes the rotation of the Earth around the Sun produces on earth. With regard to movement in orbit/rotation, a response was considered scientific if the student demonstrated an understanding that the Earth orbits the Sun, and the Moon orbits the Earth (SCI_ORBIT) (NGSS, 2012; ODE, 2012). A scientific understanding of the importance of gravity to the Earth-Sun-Moon relationship (SCI_GRAVITY) holds that the moon is held in orbit around Earth because of Earth’s gravity, or gravity holds the Earth and moon together (Houghton Mifflin Harcourt, 2012; NGSS, 2012). A response to the third component was considered scientific if the student conveyed an understanding that the Earth’s
rotation and revolution produce changes that can be seen from earth (i.e., days, seasons) (SCI_CHANGE) (Houghton Mifflin Harcourt, 2012).

*Scientific understanding: Lunar concepts.* Students’ understanding of lunar concepts was assessed in three areas. Students were asked: (a) if it is possible to see all sides of the Moon from earth; (b) to describe the lunar cycle and how the Moon looks different at different times; and (c) to explain what happens during a lunar eclipse. A response to the question, “Is it possible to see the whole moon from earth?” was considered scientific if the student explained that only one side of the Moon is visible on earth (SCI_SIDE) (Houghton Mifflin Harcourt, 2012). A response to the question regarding the lunar cycle was considered scientific if the student included all of the phases of the moon in the correct order (SCI_CYCLE) (Houghton Mifflin Harcourt, 2012; NGSS, 2012). A response to the question regarding the lunar eclipse was considered scientific if the student explained that a lunar eclipse happens when the Earth passes between a full moon and the Sun, so the side of the Moon visible on earth travels through the Earth’s shadow (SCI_ECLIPSE) (Houghton Mifflin Harcourt, 2012; ODE, 2012).

The following transcript from a post-instruction student interview provides an example of a response that is indicative of scientific understanding of a component lunar concept. Student 5 was asked if the whole moon was visible from earth (Question 3a).

**Student 5: Post-Instruction Interview.**

Researcher: Can you see the whole moon from Earth?

Student 5: Some, not see all…
Researcher: [holding up the Moon model] What part can you see? [holds up the Earth model]

Student 5: [indicates perspective from earth] Can see [indicates side of the Moon facing the Earth], not [indicates side of the Moon facing away from the Earth] back. (SCI_SIDE)

The SCI_SIDE code was assigned because the student indicated that only the side of the Moon that faces the Earth is the visible side, which is consistent with a scientific understanding.

**Scientific fragments.** Participants’ understanding was coded as a scientific fragment (SCI_FRAG) if their response included some, but not all, of the concepts identified as scientific understandings, and did not include any alternative conceptions (Trundle et al., 2007a, 2007b). The following transcript from a pre-instruction student interview provides an example of a response that exhibits scientific fragments of understanding. Student 2 was asked to describe the lunar cycle (Question 3b) and explain how the Moon looks different at different times.

**Student 2: Post-Instruction Interview.**

Researcher: Can you explain how the moon looks different at different times?


This response was coded SCI_FRAG_CYCLE because the student exhibited fragments of understanding that were scientific in nature, but the response did not include all of the elements of a scientific understanding. The student recalled four of the phases of the lunar cycle (with the exception of misspelling _crescent_), but did not provide the
remaining phase names (waning crescent, waxing gibbous, waning gibbous, third quarter).

**Scientific fragments with alternative fragments.** Participants’ understanding was coded as “scientific with alternative fragments” (SCI_FRAG w/ALT_FRAG) if their response included some, but not all, of the components of a scientific conception and at least one fragment of an alternative conception (Saçkes, 2010). The following transcript from a post-instruction student interview provides an example of a response that exhibits a scientific understanding with alternative fragments of understanding when asked about the Earth-Sun-Moon relationship (Question 2).

**Student 5: Post-Instruction Interview.**

Researcher: How are the Earth, Moon, and Sun related?

Student: Sun, Earth, Moon…Moon orbits [Earth]… Earth pulls like gravity, Moon keeps orbiting, never leaves.

Researcher: Show me, I will hold the Sun, show me how it moves. [holding sun model]

Student: [picks up Moon and Earth, points to Earth] Earth?

Researcher: *nods*

Student: Moon around [moves moon model slowly to the right of the earth model, then indicates full orbit]

Researcher: Around?

Student: [points to the earth model] Moves slowly around [indicating the Earth’s rotation], Moon orbits too.

Researcher: And does [the Earth] move?

Student: No…

Researcher: Stay?
Student: Stay. *(SCI_FRAG w/ALT_FRAG_ORBIT)*

The code SCI_FRAG w/ALT_FRAG_ORBIT indicates the student’s response was partially scientific (the Moon orbits the Earth), but that it also included an alternative understanding (the Earth does not orbit the Sun, just rotates on its axis).

**Alternative fragment with a scientific fragment.** A participant’s understanding was coded as an “alternative fragment with scientific fragment” (ALT_FRAG w/SCI_FRAG) if his or her response contained multiple alternative conceptions and only one fragment of a scientific concept (Saçkes, 2010). The following transcript from a post-instruction student interview provides an example of a response that exhibits an alternative understanding with scientific fragments of understanding when asked about the importance of gravity to the Earth-Sun-Moon relationship (Question 2a).

**Student 2: Post-Instruction Interview.**

Researcher: How is gravity important to that [relationship]?

Student: Because the Moon pulls the Earth.

Researcher: Okay, good. If there were no gravity, what would happen?

Student: If there were no gravity, some people would die. *(ALT_FRAG w/SCI_FRAG_DIE)*

The code ALT_FRAG w/SCI_FRAG_DIE was assigned because the student’s response “the Moon pulls the Earth” is a fragment of a scientific understanding of the force of gravity, and the response, “If there were no gravity, some people would die”
demonstrates an alternative understanding of the role of gravity in the Earth-Sun-Moon relationship.

**Alternative.** A participant’s understanding was coded as “alternative” (ALT_) if the response demonstrated an understanding of a concept that was not in agreement with the scientifically accepted view (Trundle et al., 2007a, 2007b). The following transcript from a post-instruction student interview provides an example of a response that exhibits an alternative understanding when asked if it is possible to see the whole moon from the Earth (Question 3a).

**Student 3: Pre-Instruction Interview.**

Researcher: Can you see the whole moon from Earth?

Student: Part.

Researcher: Part? Where’s the other part?

Student: Like hiding under the clouds. The clouds go in front of it. (ALT_CLOUDS)

**Alternative fragments.** A participant’s understanding was coded as “alternative fragments” (ALT_FRAG) if the response contained a subset or subsets of alternative conceptual understanding (Trundle et al., 2007a, 2007b). The following transcript from a post-instruction student interview provides an example of a response that exhibited alternative fragments of understanding when the participant was asked about the importance of gravity to the Earth-Sun-Moon relationship.

**Student 3: Post-Instruction Interview.**

Researcher: And gravity is important, why?
Student: Gravity has [indicates space around the Earth by tracing parameter]. If a rocket goes out of the area (around the Earth), will not have A-I-R.

(ALT_FRAG_AIR)

Researcher: So…how is gravity important to the Earth and the Moon together?

Student: Move (orbit) Earth - Moon orbits.

Researcher: If there was no gravity, what would happen?

Student: shakes head I don’t know.

The code ALT_FRAG_AIR was assigned because the alternative fragment of understanding that conflated “air” with “gravity” was the only understanding expressed by the student.

**Conceptual Change**

Students’ conceptual understandings were investigated through semi-structured interviews with the researcher, before and after instruction, in order to address research questions 1 and 2:

1. What are seventh-grade DHH students’ pre-instruction conceptions of the relationship between the Earth, the Sun, and the Moon?

2. How do seventh-grade DHH students’ post-instruction conceptions of the Earth-Sun-Moon relationship differ from their pre-instruction conceptions?

Analysis of the data involved comparing each student’s pre-instructional responses against his or her post-instructional responses to determine the degree to which conceptual change occurred. Additional codes for students’ alternative understandings were added to the preliminary coding framework that emerged in the data. See Table 4.1 for a list of the preliminary and added (indicated with an *) ALT_ codes.
Table 4.1.

*Alternative Understanding Codes, Preliminary and Added*

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition of Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALT_ECLIPSE</td>
<td>Dark part of the Moon in the Earth’s shadow; phases caused by the Earth’s shadow</td>
</tr>
<tr>
<td>ALT_ROT</td>
<td>The Earth’s rotation on its axis causes moon phases</td>
</tr>
<tr>
<td>ALT_ETILT</td>
<td>Tilt of the Earth on its axis causes moon phases</td>
</tr>
<tr>
<td>ALT_GEO</td>
<td>Moon phases are relative to the observer’s position on earth; people in different geographical positions see different moon phases</td>
</tr>
<tr>
<td>ALT_WEATHER *</td>
<td>The Earth-Sun-Moon relationship causes weather</td>
</tr>
<tr>
<td>ALT_AIR *</td>
<td>Air and gravity are the same; an absence of gravity is similar to an absence of air.</td>
</tr>
<tr>
<td>ALT_MOVE *</td>
<td>In the Earth-Sun-Moon system, the Earth is the only planetary object that moves in orbit</td>
</tr>
<tr>
<td>ALT_CLOUDS *</td>
<td>When parts of the Moon are not visible, it is because they are covered by clouds</td>
</tr>
<tr>
<td>ALT_COLOR *</td>
<td>At times, the Moon appears to change colors</td>
</tr>
<tr>
<td>ALT_SEASON *</td>
<td>The Moon’s changing appearance is related to the change of seasons</td>
</tr>
</tbody>
</table>

Note: * indicates new codes that emerged during the coding process

**Conceptual understandings before instruction.** Approximately two weeks before beginning instruction, students were interviewed to assess their scientific understanding in two areas: the Earth-Sun-Moon relationship, and lunar concepts.
**Earth-Moon-Sun relationship.** Students were asked to describe how the Earth, the Sun, and the Moon are related to one another, particularly with regard to the importance of gravity, and how they orbit or move through space in relation to one another. Prior to instruction, none of the students expressed a scientific understanding of the Earth-Sun-Moon relationship.

*Student 1* expressed scientific fragments of understanding regarding the Earth-Sun-Moon relationship, alternative fragments of understanding of the role of gravity, and an alternative view with scientific fragments of understanding of the movement patterns of the Earth, Sun, and Moon.

