The Role of Cognitive, Metacognitive, and Motivational Variables in Conceptual Change: Preservice Early Childhood Teachers' Conceptual Understanding of the Cause of Lunar Phases

DISSERTATION

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Abstract

This study seeks to explore and describe the role of cognitive, metacognitive, and motivational variables in conceptual change. More specifically, the purposes of the study were (1) to investigate the predictive ability of a learning model that was developed based on the intentional conceptual change perspective in predicting change in conceptual understandings of the cause of moon phases, (2) to examine the relationship between the coherency of participants' conceptual understandings and their level of metacognitive strategy use and the type of conceptual understandings they construct after instruction, and (3) to explore the role of metaconceptual awareness in the change and the durability of conceptual understandings. A total of 52 preservice early childhood teachers participated in the study. Participants were enrolled in a science method course, which was part of the early childhood education program. All 52 participants were interviewed before and after instruction. Sixteen out of 52 participants were randomly selected based on their level of metacognition for delayed-post interviews.

Two data gathering techniques were used in the study: a self-report instrument and semi-structured interviews. To measure participants' use of cognitive and metacognitive strategies and their motivational beliefs, the *Motivated Strategies for Learning Questionnaire* was used. To reveal the participants' understanding of moon phases, semi-structured interviews were conducted before, one to two weeks after, and 13 to 15 weeks after instruction. In delayed-post interviews, participants' level of metacognitive awareness was also assessed using an interview protocol that was designed for the study.

Data obtained through interviews were analyzed using constant comparative method of analysis to reveal participants conceptual and metacognitive profiles. To make statistical analysis possible, participants' Pre-, post-, delayed-post conceptual understandings and metacognitive awareness were scored with rubrics designed for this study. Quantitative data were analyzed using a partial least squares path analysis and Kruskall-Wallis test.

Results indicated that participants who frequently used elaboration and organization strategies were more likely to engage in conceptual change and construct a scientific understanding of the cause of the lunar phases. The use of metacognitive strategies facilitated participants' use of deep-level cognitive strategies, which in turn promoted conceptual change. Motivational beliefs had direct influences on participants' use of cognitive and metacognitive strategies. Participants with high motivational beliefs were more likely to use cognitive and metacognitive strategies. Thus, they were more likely to engage in conceptual change. The results provided evidence that the hypothesized model has a high predictive ability in explaining change in participants' conceptual understandings from the pre to post-interviews.

Results demonstrated that participants with high a metacognitive state were more likely to construct coherent mental models. In other words, these participants' conceptual understandings of the cause of lunar phases included a single, coherent, causal

explanation before instruction. They were also more likely to construct coherent mental models after instruction.

Results also indicated that the participants who maintained their scientific conceptual understandings or progressed toward scientific conceptual understandings throughout the study obtained significantly higher metaconceptual awareness scores than those participants who regressed in their conceptual understandings or maintained alternative conceptual understandings. The direct effects of metaconceptual awareness on conceptual change and the durability of conceptual change were both statistically significant. Participants with high metaconceptual awareness score were more likely to change their alternative conceptual understandings after instruction and they also were more likely to retain their scientific conceptual understandings several months after instruction. The results provided evidence that metaconceptual awareness plays a significant role in the change and the durability of conceptual understandings.

Dedication

This dissertation is dedicated to my grandmother Havva.

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Fields of Study

Major Field: Education

Specialization: Early Childhood Education

Minor: Statistical Data Analysis.

Minor: Research Methods in Human Resource Development.

Table of Contents

List of Tables

List of Figures

Chapter 1: NATURE and SCOPE of the STUDY

Introduction

The discovery of the importance of prior knowledge in subsequent learning (Ausubel, 1963, 1968) and Piaget's groundbreaking research on children (1972a, b) led researchers to take interest in what students know before formal instruction. As a result of this interest, a large body of literature has been generated to investigate children's ideas about how the natural world works (Bar, 1989; Carey, 1985; Dove, 1998; Inbody, 1964; Moyle, 1980; Munn, 1974; Nussbaum, 1985; Osborne & Cosgrove, 1983; Russell, Bell, Longden, & McGuigan, 1993; Russell &Watt, 1990; Vosniadou & Brewer, 1992; Za'rour, 1976). These studies revealed that, although they are mostly divergent from scientific explanations, children have ideas, beliefs, and explanations of how things happen in the world around them. Piaget (1972a, b) used the term *naïve ideas* to describe these types of ideas held by children. Children's ideas also have been variously referred to as *alternative conceptions* (Dove, 1998), *misconceptions* (Posner, Strike, Hewson, & Gertzog, 1982;), *children's science* (Bell, 1993), *preconceptions* (Novak, 1977), *mini-theories* (Claxton, 1993), *initial explanatory frameworks (*Vosniadou, 2002a*), alternative frameworks* (Barnett & Morran, 2002; Gilbert & Watts, 1983), and *children's ideas* (Driver, Guesne, & Tiberghien, 1985a) in the literature. Many studies also revealed that like unschooled children, students, adults, and teachers also hold alternative ideas in various domains of science (Atwood & Atwood, 1995; Atwood & Atwood, 1996; Hynd, 1998; Schoon, 1995; Trundle, Atwood, & Christopher, 2002; Tytler, 2000).

Researchers' documentation and description of the nature of conceptual understandings that are contrary to scientific explanations have laid a foundation for the conceptual change learning theory (Posner et al., 1982). The first conceptual change theory proposed by Posner et al. (1982) was followed by several other conceptual change theories, including conceptual capture and conceptual exchange (Hewson, 1981,1982), weak and strong restructuring (Carey, 1985), branch jumping and tree switching (Thagard, 1991), knowledge in pieces (diSessa, 1993), ontological categories (Chi & Slotta, 1993), weak revision and strong revision (Vosniadou, 1994a), and development of tool using practice (Ivarsson, Schoultz, & Saljo, 2002). These theories were developed based on different theoretical frameworks to explain how students learn scientific concepts as well as change their existing conceptions in science classrooms.

Informed by the above mentioned conceptual change theories, several instructional strategies were designed to promote conceptual change in understanding scientific concepts (Champagne, Gunstone, & Klopfer, 1985; Chinn & Brewer, 1993; Cosgrove & Osborne, 1985; Driver, Guesne, & Tiberghien, 1985b; Hewson & Hewson, 1984; Nussbaum & Novick, 1982; Osborne & Wittrock, 1983). Reviews of those research studies indicated that instructional strategies based on the conceptual change model of learning are generally more effective than the traditional instructional strategies in enhancing and changing the students' conceptual understandings of scientific concepts (Scott, Asoko, & Driver, 1997; Tobin, Tippins, & Gallard, 1994; Wandersee, Mintzes, &

Novak, 1994). Although more effective than the traditional instructional strategies, the results of conceptual understandings that were constructed through instruction designed based on the conceptual change model of learning still were not very impressive (Callison & Wright, 1993; Sadler, 1987; Targan, 1988; Zeilik, Schau, & Mattern, 1999), and in most cases they also were not durable over time (Georghiades, 2004a; Trundle, Atwood, & Christopher, 2007a; Tytler & Peterson, 2004).

Researchers suggest that earlier conceptual change theory-based instructional strategies had limited impact on learners' understanding because these theories did not consider affective and metacognitive factors learners possess or experience as a function of learning environment in explaining how students engage in conceptual change (Hennessy, 2003; Linnenbrink & Pintrich, 2003; Mayer, 2002; Pintrich, Marx, & Boyle, 1993; Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001; Georghiades, 2000, 2004b). Many researchers seem to agree that a learning theory must include the "skill and will" components to adequately describe and explain how students learn in school (Ausubel, 2000; VanderStoep & Pintrich, 2003; Vosniadou, 1999; Zimmerman, 1995; Zusho & Pintrich, 2003). While the skill components, such as cognitive and metacognitive strategies, provide the necessary tools to process information and construct conceptual understanding, the will components, such as self-efficacy and goal orientation, incite learners to initiate and sustain the use of those mental tools in learning.