*Student 2* expressed no understanding of the questions asked during this section of the interview.

*Student 3* expressed scientific fragments of understanding regarding the Earth-Sun-Moon relationship, no understanding of the role of gravity in this relationship, and scientific understanding of the movement patterns of the Earth, Sun, and Moon.

*Student 4* expressed scientific fragments with alternative fragments of understanding regarding the Earth-Sun-Moon relationship, no understanding of the role of gravity, and a scientific understanding of the movement patterns of the Earth, Sun, and Moon.

*Student 5* expressed no understanding regarding the Earth-Sun-Moon relationship or of the role of gravity in this relationship, and an alternative view with scientific fragments of understanding of the movement patterns of the Earth, Sun, and Moon.
Student 6 expressed alternative fragments of understanding regarding the Earth-Sun-Moon relationship, no understanding of the role of gravity in this relationship, and an alternative understanding of the movement patterns of the Earth, Sun, and Moon.

**Lunar concepts.** Students were asked questions to assess their understanding of lunar concepts, including whether or not it is possible to see both sides of the Moon from earth, and how the Moon looks from earth as it cycles through its phases. Students’ pre-instructional conceptions regarding lunar phases were somewhat more established than their conceptions regarding the Earth-Sun-Moon relationship. Almost all—five of the six students—expressed some scientific fragments of understanding prior to instruction.

Student 1 expressed alternative fragments of understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments of understanding about lunar phases and the changing appearance of the Moon.

Student 2 expressed scientific fragments of understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments with alternative fragments of understanding about lunar phases and the changing appearance of the Moon.

Student 3 expressed an alternative understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments of understanding about lunar phases and the changing appearance of the Moon.

Student 4 expressed no understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments of understanding about lunar phases and the changing appearance of the Moon.
Student 5 expressed scientific fragments of understanding when asked if it was possible to see both sides of the Moon from earth and an alternative understanding of lunar phases and the changing appearance of the Moon.

Student 6 expressed no understanding when asked if it was possible to see both sides of the Moon from earth and an alternative understanding of lunar phases and the changing appearance of the Moon.

Table 4.2

*Students’ Conceptual Understandings Before Instruction, by Question*

<table>
<thead>
<tr>
<th></th>
<th>No_Und</th>
<th>Alt_Frag</th>
<th>Alt_</th>
<th>Alt_Frag</th>
<th>Sci_Frag</th>
<th>Sci_Frag</th>
<th>Sci_Frag</th>
<th>Sci_Frag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earth-Sun-Moon Relationship</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Gravity</td>
<td>5</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Patterns of orbit</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Moon-Earth Relationship</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Side of the Moon</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Lunar phases</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Conceptual understandings after instruction. Approximately two weeks after the completion of the unit, students were again interviewed to assess their scientific understanding in two areas: the Earth-Sun-Moon relationship and lunar concepts.

Earth-Moon-Sun relationship. Students were asked to describe how the Earth, the Sun, and the Moon are related to one another, particularly with regard to the importance of gravity and to how they orbit or move through space in relation to one another. After completing the unit of instruction, most students had experienced some positive degree of conceptual change in this area.

Student 1 expressed scientific fragments with alternative fragments of understanding regarding the Earth-Sun-Moon relationship, no understanding of the role of gravity in this relationship, and scientific fragments with alternative fragments of understanding about the movement patterns of the Earth, the Sun, and Moon.

Student 2 expressed scientific fragments of understanding regarding the Earth-Sun-Moon relationship, alternative fragments with scientific fragments of understanding of the role of gravity, and alternative fragments with scientific fragments of understanding of the movement patterns of the Earth, the Sun, and the Moon.

Student 3 expressed alternative fragments with scientific fragments of understanding regarding the Earth-Sun-Moon relationship, alternative fragments of understanding of the role of gravity, and alternative fragments with scientific fragments of understanding about the movement patterns of the Earth, the Sun, and the Moon.

Student 4 expressed a scientific understanding with alternative fragments of understanding regarding the Earth-Sun-Moon relationship, scientific fragments of
understanding of the role of gravity, and a scientific understanding of the movement patterns of the Earth, the Sun, and the Moon.

*Student 5* expressed a scientific understanding with alternative fragments of understanding regarding the Earth-Sun-Moon relationship, a scientific understanding of the role of gravity, and alternative fragments with scientific fragments of understanding of the movement patterns of the Earth, the Sun, and the Moon.

*Student 6* expressed an alternative understanding regarding the Earth-Sun-Moon relationship, an alternative understanding of the role of gravity, and an alternative of the movement patterns of the Earth, the Sun, and the Moon. The total number of pre-instruction interview responses in each conceptual category code are presented in Table 4.2.

**Lunar concepts.** During post-instruction interview, students were asked questions to assess their understanding of lunar concepts, including whether or not it is possible to see both sides of the Moon from earth, and how the Moon looks from earth as it cycles through its phases. Four of the six students’ post-instructional conceptions regarding lunar phases evidenced a scientific understanding of at least one of the components.

*Student 1* expressed a scientific understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments of understanding about lunar phases and the changing appearance of the Moon.

*Student 2* expressed a scientific understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments of understanding about lunar phases and the changing appearance of the Moon.
Student 3 expressed scientific fragments of understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments with alternative fragments of understanding about lunar phases and the changing appearance of the Moon.

Student 4 expressed a scientific understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments with alternative fragments of understanding about lunar phases and the changing appearance of the Moon.

Student 5 expressed a scientific understanding when asked if it was possible to see both sides of the Moon from earth and scientific fragments of understanding about lunar phases and the changing appearance of the Moon.

Student 6 expressed an alternative understanding when asked if it was possible to see both sides of the Moon from earth and an alternative understanding of lunar phases and the changing appearance of the Moon.

Comparison of conceptual understandings before and after instruction. Students’ conceptual understandings in each domain were compared for gains from pre- to post-instruction. The results are detailed as follows.

Earth-Sun-Moon relationship. Results from the measure of students’ knowledge of the Earth-Sun-Moon relationship on the three component questions (Earth-Sun-Moon relationship, gravity, patterns of orbit) indicated a moderate degree of conceptual change. Response codes from all three questions were combined to compare gains in understanding at three levels of understanding: no understanding, alternative understanding (which includes codes ALT_FRAG, ALT_, ALT_FRAG w/SCI_FRAG,
and SCI_FRAG w/ALT_FRAG), and scientific understanding (which includes codes SCI_FRAG and SCI_).

Table 4.3.

Students’ Conceptual Understandings After Instruction

<table>
<thead>
<tr>
<th></th>
<th>No_Und</th>
<th>Alt_Frag</th>
<th>Alt_</th>
<th>Alt_Frag w/ Sci_Frag</th>
<th>Sci_Frag w/ Alt_Frag</th>
<th>Sci_Frag</th>
<th>Sci_</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth-Moon-Sun Relationship</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Gravity</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Patterns of orbit</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Moon-Earth Relationship</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Side of the Moon</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Lunar phases</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>

Before instruction, eight of the responses provided by students were coded as NO_UND; after instruction, the number of NO_UND responses reduced to two. During the pre-instruction interview, students provided five responses that were considered alternative understanding; this number increased to 12 alternative responses post-instruction. Prior to instruction, three responses were considered indicative of scientific
understanding, and after instruction there were four responses that met the criteria for scientific understanding.

**Lunar concepts.** Results from the measure of students’ understanding of lunar concepts showed a greater gain in conceptual understanding than was shown on the Earth-Sun-Moon relationship measure. Response codes from all three questions (Moon-Earth relationship, side of the Moon, lunar phases) were combined to compare gains in understanding at three levels of understanding: no understanding, alternative understanding (which includes codes ALT_FRAG, ALT_, ALT_FRAG w/SCI_FRAG, and SCI_FRAG w/ALT_FRAG), and scientific understanding (which includes codes SCI_FRAG and SCI_).

Before instruction, three of the responses provided by students were coded as NO_UND; after instruction, the number of NO_UND responses reduced to zero. During the pre-instruction interview, students provided eight responses that were considered indicative of alternative understanding; this number increased to nine alternative responses post-instruction. Prior to instruction, seven responses were considered indicative of scientific understanding, and after instruction there were 11 responses that met the criteria for scientific understanding.

See Table 4.4 for data comparing students’ pre- to post-instruction conceptual change for each of the questions.
**Table 4.4.**

*Student Conceptual change, Pre- and Post-instruction, by Question*

<table>
<thead>
<tr>
<th>Question</th>
<th>Student 1</th>
<th>Student 2</th>
<th>Student 3</th>
<th>Student 4</th>
<th>Student 5</th>
<th>Student 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>How are the Moon, the Sun, and the Earth related?</td>
<td>PRE</td>
<td>SCI_ FRAG</td>
<td>NO</td>
<td>SCi_ FRAG</td>
<td>SF w/ AF</td>
<td>NO</td>
</tr>
<tr>
<td>POST</td>
<td>SF w/ AF</td>
<td>SCI_ FRAG</td>
<td>AF w/ SF</td>
<td>SF w/ AF</td>
<td>SF w/ AF</td>
<td>ALT_</td>
</tr>
<tr>
<td>Is gravity important to this relationship? How?</td>
<td>PRE</td>
<td>ALT_ FRAG</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>POST</td>
<td>NO</td>
<td>AF w/ SF</td>
<td>ALT_ FRAG</td>
<td>SCI_ FRAG</td>
<td>SCI</td>
<td>NO</td>
</tr>
<tr>
<td>Use this model to show me how the Earth, the sun, and the Moon rotate.</td>
<td>PRE</td>
<td>AF w/ SF</td>
<td>NO</td>
<td>SCI_</td>
<td>SCI_</td>
<td>AF w/ SF</td>
</tr>
<tr>
<td>POST</td>
<td>SF w/ AF</td>
<td>AF w/ SF</td>
<td>AF w/ SF</td>
<td>SCI_</td>
<td>SCI_</td>
<td>AF w/ SF</td>
</tr>
<tr>
<td>How does the Moon move in relation to the Earth?</td>
<td>PRE</td>
<td>ALT_</td>
<td>NO</td>
<td>SCI_</td>
<td>SCI_</td>
<td>AF w/ SF</td>
</tr>
<tr>
<td>POST</td>
<td>SCI_</td>
<td>AF w/ SF</td>
<td>AF w/ SF</td>
<td>SCI_</td>
<td>SCI_</td>
<td>AF w/ SF</td>
</tr>
<tr>
<td>Is it possible to see the whole moon from Earth?</td>
<td>PRE</td>
<td>ALT_ FRAG</td>
<td>SCI_ FRAG</td>
<td>ALT_</td>
<td>NO</td>
<td>SCI_ FRAG</td>
</tr>
<tr>
<td>POST</td>
<td>SCI_</td>
<td>SCI_</td>
<td>SCI_ FRAG</td>
<td>SCI_</td>
<td>SCI_</td>
<td>ALT_</td>
</tr>
<tr>
<td>Describe the lunar cycle. How does the Moon look different at different times?</td>
<td>PRE</td>
<td>SCI_ FRAG</td>
<td>SF w/ AF</td>
<td>SCI_ FRAG</td>
<td>SCI_ FRAG</td>
<td>ALT_</td>
</tr>
<tr>
<td>POST</td>
<td>SCI_ FRAG</td>
<td>SCI_</td>
<td>SF w/ AF</td>
<td>SF w/ AF</td>
<td>SCI_ FRAG</td>
<td>ALT_</td>
</tr>
</tbody>
</table>
Vocabulary. In order to assess their knowledge of target vocabulary, students were asked to provide the ASL sign for each of the words that were studied during the unit: satellite, eclipse, umbra, lunar phase, penumbra, Earth, moon, sun, rotation, revolution, and axis.