The contemporary conceptual change literature suggests a need for a comprehensive learning model that takes affective, cognitive, and metacognitive variables into account to describe and explain how students learn scientific concepts and to inform instructional strategies to promote conceptual change. Intentional learning theory might provide the necessary theoretical basis for construction of such a comprehensive learning model (Bereiter & Scardamalia, 1989; Margaret, 1997). The intentional conceptual change theory, which synthesizes intentional learning and cognitive developmental perspective to conceptual change, suggests that learners' level of metacognition and motivation and their use of various cognitive strategies might play an important role in conceptual understanding of scientific concepts (Luques, 2003; Pintrich, 1999; Sinatra & Pintrich, 2003; Vosniadou, 2003, 2007).

Although some researchers have been interested in examining the suggested relationship between cognitive, metacognitive, motivational variables and conceptual understanding and change (Barlia & Beeth, 1999; Georghiades, 2000; Linnenbrik & Pintrich, 2002), no research has been conducted to investigate the role of those variables in conceptual change as a whole. Therefore, this study aimed to investigate the role of a set of the variables (e.g., metacognition, motivation, and cognitive strategies) that were suggested as being related to conceptual change in the preservice teachers' conceptual understanding of lunar concepts based on the theoretical framework of intentional conceptual change theory.

The Purpose of the Study

The current descriptive study aimed to explore and describe the role of motivational, cognitive, and metacognitive variables in conceptual change. This study, however, was not an experimental study nor did it investigate the effect of the instruction on conceptual change.

More specifically, the purposes of the study were:

1. To investigate the predictive ability of a learning model that was developed based on the intentional conceptual change perspective in predicting change in conceptual understandings of the cause of moon phases.
2. To examine the relationship between the coherency of participants' conceptual understandings and their level of metacognitive strategy use and the type of conceptual understandings they construct after instruction.
3. To explore the role of metaconceptual awareness in the change and the durability of conceptual understandings.

In line with the above purposes, three sets of hypotheses, a total of 12 hypotheses, were generated for the study. These hypotheses are provided in chapter 2 along with a theoretical basis for each hypothesis.

Problem Statement

The initial conceptual change theory, proposed by Posner et al. (1982), has been criticized because it puts too much emphasis on the rational aspect of learning and neglects affective and social issues of conceptual change (Duit, 1999; Pintrich et al., 1993). Motivational constructs such as goal orientation, task value, and self-efficacy were not included in the theory. Therefore, this initial theory was considered to be based on "cold and isolated" cognition (Pintrich et al., 1993). Moreover, the initial conceptual change theory proposed by Posner et al., did not take learners' use of cognitive and metacognitive strategies and metacognitive awareness, which were suggested being related to conceptual change by several researchers, into consideration for conceptual change (Linnenbrik & Pintrich, 2002; Sinatra & Pintrich, 2003; Vosniadou, 1994a, 2003). However, Strike and Posner (1992) later agreed that motivational variables play an important role in conceptual change. Although these scholars revised their theory, the influences of identified variables on conceptual change have yet to be examined thoroughly in the literature.

Although there have been some attempts to investigate the relationship between learners’ motivational factors (Barlia & Beeth, 1999; Chambers & Andre, 1995; Qian & Alverman, 1995), their use of cognitive and metacognitive strategy use (Alao & Guthrie, 1999; Linnenbrik & Pintrich, 2002) and metacognitive awareness (Thorley, 1990; Yuruk, 2007) on conceptual change, no research has been conducted to explore these variables together using a learning model based on an integrative theoretical framework. Moreover, most previous studies assessed participants’ conceptual understanding using a multiple choice instrument rendering them to be indistinguishable from studies that investigated the relationship between academic achievement and motivation and use of learning strategies. Because multiple choice instruments tend to overestimate conceptual understanding and fail to accurately detect misconceptions, many researchers have suggested using assessment methods such as semi-structured interviews in studying conceptual change (Gilbert, Watts, & Osborne, 1985; Posner & Gertzog, 1982; Trundle et al., 2002).