Baseline for vocabulary accuracy in teacher interview data. During the pre-instruction interview, the teacher was asked to provide signs for the 12 vocabulary words that were to be learned during the unit on the Earth-Sun-Moon relationship. The aim of this task was to obtain a baseline from which to assess how these words were used by the teacher, and then, further, how they were used by individual students, and how they were used during the knowledge construction process during instruction.

The teacher read the words from a printed list and provided signs for 7 of the 12 words on the list: gravity, eclipse, Earth, moon, sun, rotation, and revolution. These words have an established and agreed-upon ASL equivalent. The teacher indicated that 5 of the 12 vocabulary words that were to be learned during this unit had an ambiguous or potentially confusing ASL equivalent: axis, umbra, penumbra, lunar phase, and satellite.

For the words umbra, penumbra, and axis, the teacher responded that she typically fingerspells these words and then utilizes descriptive handshapes (classifiers) to provide additional information. She added that she often scaffolds these concepts using visual information like diagrams and models in addition to the fingerspelled word. Regarding the word axis, she explained, as part of her pre-instruction interview,

Teacher: Axis, I spell, but then I’ll kind of (indicates handshape movement)… depending on what I’m talking about, you know, maybe I’ll do this [holds up index finger and moves it from left to right, like a metronome].

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The teacher explained that she does not use an established or consistent sign for the term *lunar phase*, and offers several options of how she might choose to sign the concept. An excerpt from the pre-instruction interview transcript follows:

**Teacher:** Lunar phase… I don’t necessarily use, like, I mean, I use the term *lunar phase*, but when I’m talking about it, it’s more like, you know, “which part of the moon, right now…what’s it look like,” so I’m more, like, asking. I guess, “part of the moon”… or, “What does the Moon look like right now?” or “What’s the Moon doing now?”

She added that she did not expect the students to know the word *phase*, possibly as rationale for not using it with students:

**Teacher:** Or if I was going to actually, I mean, if I needed to use the word, then I would spell it – P-H-A-S-E [fingerspelling]. But this group of kids probably don’t understand that word “phase,” so….

When asked to provide the sign for *satellite*, the teacher’s first response was to sign the conceptual equivalent of a communications satellite; but then, she added, “Or, sometimes if I’m talking about the satellite revolving around the Earth, I might go like this,” and provided a sign conceptually and visually very different from the first (e.g., the sign language equivalent of a body orbiting the Earth or another planet). The teacher’s explanation shows the difficulty encountered when everyday and scientific language come into contact, and potentially, conflict with one another, as seen in the classroom observation data presented in the following section.

**Word recognition, before instruction.** Students were asked to provide the sign for each of the 12 vocabulary words that were to be studied during the unit. Prior to
instruction, students’ responses were consistently straightforward; in other words, they demonstrated that they either knew the word or did not. One student provided the correct sign for gravity. Five of the six students provided the correct signs for moon and sun. All six students provided the correct sign for earth. No students were able to provide signs for the words satellite, eclipse, umbra, penumbra, lunar phase, rotation, revolution, or axis.

Table 4.5.

<table>
<thead>
<tr>
<th>Word Recognition, Before Instruction</th>
<th># of students: did not know/incorrect</th>
<th># of students correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>satellite</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>gravity</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>eclipse</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>umbra</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>lunar phase</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>penumbra</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Earth</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>moon</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>sun</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>rotation</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>revolution</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>axis</td>
<td>6</td>
<td>-</td>
</tr>
</tbody>
</table>

Word recognition, after instruction. Two students provided the correct sign for the word satellite. Three students provided the correct sign for gravity. One student
provided the correct sign for *umbra*. Two students provided the correct sign for *penumbra*. All students provided the correct signs for *earth*, *moon*, and *sun*. No students provided the correct signs for *eclipse*, *lunar phase*, *rotation*, *revolution*, or *axis*.

Table 4.6

*Word Recognition, After Instruction*

<table>
<thead>
<tr>
<th></th>
<th># of students: did not know/incorrect</th>
<th># of students correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>satellite</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>gravity</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>eclipse</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>umbra</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>lunar phase</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>penumbra</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Earth</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>moon</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>sun</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>rotation</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>revolution</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>axis</td>
<td>6</td>
<td>-</td>
</tr>
</tbody>
</table>

*Comparison of pre- and post-instruction word recognition.* On the measure of word recognition before and after instruction, very little gain was noted in students’ recognition of the 12 vocabulary words. Two students who did not know the word *satellite* prior to instruction were able to correctly identify the word in the post-instruction interview. Two students who did not know the word *gravity* prior to
instruction were able to correctly identify the word in the post-instruction interview. One student who did not know the word *umbra* prior to instruction was able to correctly identify the word in the post-instruction interview. Two students who did not know the word *penumbra* prior to instruction were able to correctly identify the word in the post-instruction interview. The student who did not know the words *moon* and *sun* prior to instruction was able to correctly identify these words in the post-instruction interview.

During the post-instruction interview, some of the students’ responses were indicative of developing conceptions. For example, one of the students who did not correctly produce the sign for *gravity* in the pre-instruction video produced this sign in the post-instruction interview, but in reverse (e.g., instead of pulling down, the motion of the sign lifted up). This error has conceptual implications, as the reversal would indicate that gravity is a force that pulls *up* rather than *down*. Another example of a developing, but not yet solidified, conceptual understanding of a vocabulary word occurred with the word *rotation*. When asked to provide this sign, one student produced instead the sign for *revolution*.

**Classroom Talk and Conceptual Change**

Data gathered from pre- and post-instruction teacher and student interviews and classroom observations were used to address the third research question:

3) How does classroom talk influence changes in seventh grade DHH students’ understanding of Earth-Sun-Moon concepts?

In order to assess whether the instructional activities and classroom talk that occurred during the instructional period had instantiated a change in students’ understanding of the concepts presented and, if so, whether that change was positive
(e.g., the student’s understanding became more scientific) or negative (e.g., the student’s understanding became less scientific), both classroom observation data and student pre- and post-instruction interview data were analyzed to identify instances where classroom talk influenced conceptual change. Results from the analysis of students’ conceptual change that utilized students’ pre- and post-instruction interview data informed the selection of excerpts of classroom discourse for further analysis. The framework developed by Mortimer and Scott (2003) was utilized as an analytical tool to characterize the various ways classroom talk is enacted by the teacher with regard to (a) teaching purposes, (b) content, (c) communicative approach, (d) patterns of discourse, and (e) teacher interventions.

The excerpts of classroom observation data presented in the following analysis represent critical instances of meaning-making in which the teacher uses students’ prior knowledge to scaffold meaning through classroom talk. In line with this study’s focus on conceptual change and classroom talk, the following analysis focuses on the teacher’s orchestration of group discussion and the use of representational models to make scientific concepts available to the students on the first day of instruction.

**Episode 1**

Episode 1 is an excerpt of classroom talk that occurred on Day 1 of the unit of instruction introduced during the study. Analysis is presented in two areas of the framework: teaching purposes, and teacher interventions. The class period began with an independent journaling activity during which the students were instructed to “write what you know about the moon.” The transcript (Episode 1, below) begins immediately after the journaling activity concluded.
Episode 1: Where is the Moon in space?

<table>
<thead>
<tr>
<th>Line no.</th>
<th>Speaker</th>
<th>Utterance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T</td>
<td>If the sun is (*) where is the Moon?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T places globe on table while holding the “moon”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* T indicates place of the Sun in space to the right of the globe</td>
</tr>
<tr>
<td>2</td>
<td>T</td>
<td>What did you say?</td>
</tr>
<tr>
<td>3</td>
<td>S6</td>
<td>What did you say?</td>
</tr>
<tr>
<td>4</td>
<td>T</td>
<td>If the Sun is (*), where is the Moon?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* T indicates place of the Sun in space to the right of the globe</td>
</tr>
<tr>
<td>5</td>
<td>S6</td>
<td>Here?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Holds “moon” in a non-specific area near the globe</td>
</tr>
<tr>
<td>6</td>
<td>T</td>
<td>Does it stay in the same place every day, or does it move?</td>
</tr>
<tr>
<td>7</td>
<td>S6</td>
<td>It moves.</td>
</tr>
<tr>
<td>8</td>
<td>T</td>
<td>Moves how?</td>
</tr>
<tr>
<td>9</td>
<td>S6</td>
<td>Moves because Earth moves.</td>
</tr>
<tr>
<td>10</td>
<td>T</td>
<td>Earth moves?</td>
</tr>
<tr>
<td>11</td>
<td>S6</td>
<td>I don’t know.</td>
</tr>
<tr>
<td>12</td>
<td>T</td>
<td>You don’t know? That’s fine! I’m just asking to see what you know.</td>
</tr>
<tr>
<td>13</td>
<td>S1</td>
<td>Raises hand</td>
</tr>
<tr>
<td>14</td>
<td>T</td>
<td>T brings globe to table in front of S1, gives S1 the “moon”</td>
</tr>
<tr>
<td>15</td>
<td>S1</td>
<td>Slowly rotates the globe while holding “moon” in place</td>
</tr>
<tr>
<td>16</td>
<td>T</td>
<td>Earth rotates, what does the Moon do? Stay in place?</td>
</tr>
<tr>
<td>17</td>
<td>S1</td>
<td>(Over here) *</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* Indicates area where “sun” is represented while holding “moon” on the opposite side of the globe</td>
</tr>
<tr>
<td>18</td>
<td>S1</td>
<td>Can’t see the Sun because sleep.</td>
</tr>
</tbody>
</table>

continued
<table>
<thead>
<tr>
<th>Line no.</th>
<th>Speaker</th>
<th>Utterance</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>T</td>
<td>The moon is asleep?</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>S1</td>
<td>The Moon is over here when (*) sleep.</td>
<td>Indicates area of globe on the same side as the “moon,” S1 seems to be referring to the people who live on that side of the world</td>
</tr>
<tr>
<td>21</td>
<td>T</td>
<td>Okay.</td>
<td>Moves globe in front of S5</td>
</tr>
<tr>
<td>22</td>
<td>S5</td>
<td>The sun and the moon rise opposite of one another on the horizon. You know, at night, the sun goes down, the moon rises *.</td>
<td>Before taking the “moon”</td>
</tr>
<tr>
<td>23</td>
<td>T</td>
<td>Show me how.</td>
<td>Gives S5 “moon”</td>
</tr>
<tr>
<td>24</td>
<td>S5</td>
<td>Shrugs, laughs. Okay, the Sun is “over here” ummm… I know the sun goes down and the moon goes up*.</td>
<td>* see Figure 4.2</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>Okay, that’s fine.</td>
<td>Moves globe in front of S4</td>
</tr>
<tr>
<td>26</td>
<td>S4</td>
<td>Okay, I’m curious, does the Moon stay still, or does it rotate?</td>
<td>Takes “moon” from S5, spins globe, and revolves moon around globe</td>
</tr>
<tr>
<td>27</td>
<td>T</td>
<td>Does not acknowledge S4’s response</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>S4 &amp; S5</td>
<td>Rotates.</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>S3</td>
<td>It stays (doesn’t rotate) but it revolves around Earth.</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>S1</td>
<td>Agrees with S3</td>
<td></td>
</tr>
</tbody>
</table>

Notes: In this excerpt, “moon” indicates the representation of the Moon using a small Styrofoam ball on a pencil as a model. Refer to * in far right column for additional information contained within an utterance in the center column.
**Teaching purposes.** The teacher begins this phase of the lesson by presenting the students with a model of the Earth (globe) and the Moon (Styrofoam ball) and asking, “If the Sun is (here), where is the Moon?” This question appears to be an attempt by the teacher to *explore students’ views* by probing their understandings of the Earth-Moon relationship. However, the teacher provides minimal context for the question aside from the representational models of the Earth and the Moon she shows the students, nor does she make clear the features and limitations of the model. When she asks Student 6 (lines 2-12) to use the model to show where the moon is in space, relative to the Earth and the Sun, Student 6 attempted to respond even though he was clearly uncertain what he was being asked.

The use of a model to represent the Earth and the Moon allowed the teacher and students to use these objects as reference points in the discussion and to incorporate them into their explanations. For example, at line 15, Student 1 responded to the question by manipulating the model (spinning the globe and holding the “moon” in place next to it), without additional commentary. The teacher articulates the student’s action, “Earth rotates,” and follows up by asking, “What does the Moon do? Stay in place?” It is important to note that the translation of the sign used by the teacher for the word “rotate” was articulated as “spin,” and the scientific term “rotate/rotation” was never explicitly associated with this sign. Student 1 continued to use the globe as a referent when explaining his viewpoint (lines 17-20), that the Moon is on the side of earth where it is dark and people are sleeping.

It was apparent from Student 5’s response (lines 22-24) that she was attempting to reconcile the observed movement patterns of the Moon and the Sun in the sky (e.g., her
prior knowledge of the concept being discussed) with the model being used. Student 5’s response (line 22) was expressed in ASL and relied heavily on the use of classifiers (handshapes and movements that are used to convey objects in space). As a supplement to the translation, Figure 4.1 depicts the handshape (two circles, indicating the Sun and the Moon) and movement (two arrows, indicating the movement of the Sun and the Moon alternately across the horizon). The student’s articulation of her established mental model of the movement pattern of the Sun and the Moon in relation to the Earth, therefore, was made explicit through her response to the teacher’s question.

Figure 4.1
Student 5’s description of the movement of the sun and moon on the horizon

When the teacher asked Student 5 to apply her prior knowledge to the model being used (line 23), the student attempted to reconcile her pre-conception with model. As depicted in Figure 4.2, Student 5 repeated the same movement pattern of the Sun (using an “o” handshape”) and the moon (Styrofoam ball) around the globe.
Figure 4.2

Student 5’s description of the movement of the Sun and the Moon around the globe

![Diagram of the movement of the Sun and the Moon around the globe]

**Teacher interventions.** Student 4 provided the most scientifically accurate response to the question, spinning the globe and simultaneously rotating the “moon” around in orbit. However, as seen in line 27, the teacher does not acknowledge the accuracy of the response, nor the response itself. Rather than *marking the key idea* contained in Student 4’s response, the teacher abruptly shifts to a different question. This appears to be a missed opportunity for the teacher to focus attention on the target idea in order to make the scientific view available to the other students.

**Episode 2**

Episode 2 occurred almost immediately following the phase of the lesson captured in Episode 1. The framework elements of *patterns of discourse* and *content* were used for the analysis of this episode.
## Episode 2: Gravity

<table>
<thead>
<tr>
<th></th>
<th>T</th>
<th>Is the Moon close to or far away from Earth?</th>
<th>T places globe on table and holds the small Styrofoam ball on a pencil (moon model), moving it closer and farther from the globe</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>S3</td>
<td>Right there—stay and revolve.</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>T</td>
<td>It stays? Why doesn’t it float away?</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>S4</td>
<td>Earth pulls it. The moon moves with Earth.</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>T</td>
<td>Why?</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>S4</td>
<td>Because the wind blows it.</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>T</td>
<td>Who wants to try something?</td>
<td>T directs S1 and S6 to stand up, hold hands, spin in circle</td>
</tr>
<tr>
<td>37</td>
<td>S1 &amp; S6</td>
<td>Spin while holding hands, then return to seats</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>T</td>
<td>What did you feel? ((S6)) Did you feel a pull?</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>S6</td>
<td>((T)) Yes</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>T</td>
<td>((S1)) Did you feel pull?</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>S1</td>
<td>((T)) Yes</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>T</td>
<td>You both pulled equally on each other.</td>
<td>((Class)) Which is stronger, Moon or Earth?</td>
</tr>
<tr>
<td>43</td>
<td>S4</td>
<td>Earth!</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>T</td>
<td>Why?</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>S4</td>
<td>It’s big! Big pull!</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>T</td>
<td>Who else wants to try?</td>
<td>T directs S4 and S5 to do the same spinning demo</td>
</tr>
<tr>
<td>47</td>
<td>S4 &amp; S5</td>
<td>Spin while holding hands, then return to seats</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>T</td>
<td>Did you feel it?</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>S5</td>
<td>Shrugs</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>S4</td>
<td>Yes.</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>T</td>
<td>What would happen if you let go?</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>S4</td>
<td>Explode apart! Boom!</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>S1</td>
<td>Fall apart</td>
<td>Mimics dying</td>
</tr>
<tr>
<td>54</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In order to demonstrate the force exerted by the Earth’s gravity on the moon, the teacher first opens up the problem, asking students why the moon does not float away from the Earth (line 33).

Patterns of discourse. In the exchange between the teacher and Student 4 at lines 33-37, the teacher uses the IRFRF pattern of discourse to elicit Student 4’s understanding of the force of gravity. Feedback to Student 4’s response (line 35; “because the Earth pulls it”) was given in the form of a second question, “Why?” to which he responded, “Because the wind blows it” (line 37). The final element of feedback was not directly addressed to Student 4, however, and it was unclear whether this was a form of implicit feedback because his answer was unscientific, or if it was intended as a reframing of the question.

Content. At line 38, the teacher asks, “Who wants to try something?” and invites two volunteers to participate in a demonstration of the force of gravity. At this point in the lesson, the teacher is using an empirical explanation to make available the concept of gravity to the students by using the students’ bodies to model the force exerted by one on the other. After Students 1 and 6, and subsequently Students 4 and 5, complete the demonstration, the teacher asks, “Did you feel the pull?” to which three of the four students answered affirmatively (lines 39-42 and 48-51).

The learning objective for this phase of the lesson was, ostensibly, to introduce the key vocabulary term gravity. However, during this episode, the teacher at no time used the ASL sign for gravity; rather, she used a sign that can be directly translated to “pull.” For example, at line 39, “Did you feel the pull?” and line 43, “You both pulled
equally on each other.” Although the concept is being made clear through the
demonstration activity, no label was provided for this key unit concept.

**Episode 3**

When introducing the word *satellite* on the first day of instruction, the teacher
opened up the discussion to, first, elicit students’ prior knowledge of the word. She
assessed students’ everyday understanding of the word “satellite” by writing the word on
the whiteboard and asking the students if they had seen the word before. One student
responded by finding the corresponding word in the textbook and reading the definition
aloud. The question at line 31 signaled the teaching purpose of *opening up the problem* to
engage students in the development of understanding. The second teaching purpose—
*exploring and working on students’ views*—is addressed as the discussion continues.