There is an ongoing discussion among the researchers from the field of educational psychology (Pintrich, et al., 1993; Sinatra, 2005; Sinatra & Pintrich, 2003) and conceptual change (Trundle et al., 2007a; Vosniadou, 1999; 2003) about the role of metacognition, cognitive strategies, and motivational factors in the conceptual change process. Although researchers from both fields have discussed a possible relationship between metacognition, cognitive strategies, motivational variables, and conceptual change, and some have suggested a theoretical explanation of conceptual change from the perspective of intentional learning, there is lack evidence from empirical studies to support the existence of such relationships. The current study aims to fill this gap in the literature by testing the predictive ability of a learning model, which was generated based on the intentional conceptual change perspective, in predicting the change in participants' conceptual understanding of the cause of the moon phases.

Significance of the Study

Although there is a body of research on the relationship between learners' use of cognitive and metacognitive strategy use, metaconceptual awareness, and motivational factors and academic performance, the studies that investigated the role of cognitive, metacognitive, and motivational variables in the process of conceptual change had some limitations. For example, previous studies utilized multiple choice instruments to assess their participants' conceptual change, which makes many of these studies indistinguishable from those studies that investigated the relationship between the variables mentioned above and academic performance. The current study utilized a semi-structured interview method, developed by Trundle et al. (2002, 2007a) and used in various conceptual change studies, to assess its participants' conceptual understanding. Moreover, in the current study an instructional strategy that was highly effective to promote conceptual change was utilized (Trundle et al., 2002, 2007a). Therefore, unlike previous studies, the present study was in a better position of assessing participants' conceptual change and examining how motivational, cognitive, and metacognitive factors helped participants benefit from the instruction that was designed to promote conceptual change.

Limitations of the Study

There are several limitations of this study. The sample was relatively homogenous. Participants of the current study were volunteers and most students were white females in their 20s. Since the sample was not randomly selected from the population, the results of this study cannot be generalized to a broader population. The multiple-choice instrument, the *Motivated Strategies for Learning Questionnaire* (MSLQ), used to assess participants' motivation and their use of cognitive and metacognitive strategies has the limitations typical with self-report instruments including participants' lack of cooperation in providing information about themselves. Also, the researcher was a non-native speaker of the English language, which may have affected the collection and transcription of the qualitative data. However, a part of the qualitative data was analyzed by a native speaker of English who was experienced in analyzing this type of interview data to establish reliability of the qualitative analysis to address this limitation. The independent variables of the study were not manipulated. Since only the association between the independent variables and the dependent variable was observed, strong causal inferences cannot be made.

Definition of Terms

Conceptual Definitions

Concept: "A mental construct consisting of a person's organized information about an item or a class of items" (Klausmeier, 1992, p.268).

Alternative Conception: A type of conceptual understanding that is not compatible with the current scientific explanation for a given phenomenon (Trundle et al., 2002)

Mental model: "… analog representations that preserve the structure of the thing they represent" (Vosniadou, 2002a, p.356).

Self-efficacy: “People’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” (Bandura, 1986, p.391).

Goal-orientation: Learners’ intentions for engaging, choosing and persisting at different learning tasks. There are two major goal orientations: mastery orientation and performance orientation (Meece, Anderman, & Anderman, 2006).

Task value: The evaluation of the given academic task in terms of how interesting, important and useful it is (Pintrich, Smith, Garcia, & McKeachie, 1991).

Cognitive strategy: Cognitive process or operations learners engage in to carry out an academic task or to acquire, retain, retrieve, and organize the different kinds of knowledge and performance (Pressley et al., 1995).

Metacognition: One’s knowledge, awareness, and control of his/her own cognitive system (Brown, 1987; Flavell, 1987; Kuhn, Amsel, & O'Loughlin, 1988)

Metaconceptual awareness: A mental state where one's knowledge is available to one's conscious reflection and verbal elaboration (Flavell, 1986).