**Episode 3: Satellite**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>56</td>
<td>T</td>
<td>Have you seen this word before?</td>
</tr>
<tr>
<td>57</td>
<td>S3</td>
<td>S-A-T-E-L-L-I-T-E * … a large body.</td>
</tr>
<tr>
<td>58</td>
<td>T</td>
<td>If something goes around (orbits) an object that is called S-A-T-E-L-L-I-T-E*.</td>
</tr>
<tr>
<td>59</td>
<td>T</td>
<td>Now sometimes maybe you’ve seen…</td>
</tr>
<tr>
<td>60</td>
<td>T</td>
<td>Have you seen these before? What are these for?</td>
</tr>
</tbody>
</table>

---

T points to the word *satellite* on the board

S3 reading from textbook

* Fingerspelling

* Fingerspelling

T stops signing, types on keyboard to search Google.com for an image of a communications satellite on the Smartboard

T referencing images of space satellites displayed on the Smartboard

continued
### Episode 3 continued

<p>| | | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>61</td>
<td>Ss</td>
<td><em>Unintelligible</em></td>
</tr>
<tr>
<td>62</td>
<td>T</td>
<td>Internet, phone.</td>
</tr>
<tr>
<td>63</td>
<td>S1</td>
<td>That’s like, you know, new bed (?) xxx *</td>
</tr>
<tr>
<td>64</td>
<td>T</td>
<td>T points to images of communications satellites on Smartboard</td>
</tr>
<tr>
<td>65</td>
<td>S5</td>
<td>D-I-S-H*.</td>
</tr>
<tr>
<td>66</td>
<td>T</td>
<td>Like a TV satellite dish.</td>
</tr>
<tr>
<td>67</td>
<td>S3</td>
<td>That grid…</td>
</tr>
<tr>
<td>68</td>
<td>T</td>
<td>Oh, oh, oh! That’s S-O-L-A-R *. Sun shines (on solar panels) for what? Remember?</td>
</tr>
<tr>
<td>69</td>
<td>S4</td>
<td>Energy!</td>
</tr>
<tr>
<td>70</td>
<td>T</td>
<td>Energy. Yes, same as you saw last week, the panels absorb the sun’s rays and become electricity. Now, satellite(2).</td>
</tr>
<tr>
<td>71</td>
<td>S5</td>
<td>I saw that (*) makes solar energy and also a windmill.</td>
</tr>
<tr>
<td>72</td>
<td>T</td>
<td>Okay.</td>
</tr>
<tr>
<td>73</td>
<td>S6</td>
<td>xxxxx</td>
</tr>
<tr>
<td>74</td>
<td>T</td>
<td>We’ll talk about that later, yes.</td>
</tr>
<tr>
<td>75</td>
<td>T</td>
<td>But the Moon.</td>
</tr>
</tbody>
</table>

* S1’s comment is not understood by teacher or others, ignored
* Fingerspelling
* T referring to image on the board
* T referring to image on the board

Satellite(1) right, communication. That communicates with things on Earth… you know, like…
S3 traces rectangular object in space to show shape
S3 traces object in space again
S3 points to image of communications satellite on Smartboard with a solar panel

T points to images of communications satellites on Smartboard

continued
### Communicative approach

During this phase of the lesson, the teacher is focused on differentiating the two meanings of the word *satellite*. She makes the assumption that the students may have some degree of prior knowledge about communications satellites, seen in lines 59-60, and attempts to elicit the students’ responses accordingly. The communicative approach discussed earlier and in Figure 2.1 that was taken by the teacher during this phase is primarily authoritative; in other words, the teacher “leads students through a sequence of questions and answers with the aim of...”

**Episode 3 continued**

| 76 | T | Does the moon ((satellite)) with Earth? | ((communicate)) |
| 77 | T | Another meaning of that word satellite(1) is satellite(2) The sign is satellite(2). This sign is satellite(1). satellite(2) Same English word, different sign, okay? | T moves “moon” around the globe again T referring to image of satellite(1) on board T referring to “moon” ball |
| 78 | T & S6 | If I... come here. | T points to S6 and then motions for him to stand and moves near T at the front of the room |
| 79 | T | I become a S-A-T-E-L-I-T-E* so to speak, okay? If something orbits something else, it is a S-A-T-E-L-I-T-E*. | T walks in circles around S6 several times * Fingerspelling * Fingerspelling S6 returns to seat |
| 80 | T | Does this orbit Earth? Yes, it doesn’t stay in one place. | T points to image of satellite(1) on board T places hand next to the globe on the table to represent satellite(1), doesn’t move hand |
| 81 | T | It orbits. Okay? | T moves satellite(1) hand around globe Earth pulls satellites(1) too. |
reaching one specific point of view” (Mortimer & Scott, 2003, p. 39). As such, the unintelligible comment made by Student 1 (line 63) went unacknowledged, with the teacher instead directing focus to the Smartboard and moving forward with the discussion.

Interestingly, the association of solar energy, made when Student 3 noticed the solar panels in one of the images of satellites (line 67), was acknowledged by the teacher. This can be seen in lines 68-72, as she shifts from an authoritative to a dialogic communicative approach. The dialogic communicative approach supports the sharing of different ideas and perspectives, which allows the teacher and students to discuss scientific concepts from multiple points of view.

Teacher interventions. Why did Student 3’s contribution trigger a classroom talk shift, while Student 1’s comment did not? Aside from the unintelligibility of Student 1’s response, the content of Student 3’s response linked previously learned concepts about solar energy to the current discussion. The teacher intervened in this case to shape and select student ideas; she focused attention on a response deemed relevant to the discussion while overlooking responses that were not (Mortimer & Scott, 2003).

As the discussion moved further off-topic, the teacher resumed control of the discussion, shifting back to an authoritative communicative approach (see Figure 2.1 for review), seen with Student 6’s comment at line 73 and the teacher’s response at line 74, “We’ll talk about that later.” When the teacher called the students’ attention back to the discussion of the word satellite, she maintained control of the discussion throughout the remainder of this phase of the lesson (lines 75-81). The teacher continued to shape student ideas by differentiating the two meanings of the word satellite. She used the
same visual model to represent the Earth (the globe) and the Moon (the Styrofoam ball) to demonstrate the concept of the Moon as a satellite of the Earth.

*Additional note on the term of gravity.* It was again noted that, when discussing the concept of an object orbiting another object as a satellite, the teacher did not explicitly use the term *gravity*. Seen at line 81, “Earth pulls satellites(1) too,” thus referencing the force exerted by the Earth’s gravity on orbiting bodies, but it is unclear if the students were able to link this explanation to the target phenomenon.

**Teacher Perceptions**

Interview data were obtained from the participating teacher in order to determine her perceptions of her instructional design and methods, and to assess her expectations for her students’ learning, in order to address Research Question 4,

4) How does the teacher perceive the effectiveness of her instruction?

The teacher was interviewed approximately two weeks prior to beginning the unit of instruction on the Earth-Sun-Moon relationship. The post-instruction interview with the teacher occurred approximately one and a half weeks after the conclusion of the lesson on the Earth-Sun-Moon relationship. The researcher audio- and video-recorded both of the interviews after first obtaining consent from the teacher. Data collected during both interviews are presented below, along with a discussion of the teacher’s perceptions with respect to the findings regarding student conceptual change and the classroom talk that occurred during this study.

It is important to note that the construct of “teacher perceptions” as defined in the literature reviewed in Chapter 2 (pp. 33-42) evolved during data analysis. As additional aspects of these perceptions on student learning emerged, data analysis provided
instances in which the teacher’s perceptions of her students’ ability to learn the target content and to engage in scientific classroom discourse became the prominent construct of teacher perceptions. This construct was analyzed to determine how instruction was delivered.

**Pre-instruction teacher interview.** The pre-instruction interview was designed to gain insight into the way the teacher planned to design instruction for the unit on the Earth-Sun-Moon relationship, and to identify her expectations for student learning. (The teacher was also asked to demonstrate the signs she uses for the vocabulary words/concepts that were included in this unit, as discussed in Chapter 3.)

The teacher was asked how she planned to teach the unit, and to detail the instructional methods she planned to utilize. The aim of this question was to gain insight into the teacher’s rationale for the way she designed instruction and the modifications she planned to utilize for students who experienced difficulty with the concepts being taught.

**Researcher:** Describe how you’ll teach the unit and what kind of instructional methods you’ll use.

**Teacher:** Well, I use the Smartboard a lot…. I’ve made, and also downloaded from like smarttech.com…. When they’re doing the phases and practicing the phases, several things where they can just come up to the Smartboard and move the phases of the Moon where they should be, label the phases of the moon, all the different phases are listed, um and they have to move them and match them with the correct phase…picture.

The teacher also explained how she planned to teach the lunar cycle, including introducing the concepts using the globe/lamp/volleyball model at the beginning of the unit.
**Teacher:** Sometimes like at one point, I’ll do some, a manipulation of pictures, of the Moon, so they, you know, what’s first, second, third, you know, make what’s next…we do… we do something where we have a light, that’s typically in the beginning, so we have a light, and then we have the Earth, and we use little Styrofoam balls on pencils, and we walk around the Earth with the light there [indicates in space where the light would be placed during the activity] to see what it looks like, and then we draw it in our journal…a little bit of work in the book but not much, so….

The teacher at several points mentioned the expectations she had of students’ ability to learn the concepts she planned to teach, and the modifications she planned to make to her instruction. While explaining her plans for teaching the lunar cycle, the teacher noted that she expected several of the students to need extra support to correctly label the moon’s phases. When asked if she felt that some of the students would develop independence in their ability to correctly label the phases of the moon, the teacher responded that she did not believe three of the six students would.

**Teacher:** There’s probably three kids in the class who could probably come up with the phase term themselves, whereas three other kids cannot, and I’ll probably, they’ll choose from a list….

**Researcher:** And you think that’ll be their accommodation the whole way? Like they won’t get to a point where they’ll be able to do that?

**Teacher:** I doubt it….

The teacher was asked if there were any concepts included in the unit on the Earth-Sun-Moon relationship that she felt may be more or less difficult for her students to understand. Excerpts from the interview transcript are provided below.
Researcher: Okay… and do you anticipate there are any particular concepts in this unit that will be more or less… er… yeah, more or less difficult for students to understand?

Teacher: No… it’s pretty concrete and visual… the only… I notice every year, the kids flip-flop the solar eclipse and lunar eclipse… even though I tell them, you know, sun [uses a fist to show where the Sun would be in space], moon [points to show where the Moon would be in space], Earth [points to show where the Earth would be in space], you know, that’s all you have to know--which way it’s aligned… but, they still flip-flop, so… depending on the kids….

Post-instruction teacher interview. The post-instruction interview questions were focused on the teacher’s reflections about her instruction, and the degree to which she thought students experienced a change in their understanding of the concepts taught during the unit. She was asked how she felt the students’ learning progressed through the course of the unit, and if she made modifications to her original plans to accommodate students’ preconceptions or otherwise differentiate instruction.