Internal coherency: The structural organization of a conceptual understanding that does not include more than one explanation (mental model), which usually contradict with each other, for a given phenomenon. Coherent conceptual understanding can be alternative or scientific.

Durability of conception: The retention of newly constructed scientific mental models within the learners' conceptual system (Georghiades, 2000; Tytler & Peterson. 2004).

Operational Definitions

Self-efficacy: The summated score of responses to the 8 items on the "self-efficacy for learning and performance" subscale of MSLQ, based on a seven point summated rating scale identifying degree of agreement and given a numerical value ranging from not at all true of me = 1 to very true of me = 7.

Goal-orientation: Mastery goal-orientation is measured by the summated score of responses to the four items on the "intrinsic goal-orientation" subscale of MSLQ, based on a seven point summated rating scale identifying degree of agreement and given a numerical value ranging from not at all true of me = 1 to very true of me = 7.

Task-value: The summated score of responses to the six items on the "task-value" subscale of MSLQ, based on a seven point summated rating scale identifying degree of agreement and given a numerical value ranging from not at all true of me = 1 to very true of me = 7.

Cognitive strategy use: Elaboration strategy use is measured by the summated score of responses to the six items on the “elaboration” subscale of MSLQ and organization strategy use is measured by the summated score of responses to the four items on the “organization” subscale of MSLQ, both are based on a seven point summated rating scale identifying degree of agreement and given a numerical value ranging from not at all true of me = 1 to very true of me = 7.

Metacognitive strategy use: The summated score of responses to the 12 items on the “metacognitive self-regulation” subscale of MSLQ, based on a seven point summated rating scale identifying degree of agreement and given a numerical value ranging from not at all true of me = 1 to very true of me = 7.

Conceptual understanding: Responses to the questions in conceptual understanding interviews that were scored, ranging from 0 to 10, using the scoring rubric for interview protocol A (Appendix D).

Conceptual change: Residuals of the post-conceptual understandings scores after it was regressed on pre-conceptual understanding scores.

Metaconceptual awareness: Responses to the questions in metaconceptual awareness interviews that were scored, ranging from 0 to 10, using the coding and scoring sheet for interview protocol B (Appendix E).

Chapter 2: LITERATURE REVIEW

Introduction

This chapter provides an overview of the theoretical framework employed in the study and a review of the relevant literature. The chapter is organized in four sections. The first section describes and discusses conceptual change theories and summarizes the theoretical foundations of the current study. The second section describes the constructs of the study (e.g., motivational beliefs, cognitive strategies, and metacognition) and discusses their relationship with conceptual understanding and change. The third section provides the research hypotheses and their theoretical bases. The last section provides a review of the alternative conceptions studies that investigated the learners' conceptual understandings of the cause of lunar phases.

Conceptual Change Theories

The term concept can be defined as a mental construct that describes an organized body of information about an object or groups of objects (Klausmeier, 1992). This mental construct could correspond to objects and events themselves such as the moon or correspond to the relationships between objects and events such as cause of the moon phases (Cohen & Murphy, 1984). Concepts help learners to reduce the complexity of the environment and order, relate, and generalize classes of events, and, most importantly, make inferences, solve problems, and learn new concepts (Howard, 1987; Klausmeier, Ghatala, & Frayer, 1974). Concepts also allow learners to identify novel members of a category (Wisniewski & Medin, 1994). Although the terms schema and concept are used interchangeably, they are different constructs. Both schemata and concepts are mental representations; however, a schema is seen as a cluster of related concepts (Howard, 1987).