The teacher began by stating that she felt her students had learned the content, at least to some degree, as a result of instruction, stating, “I think it went well… my assessments show that students did improve, and, you know, they did learn, you know, compared to the pre-assessments I had done.” When asked if there were any modifications she had made to instruction during the course of the unit, the teacher noted the difficulty experienced by two of the students.

Researcher: Did you need to modify anything, different from your original lesson plans that, …modify things to, like, accommodate student learning?
Teacher: Yeah, umm, so after the… whichever day I did that we worked on where I had, you know, the lamp set up, and the Earth and the Moon, and we went around and they had to draw…

Researcher: Like, at the beginning?

Teacher: Mmm-hmm, more towards the beginning… and then, when they had to figure out what it really should’ve looked like compared to what they drew–most of the kids got it except two, so then those two didn’t… they just struggled with the concept of what the light looked like and how it was shining on the ball…. 

She also explained that there were environmental factors that caused some of the students’ confusion, and how she modified the activity for the two students who were experiencing difficulty.

Teacher: (continued from above) …and it didn’t help that my room was not totally dark…so what I did was, I made cards of the actual moon phases with the name right on the card so we could just use that–as they went around, they could reference that card, so….

Researcher: So that was an addition?

Teacher: Yes, I didn’t have that planned….

Researcher: Were you planning, already, on having the two separate tests like you did?

Teacher: Yes.

Researcher: Okay, so that was something that you usually do?

Teacher: Yes, I usually do that with that class.

The teacher was asked if there were any changes she would make to the lesson when teaching the same content to a different group of students. She reflected on what she would do differently if her students were “on grade level” and able to work more independently than her current group of students. This indicated a view of her current
students as dependent learners as described in Chapter 2. She also stated that, if she were teaching the same content to students who were “on grade level,” she would not have to modify the unit assessment in the same way she did for her current group of students.

**Researcher:** Okay, going forward with the same lesson next year, different group of kids, is there anything that you’d change or do differently?

**Teacher:** You know, it all just depends on the group of kids that I get… let’s say if I got a group of kids who were on grade level…a lot of those lessons would be totally different, as far as a lot more independence…where I did the… the… they had the light and they moved around, you know that activity, it would be more independent, and I wouldn’t have to be there like, holding the Earth, and holding the Moon and saying… you know, they would be able to go around….The assessment would look different… umm, they could handle the assessment from the book, but you know, typically, I’ll make my own, but just, you know, make it at a higher level….

She then reflected on an element of one of the activities she utilized during the completed lesson, the independent work stations students completed on Day 8. She speculated that the difficulty her students had with completing this activity independently resulted from a lack of structure and information provided to them on their answer sheet.

**Teacher, continued:** I think I noticed that, when I did the eclipse review stations set up all around the room, the sheet that I had given them was more open-ended, and just kind of blank–they had to follow the cards and figure out what to do, but the answer sheet was more blank… I would have set it up more, where I had more information on there. Like, even though, like, the one question said, you know, “put in order and draw a solar and lunar eclipse” and then, so it was blank, and some of them weren’t way off, but didn’t necessarily follow the directions… so maybe on the paper, I would have set up like “lunar eclipse,” “solar eclipse,” like, organized it for them a little bit more, so…
**Researcher:** Just visually organized it…

**Teacher:** Yeah.

Finally, the teacher was asked about the impact of her instruction on students’ learning.

**Researcher:** Umm, did the students’ learning progress the way you expected it to?

**Teacher:** Yeah. It was pretty typical of that classroom, it’s what I expected.

**Researcher:** Okay.

**Teacher:** Especially as far as individual differences…

**Researcher:** Do you think from the beginning to the end, each student’s understanding of the concepts you were teaching improved?

**Teacher:** Each student’s?

**Researcher:** nods

The teacher then discussed two students who had particular difficulty with learning the concepts presented. She confirmed that these difficulties were typical for the two students, and then provided some context for this in the case of Student 6.

**Teacher:** Yes… there’s one student in particular in that class that, on certain days, things don’t stick, or is just off… he’s kind of in a, I want to call it a “fantasy world” sometimes… um, but I always expect that, so…

**Researcher:** It’s pretty typical?

**Teacher:** Yeah, it’s pretty typical.

**Researcher:** But the rest, I mean, as far as their typical learning, it was pretty representative?

**Teacher:** Yes. And then the one student, he struggles a little bit more too, because he’s only been in this country for two or three years… and prior to that, had no language when he came here first, had no language at all…

**Researcher:** Ahh… wow…
**Teacher:** …was not in any kind of formal schooling in his other country, so... he struggles sometimes and needs, I mean he was one of the students that needed the ca- the visual cards… um, but again, I expect that from him, you know what I mean?

Student 6 had the highest number of alternative conceptions, and these remained relatively unchanged throughout the course of instruction, including his understanding of the movement patterns of the Earth, the Sun, and the Moon. The teacher’s assessment of the learning challenges of the two students was consistent with the instruction provided and the modifications made to accommodate these students’ learning.

**Chapter Summary**

Prior to receiving instruction, the majority of students possessed an alternative or fragmented understanding of the Earth-Sun-Moon relationship and lunar concepts. Results from the measure of students’ knowledge of the Earth-Sun-Moon relationship on the three component questions (Earth-Sun-Moon relationship, gravity, patterns of orbit) indicated a moderate degree of conceptual change. Results from the measure of students’ understanding of lunar concepts showed a greater gain in conceptual understanding than was shown on the Earth-Sun-Moon relationship measure.

Analysis of the scientific classroom talk that occurred during instruction showed that the teacher maintained a high level of control over the discourse. Another notable element of classroom talk that may have been altered, whether consciously or unconsciously as a result of the teacher’s perception of her students’ ability, is how infrequently key vocabulary was used during scientific discourse. This was true for words that both did and did not have a standard ASL sign equivalent. Student interview
data indicated that very few of the words were learned, at least at the level of print recognition, by students during instruction.

Data from pre- and post-instruction interviews with the teacher provided insight into her perceptions of her students’ abilities. The teacher expressed her perception of her students as largely dependent learners, which seemed to have an effect on how she delivered instruction. The teacher’s perception of her students’ ability to engage in a productive dialogue may have resulted in a greater level of teacher control over classroom talk.
CHAPTER 5
CONCLUSIONS

Introduction

The purpose of this qualitative study was to identify and analyze the misconceptions DHH students may have regarding scientific concepts. This study addressed DHH students’ understandings, and/or misconceptions, of the Earth-Sun-Moon relationship. Analysis focused on students’ conceptual understandings both before and after participation in an instructional unit on the Earth-Sun-Moon relationship. The data analyzed for this study included classroom observation videos and fieldnotes that were taken during each day of the unit on the Earth-Sun-Moon relationship, as well as audio- and video-recorded interviews with the teacher and with each of the student participants 2 weeks prior to, and 2 weeks after instruction. Data from classroom observations conducted during instruction were analyzed to determine the influence of the language used during instruction on students’ understanding of concepts. The influence of the teacher’s perceptions of students’ knowledge and learning was also analyzed using classroom observation and pre- and post-instruction teacher interview data. The setting for the study was a seventh grade science classroom at a Midwestern residential school for the deaf and hard of hearing. The instruction that occurred during the study was reviewed in detail in Chapter 3.
Discussion of Findings

In this chapter, the findings presented in Chapter 4 will be reviewed and synthesized with the findings of previous research on conceptual change, classroom talk, and teacher perceptions that were presented in Chapter 2.

Conceptual Change

According to state content standards, students in the middle grades (6-8) are expected to demonstrate the ability to recognize that the moon orbits around Earth, recognize different stages in the lunar cycle (e.g., full moon, new moon), and show how the positions of Earth, moon and sun cause tides and eclipses (ODE, 2012, p. 7). Research conducted on the conceptual understanding of these Earth-Sun-Moon concepts by students in all grades, from elementary through post-secondary, shows that misconceptions in this area are common and persistent across age groups (Trundle et al., 2002, 2006, 2007a, 2007b, 2010).

Students’ conceptual understandings were investigated through semi-structured pre- and post-instruction interviews with the researcher. With regard to students’ conceptual change, the findings of the present study indicate that, prior to instruction, most students held either fragmented or alternative understandings concepts related to Earth-Moon-Sun concepts. A comparison of pre-instruction and post-instruction student responses (n= 35) showed a positive change in conceptual understanding in fifty-seven percent (20/35) of student responses to questions. Twenty-six percent (9/35) of student responses indicated no change in understanding from pre- to post-instruction, and seventeen percent (6/35) of responses were indicative of an understanding that became less scientific following instruction.
Prior to instruction, none of the students were able to explain the importance of gravity to the Earth-Sun-Moon relationship, several students believed it was possible to see the whole moon from Earth, and all of the students described the lunar phases without using any scientific language (e.g., phase names). Two students, however, did express a scientific understanding of the movement patterns of the Earth-Moon-Sun system prior to instruction. These students modeled the orbit of the moon around Earth, and Earth around the sun.

**Alternative conceptions.** The students held many of the same alternative conceptions about the Earth-Moon-Sun relationship as have been documented in previous research, and some of these are of note. In Watts’ (1982) study of students’ misconceptions about gravity, the understanding that “Where there’s no air, there’s no gravity” (p. 118) was identified as an alternative conception among secondary students. A similar alternative understanding of the nature and importance of gravity to the Earth-Moon relationship was seen in two different students’ interview responses during the present study. During the post-instruction interview, for example, Student 3 stated, “Gravity surrounds Earth. If a rocket goes to space, it will have no air, only around Earth.”

Jones, Lynch, and Reesink (1987) documented third and sixth grade students’ models of the movement pattern of the Earth-Moon-Sun system and found that the majority (12/16) of third graders’ models were Earth-centered, while the majority (10/16) of sixth graders’ models were sun-centered. The findings of this study indicate that the majority (5/6) students’ models of the movement pattern of the Earth-Moon-Sun system are Earth-centered, consistent with the models of the younger group of students in the
Jones et al. (1987) study. Following instruction, four of the students in the present study stated that the moon orbits Earth, while the sun and Earth are stationary. Two of these four students included an explanation of the rotation of Earth in their response. Another student responded that the moon orbits both the sun and Earth, which was an alternative understanding also identified by Jones et al. (1987).