Previous studies in concept learning have been done in artificial settings focusing on non-school related concepts (Klausmeier et al., 1974). During that era, researchers focused on how people learn (e.g., nonsense symbols, aggregates of nonsense symbols, and isolated words), and how people sort objects into categories (Clark, 1971; Wisniewski & Medin, 1994; van der Veer, 1998). This initial focus of concept learning or concept attainment evolved into a new area of studies during the 1970s, which is how people learn more complex concepts taught in schools such as scientific concepts (Novak, 1971). The rediscovery of Piaget’s studies with young children, which revealed that even young children have ideas (naive ideas) about the how natural world works, and Ausubel's (1968) meaningful learning theory, which emphasized the importance of prior knowledge as a central variable affecting subsequent learning, led researchers to study children’s initial ideas. These studies revealed that children’s conceptual understandings are mostly inconsistent with the scientific thinking presented in schools (Bell, 1993; Dove, 1998; Driver et al., 1985b; Gilbert & Watts, 1983; Novak, 1977; Posner et al., 1982; Vosniadou, 2002b).

Research studies, which documented alternative conceptions of children in various domains, revealed that alternative conceptions are often pervasive and resistant to change through traditional forms of instruction (Driver et al., 1985b; Gilbert & Watts, 1983). For many researchers this is because alternative conceptions are embedded in organized cognitive structures and reinforced by everyday experiences (Vosniadou, 1994b, 2002a). Alternative conception studies have changed researchers' understandings of what learning is and how it occurs. Thus, researchers' changing understanding of learning from concept attainment to concept construction led to the development of a learning model called conceptual change (Posner et al., 1982; Strike & Posner, 1992; Van der Veer, 1998).

Learning as Conceptual Change

Conceptual change is a learning theory based on constructivist epistemology which posits that learners actively construct their own understanding, and the findings of the alternative conceptions movement revealed that learners do not come to school like empty vessels (Driver et al., 1985a, b; Fosnot, 1996; Tyson, Venville, Harrison, & Treagust, 1997). Conceptual change theory is based on the idea that children come to school with preconceptions that are mostly organized, coherent and resistant to change through traditional forms of instructions. These initial concepts, which often are at odds with scientifically accepted norms, may facilitate or impede learning of other concepts (Trundle et al., 2002, 2007a).

After the initial conceptual change model of Posner et al. (1982) appeared in the literature, several other models were proposed by researchers from different theoretical backgrounds (Carey, 1985; Chi & Roscoe, 2002; diSessa, 1993; Hewson & Hewson, 1984; Thagard, 1991; Vosniadou, 1994a). These conceptual change models seem to have their roots in two different research traditions: cognitive psychology and science education (Vosniadou, 1999). In this chapter, two major approaches to conceptual change, the framework theory and intentional conceptual change theory, are discussed in detail and these theories provide the theoretical framework of the study.

Framework Theory

Framework theory for this study describes participants' cognitive representations of the cause of the moon phases and explains the mechanism of conceptual change. Framework theory is rooted in contemporary cognitive and developmental psychology traditions and is based on the neo-Piagetian view that cognitive development involves *domain-specific restructuring* rather than *global restructuring* (Carey, 1985; Vosniadou, 1999).

Framework theory uses the term *enrichment* (accretion), which refers to basic knowledge addition into an existing conceptual structure, and the term *revision*, which refers to a change in this conceptual structure, to explain the mechanisms of conceptual change (Vosniadou (1994a; 1999; 2002b). The terms "enrichment" and "revision" are based on Piaget's concepts of assimilation and accommodation respectively.

While enrichment refers to the addition of basic knowledge into an *existing framework*, revision refers to a change in this framework. Vosniadou (1994a) described two types of revision: revision at the level of *specific theory* or *weak revision*, and revision at the level of *framework theory* or *strong revision*. The term framework theory refers to the conceptual system learners form to interpret their observations about the physical world and the information provided by the culture. Framework theories constrain the knowledge construction process through either facilitating or hindering later learning, particularly in the case of learning scientific concepts. This is due to qualitative differences between scientific explanations of natural phenomena and explanations constructed on the basis of everyday experiences (Vosniadou, 1999). A framework theory includes entrenched *ontological* and *epistemological presuppositions* about the phenomena that are acquired early in life and reinforced by everyday experience (Schnotz, Vosniadou, & Carretero, 1999). Ontological presuppositions refer to the assumptions about what exists and how existed entities are categorized. Epistemological presuppositions refer to the assumptions about the nature of the knowledge, explanation, and learning (Vosniadou & Ioannides, 1998). The presuppositions of framework theory do not operate *in pieces* but form a relatively coherent explanatory structure (Vosniadou & Brewer, 1992).