**Overall conceptual change.** The students who participated in this study each experienced a varying degree of conceptual change. While two of the students experienced a positive degree of conceptual change across all six of the target concepts, the other four students showed a positive degree of conceptual change in three or fewer of the six target concepts. Moreover, post-instruction student interview data indicated that none of the students developed a fully scientific understanding of all six target concepts. The student who had the highest number of alternative conceptions prior to instruction exhibited post-instruction understanding that was relatively unchanged. Following instruction, all of this student’s responses were indicative of an alternative understanding. Two students exhibited understanding that was nearly fully scientific following instruction. At least half of each students’ responses were indicative of scientific understanding, and the remainder were coded as scientific fragments of understanding or scientific fragments with alternative fragments following instruction.

**Classroom Talk**

The acquisition of scientific language is a key part of students’ learning and requires students to become socialized into the discourse of science through participation in classroom talk. Morton argued that an investigation of classroom talk is an essential dimension of conceptual change research because of central roles of “discourse and
dialogue in bringing about changes in learners’ understandings” (Morton, 2012, p. 102). And, according to Morton, it is the teacher’s role to mediate a shift in students’ understandings of scientific concepts from an “everyday” view to a more scientific view.

However, the concepts and meanings relayed to students through teacher talk are not always clear to students; as each individual constructs his or her own meaning from the talk and from other stimuli present in the classroom, and these meanings may be taken up differently by different students (Bell & Freyberg, 1985). The findings of the present study show that classroom talk and instructional activities directly influence the degree to which students who are DHH undergo conceptual change in ways that are both similar to and uniquely different from that of their peers with typical hearing.

**Vocabulary and word meanings.** Twelve words made up the list of target vocabulary for the unit on the Earth-Sun-Moon relationship: gravity, eclipse, Earth, moon, sun, rotation, and revolution, axis, umbra, penumbra, lunar phase, and satellite. Of these twelve words, the teacher stated that five do not have an established ASL sign translation: axis, umbra, penumbra, lunar phase, and satellite.

Students’ pre- and post-instruction interview results showed that all of the students exhibited limited knowledge of the target vocabulary both before and after instruction; three of the six students maintained the same limited ability to recognize target vocabulary from the beginning of instruction until the end. Of the other three students who learned at least one of the target vocabulary words during instruction, two students learned the word satellite, two students learned the word gravity, one student learned the word umbra, and one student learned the word penumbra. None of the students were able to identify the words eclipse, lunar phase, rotation, revolution, or axis,
either before or after instruction, and none of the students were able to correctly identify any more than half of the words.

It is suspected that students’ minimal progress in recognition of target vocabulary is a result of limited exposure to these words in either print or sign language. Analysis of classroom observation data confirms that a consistent sign for the terms *axis*, *umbra*, *penumbra*, or *lunar phase* was not used during instruction. Instead, it was noted that fingerspelling (manually representing each letter of a word) and chaining (presenting multiple representations of the word) were used to convey these concepts, and, in some cases, the target concepts were explained but the associated word was not made explicit. Consistent with the findings of Lang et al. (2007), the absence of an agreed upon word to label particular concepts seemed to constrain students’ ability to meaningfully connect the concepts being presented to language that they understood, or to facilitate integration of these new concepts to an existing framework of understanding.

These findings are consistent with the research of Molander et al. (2010), who found that students who are DHH demonstrate limited understanding of scientific meanings of words and are less skilled than their hearing counterparts at using these words to reason about phenomena (p. 44). Molander et al. (2010) went on to caution that, when students who are DHH learn new words, or words that have a different meaning in a scientific context than in an everyday context, these words may not be meaningfully integrated into a coherent framework, but may be learned as “isolated facts” (p. 44).

**Construction of meaning and conceptual change through classroom talk.**

Based on their study of meaning construction through classroom talk of kindergarten children, Bell and Freyberg (1985) identified some examples of how classroom talk may
or may not facilitate a fruitful construction of meaning. Some of these include: (a) teacher ignoring student talk that is off-topic or presented in unscientific language, (b) student(s) ignoring teacher talk that is not understood, or (c) students and teachers engaging in classroom talk that contains an unidentified mismatch in understanding of subtle differences in the meanings of words when used in a scientific context versus an everyday context. In the case of the present study there were several occasions where each of these examples were noted during instruction.

During teacher-led discussions in which student participation was invited through teacher questioning, the teacher often did not respond to student comments that were off-topic or not scientific. As seen in the discussion of the term *satellite*, presented in Chapter 4 (pp. 130-133), two of the students made comments that were not taken up by the teacher or evaluated, potentially because these comments were not understood by the teacher, or because they were off-topic. This occurred in several other instances, particularly with students who had the weakest conceptions of material, which seemed to have negative consequences to learning. For example, when Student 1 was attempting to answer a question posed by the teacher and his response was incorrect, the teacher did not acknowledge the response of Student 1, and instead, repeated the question to the rest of the class. Student 1 was then observed to sign (to himself) “I don’t care…” which could also be interpreted as “whatever” repeatedly.

The findings of this study are in line with those of Molander et al. (2007) who found that group discussion with students who are DHH tends to be unproductive because the different perspectives and prior knowledge of students “constitute sidetracks rather than opportunities to elaborate on earlier statements, and there is no joint platform
upon which to try alternative perspectives” (p. 339). The intention of building understanding through the discussion of a variety of student perspectives is not realized if student contributions are too disparate, which, Molander et al. (2007) contend, results not in the development of scientific understanding, but “rather where various parallel monologues take place” (p. 339). Molander et al. (2007) discussed the implications for group work in science learning for students who are DHH where the goal is to further learning through collaboration and group discussion. Considering the results of their study on the difficulty of DHH students to construct meaning through joint dialogue, they suggested that “if ideas and conceptions are not congruent to a certain extent, the risk is that group work instead becomes an individual guessing game, and may even reinforce the view of science as incomprehensible” (p. 339).

Borgna et al. (2011) asserted that many students who are DHH possess “a generalized tendency toward superficial processing of to-be-learned text or to-be solved problems that can result in reduced cognitive growth” (p. 94) and "a tendency to focus on individual items or dimensions of a task rather than to engage in integrative or relational processing” (p. 95). The authors went on to suggest that, rather than focusing on domain-specific skills, instruction and classroom dialogue that support the development of cognitive and metacognitive skills would be more of more benefit to students who are DHH. Consistent with the findings of Borgna et al. (2011), the students in the present study exhibited difficulty integrating their knowledge across conceptual dimensions.

The teacher’s perception of her students’ ability to engage in a productive dialogue may also result in a greater level of teacher control over classroom talk. It was clear in interviews with the teacher that she expected at least some of her students to be
unable to handle “grade-level” expectations of ability or understanding, and that she perceived most or all of the students as dependent learners. These factors will be discussed in the following section, which details the convergence of teacher perceptions with classroom talk and student learning.

**Teacher Perceptions**

An understanding of the influence of classroom talk on student learning must take into account the perceptions of the orchestrator of the talk and instruction, the science teacher. Instruction aimed at instantiating conceptual change requires the teacher be aware of the existing and emerging understandings of students, to attend to the ways students are talking about these understandings, and to incorporate students’ lived experiences as part of this apprenticeship (Mortimer & Scott, 2003). Teachers with predetermined assumptions about the validity of their students’ initial conceptions or ability to understand the concepts that are being presented may unintentionally restrict or alter the classroom discourse and learning that occurs. Tasker and Freyberg (1985) found that if teachers design instructional activities from their own scientific perspective, discrepancies between the teacher’s expectation of what students will learn and what students actually learn are common.

Students who are DHH have been characterized as exhibiting “dependent” learning styles (Lang et al., 1999; Marschark et al., 2002), e.g., one who relies on explicit direction and guidance without taking ownership of his or her own learning (Kahn et al., 2013; Lang et al., 1999). The findings of this study are consistent with the observation made by Kahn et al. (2013) that teachers who are attempting to teach to the perceived dependent learning styles of their students by providing “highly ordered instruction” (p.
may actually constrain students’ ability to develop the skills required for authentic scientific inquiry. Data from pre- and post-instruction interviews with the teacher provided insight into her perceptions of her students’ abilities. The teacher expressed her perception of her students as largely dependent learners (see Chapter 4, p. *), which seemed to have an effect on how she delivered instruction.

As detailed in Chapter 3, the instructional activities that occurred during the unit on the Earth-Sun-Moon relationship consisted primarily of lecture and teacher-led group discussion, and small-group or individual teacher-guided activities (see Appendix D for a summary of each day of instruction). The teacher utilized visual representations, or models, of the concepts being learned throughout instruction.

Findings from student interview data indicated that, in some cases, the models may have done more to contribute to students’ misconceptions than to support conceptual change. For example, in the case of the globe/lamp/volleyball model, some students’ understanding of the movement patterns of Earth were altered based on the characteristics of the model. For example, the two students who held a scientific understanding of how the Earth orbits the sun in the pre-instruction interview indicated during the post-instruction interview that they had revised their conception during instruction. During the post-instruction interview, the same two students responded that, while the moon orbits Earth, Earth is stationary (e.g., does not orbit the sun). The change from a scientific to an alternative understanding of the movement patterns of the Earth may be attributed to the use of the globe/lamp/volleyball model in which the globe (Earth) was stationary, and only able to rotate. In this case, the teacher did not explicitly state the
limitations of the model with regard to the orbit of Earth, which may have resulted in creating or reinforcing students’ misconceptions.

Students’ individual differences in language and prior knowledge may have been a factor in their ability to interpret models and integrate the concepts represented by a model into their established frameworks. According to Krajcik and Varelas (2006), “individual differences, especially in prior knowledge, are critical in determining what impact visual representations and their design will have on learners’ cognitive structures and processes” (p. 1074). Harrison and Treagust (1998) found that models contributed to 8th – 10th grade students’ alternative conceptions when the students believed there was a “one-to-one correspondence between the models used and reality” (p. 425). If students are not made aware of the salient features of a model and of its limitations, the learning activity may lead to “unintended or incomplete” (Gilbert & Boulter, 1998, p. 58) understandings, as seen in the case of the two students in the present study. Further, conceptual change data also indicated students’ weak understanding of the importance of gravity to the Earth-Moon system persisted from pre- to post-instruction. It should be noted, however, that the researcher phrased the question using the sign for gravity provided by the teacher, while the teacher did not use this sign consistently during instruction (more frequently using the sign pull).

Limitations to the Present Study

There were several limitations to the present study. The sample of students who participated was small and non-random. The research was conducted at a residential school for students who are DHH. Because the majority of students who are DHH
receive instruction in a general education setting (Mitchell & Karchmer, 2011; Reed et al., 2008), this is also a limitation to the generalizability of findings.

The teacher was responsible for the design of the instruction and the methods used, the researcher did not influence the way the content was presented. This may also be a limitation to the present study, as the findings are based on only the researcher’s interpretation of the teacher’s intentions for this design (with the exception of the information obtained through the teacher interviews). The teacher was not aware of the research questions or of what particular aspects of the instruction the researcher was investigating, again making findings interpretive rather than conclusive.

There were several breaks in instruction that occurred at the beginning of the unit, as described in detail in Chapter 3. These breaks may have had an effect on student learning, another limitation of the present study.

The interview questions were based on the learning goals of the unit, as provided in the curriculum materials that were used by the teacher, as well as on state and national content standards. The interview format allowed students to demonstrate their knowledge through verbal (signed) responses and with the use of a simplified Earth-Moon-Sun model. Analysis of each students’ degree of conceptual change was limited by the potential for such change to occur within the confines of time established for the present study. Additionally, assessments of students’ prior knowledge of science concepts or language used within science classroom were not obtained, which may influence the interpretation of findings.

Several limitations should be noted with regard to the methodological impact of sign language (Roald & Mikalsen, 2001). Student interview questions were translated
from printed English into sign language, which may have unintentionally altered the question or the way the question was perceived by students. In their study of DHH students’ conceptions of the Earth-Moon-Sun system, Roald and Mikalsen (2001) suggested that the spatial nature of sign language may have influenced students’ responses to questions. The researcher’s translation of classroom discourse and the interview responses of students from sign language into English may have altered their original meaning either due to errors in translation or issues of precise translatability between languages. Finally, a limitation in the ability to adequately represent a visual-spatial language (ASL) in writing may have a limiting effect on the researcher’s ability to convey potentially relevant intricacies of meaning in the translation to English.

Implications and Recommendations for Future Research

The purpose of this study was to identify and analyze the misconceptions students who are DHH may have regarding the Earth-Moon-Sun relationship, to explore the ways classroom talk and teacher perceptions affect learning outcomes, and to provide recommendations for ways classroom teachers can most effectively utilize classroom talk to maximize the learning of their students. The findings of this study have significant implications for both research and practice.

*Intentional and explicit use of the scientific terms for target concepts.* A component of classroom discourse that seemed to influence students’ conceptual change was the infrequent use of scientific terms when discussing target concepts such as *gravity* and *lunar phase*. Studies of the use of sign language in science have shown a lack of standardization in the vocabulary of science (Lang et al., 2007) and issues with ambiguity of meaning in translation from scientific terms into sign language (Molander et al., 2007,
2010). However, data from this study show several instances where the scientific term was simply omitted, and student conceptual change data suggests that this may have had an influence on learning.

The findings of this study along with the findings of previous research suggest that the language of science needs careful attention by teachers and interpreters (for students who are DHH in mainstream settings) to ensure the language being used is consistent and conceptually accurate. An increased use of resources such as the STEM Sign Lexicon website from the National Technological Institute for the Deaf (www.rit.edu/ntid) would support the standardization and use of conceptually accurate signs used during instruction.

Teacher awareness of and attention to student misconceptions during instruction. In order to provide instruction that supports conceptual change and development of scientific understanding, teachers must be aware of their students’ potential misconceptions or alternative understandings of scientific concepts. Although there is a substantial and growing body of research documenting the misconceptions of students with typical hearing at all ages and grade levels, this is the first study to explore the conceptual change of students who are DHH. It is reasonable to assume, then, that teachers who are DHH are unaware of the potential benefit to student learning that can occur when misconceptions are discovered and addressed. As suggested by Lang (1994), teacher preparation programs and professional development for in-service teachers of students who are DHH that focus on the development of thinking and language skills within the context of science instruction are critical. The findings of this study indicate
that an awareness of the importance of attention to student misconceptions would also be of great benefit.

With respect to future research, the field would benefit from continued investigation of the misconceptions of students who are DHH. Further study of student misconceptions across grade levels and conceptual areas would provide an evidence-base from which to more accurately and effectively adapt the science curriculum to the unique needs of students who are DHH.
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APPENDIX A

Figure A.1  SHARK (1) (retrieved from Vicars, 2004)

Figure A.2  SHARK (2) (adapted from Vicars, 2004)
APPENDIX B

Student Interview Questions

1) Please tell me the signs for these words (show vocabulary cards):
   a) satellite  b) gravity  c) eclipse  d) umbra
   e) lunar phase  f) penumbra  g) Earth  h) moon
   i) sun  j) rotation  k) revolution  l) axis

2) How are the sun, the moon, and Earth related?
   a) Is gravity important to this relationship? How?
   b) Use this model to show me how the sun, the moon, and Earth rotate.
   c) What kinds of changes does this rotation produce on the Earth?

3) How does the moon move in relation to Earth?
   a) Is it possible to see the whole moon from Earth?
   b) Describe the lunar cycle – how does the moon look at different times?
   c) What is a lunar eclipse? Explain what happens during a lunar eclipse.
APPENDIX C

Teacher Interview Questions

Pre-instruction interview

1) How many years have you taught? How many years have you taught students who are DHH? What is your educational background?

1) Please tell me the signs you use for these science terms (show vocabulary cards):
   a) satellite    b) gravity    c) eclipse    d) umbra
   e) lunar phase  f) penumbra  g) Earth      h) moon
   i) sun         j) rotation   k) revolution l) axis

2) Describe how you will teach the unit; what instructional methods will you use?

3) Are there any concepts you anticipate will be more or less difficult for students to understand?

Post-instruction interview

1) How do you think the lesson went?

2) Was there anything that you needed to modify that was different from your original lesson plans to accommodate student learning during instruction?

3) Is there anything you would change?

4) How do you think the students’ learning progressed?

5) How did your instruction impact students’ concept development?
### APPENDIX D

Instructional activities and models/representations used, by day

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Target Concept/Topic</th>
<th>Instructional Activities</th>
<th>Models/Representations</th>
</tr>
</thead>
</table>
|       | - Earth-Moon relationship (movement patterns, relative location in space)  
- Vocabulary/concept introduction: moon, gravity, orbit, satellite, | - Journaling: “What do you know about the moon?”  
- Lecture/Group discussion: The moon’s orbit around Earth  
- Lecture/Group discussion of vocabulary (i.e., satellite, gravity) | - Globe (Earth) and Styrofoam ball (moon)  
- Force of gravity demonstration (2 students holding hands and spinning in a circle to feel “pull”) |

<table>
<thead>
<tr>
<th>Day 2</th>
<th>Target Concept/Topic</th>
<th>Instructional Activities</th>
<th>Models/Representations</th>
</tr>
</thead>
</table>
|       | - Review of Earth-Moon relationship  
- Orbit of moon around Earth and one visible side of the moon  
- Lunar phases | - Lecture/group discussion  
- Students modeling rotation and revolution of Earth and the moon  
- Lunar phase calendar assignment | - Globe (Earth) & Styrofoam ball (moon)  
- Students’ physical demonstration of orbit  
- Lunar phase simulator website |

<table>
<thead>
<tr>
<th>Day 3</th>
<th>Target Concept/Topic</th>
<th>Instructional Activities</th>
<th>Models/Representations</th>
</tr>
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</table>
|       | - Review of lunar phase calendar assignment from Day 2  
- Lunar phases and movement patterns of moon around Earth relative to the sun | - Teacher guided review of a completed lunar phase calendar  
- Teacher-led demonstration of lunar phases with model  
- Student recording of changing appearance of moon on lunar phase diagram | - Lunar phase calendar projected on Smartboard  
- Globe (Earth), lamp (sun), volleyball (moon) model  
- Lunar phase diagram |

<table>
<thead>
<tr>
<th>Day 4</th>
<th>Target Concept/Topic</th>
<th>Instructional Activities</th>
<th>Models/Representations</th>
</tr>
</thead>
</table>
|       | - Importance of gravity to the Earth-Moon Sun system  
- Vocabulary: Lunar phase names | - Lecture/group discussion: gravity  
- Lecture/review of lunar phases  
- Lunar phase labeling activity  
- Teacher-guided notetaking of Bird’s-eye view diagram of Earth-Moon-Sun system on Smartboard | - Lunar phase diagram, blank lines for phase names |
| Day 5 | - Lunar phase labeling  
- Lunar eclipses | - Focused, modified instructional support; teacher with two students  
- Four students working collaboratively to complete lunar phases workbook assignment  
- Lecture, vocabulary introduction | - Globe (Earth), lamp (sun), volleyball (moon) model  
- Lunar phase simulation video on Smartboard |
| Day 6 | - Lunar phase names: **waxing**, **waning**  
- Lunar phase labeling, ordering | - Lecture: vocabulary  
- Small group work (2 groups of 3 students) at stations:  
  1) Interactive Smartboard module: order and label the phases of the moon according to the lunar phase chart;  
  2) Peer-checked review of lunar phases using volleyball model | - Globe (Earth), lamp (sun), volleyball (moon) model  
- Lunar phase diagram |
| Day 7 | - Solar and lunar eclipses  
- Orbit of moon on tilted axis of Earth/equator  
- Movement pattern of Earth/Moon/Sun that creates lunar and solar eclipses | - Lecture/group discussion: eclipses  
- Journaling: “what do you think happened in the three videos?”  
- Lecture/teacher-led demonstration of lunar and solar eclipses using model | - Video clips of lunar and solar eclipses  
- Globe (Earth), lamp (sun), Styrofoam ball (moon) on pencil model |
| Day 8 | - Review of all unit concepts | - Individual work at stations (**Illustrate It, Assess It, Research It, Organize It, Watch It, Explore It**) | - Activity instruction cards  
- Computer simulation, lunar phase cards, online video |
| Day 9 | - Review of all unit concepts | - Review “game” with questions displayed on the Smartboard, students answering with clickers  
- Discussion of students’ answers as review for assessment | - Teacher-created quiz on Smartboard |
| Day 10 | - Unit Assessment | - Students completed end-of-unit assessment, teacher provided 1:1 support for all | - Teacher-created assessment in 2 formats (modified and simplified) |