A specific theory, on the other hand, includes "a set of interrelated propositions or beliefs that describe the properties and behavior of physical objects" (Vosniadou, 1994a, p.47). Vosniadou and Brewer (1992) distinguished between *beliefs* that are based on superficial observations and that are relatively easy to change compared to presuppositions that are deeper theoretical constructs, which are more difficult to change. A specific theory is formed under the constraints of the framework theory through observation or information provided by the culture (Vosniadou & Ioannides, 1998).

According to Vosniadou (1994a), children's initial conceptual knowledge of the physical world is organized in a framework theory of physics on which further knowledge is constructed. Vosniadou (1999) also states "the difficulty of understanding science concepts and the creation of misconceptions is to be found in the inconsistencies that exist between the fundamentally contradictory systems of presuppositions and beliefs that lie behind different ontological categories" (p.8). Unlike theorists of initial conceptual change model (Posner et al. 1982), Vosniadou believes that conceptual change does not happen suddenly. Rather, it is a gradual and time-consuming process because learners are not aware of their implicit ontological and epistemological presuppositions, and these presuppositions are deeply entrenched as a result of repeated confirmation by everyday experiences (Schnotz et al., 1999; Vosniadou, 1999).

Vosniadou (2002b) makes a distinction between initial explanations before instruction (preconceptions or naïve ideas/ initial mental models) and those that result after instruction, which may include misconceptions/ synthetic models). According to Vosniadou, synthetic models constantly change as children's knowledge systems evolve. To reconcile new information with prior knowledge, learners' initial models may be transformed into synthetic models.

In this model of conceptual change learners are seen as mental model builders who experience conflict due to newly presented knowledge that is inconsistent with their existent conceptual structure and seek to build internally coherent conceptual understanding. Learners build their own mental models by integrating new material from science instruction with their existing alternative frameworks (Mayer, 2002). In terms of Vosniadou's theory, the conceptual change process can be described as "a gradual process that leads from initial mental models via synthetic models to scientifically correct models" (Schnotz et al., 1999, p.xv). However, in some cases it is possible for initial models to directly change into a scientific model.

Mental Models

Conceptual change is defined as the gradual modification of existing mental models into synthetic mental models or mental models that accurately represent the current scientific understanding of a given phenomenon (Vosniadou, 1994a). Vosniadou and Brewer (1992) used the term “mental model”, borrowed from Johnson-Laird (1983), to refer the cognitive representations learners constructed of phenomena. “Mental models are analog representations that preserve the structure of the thing they represent” (Vosniaodu, 2002, p.356). Mental models are constructed from specific theories under the constraints of presupposition of the framework theories (Vosniadou & Ioannides, 1998).

Mental models are similar to schemata in the sense that both are constructed to be representations of the external world. However, schemata are generic representations based on generic knowledge structures, whereas mental models are specific knowledge structures constructed at the moment (Brewer, 1987). Most mental models are constructed on the spot to generate explanations for specific situations. However some mental models that are proven to work by experience may be stored in the long-term memory and retrieved when needed (Vosniadou, 1994a, b; 2002b). Mental models are usually internally coherent, explanatory, and predictive systems. They have three important functions: 1) aid in the construction of explanation, 2) work as mediators in the interpretation and acquisition of new information, and 3) work as a tool that allows experimentation and theory revision (Vosniaodu & Brewer, 1992; Vosniadou, 1994a, b, 2002b).

In the case of learners’ mental models in astronomy, three different mental models learners generated and used to explain the shape of the world were identified: intuitive models that are based on every day experiences, scientific models that are based on scientifically accepted knowledge, and synthetic models that are formed as a result of the learners' attempt to combine intuitive knowledge with scientific knowledge (Vosniadou & Brewer, 1992). A series of studies on children’s understandings of the shape of the world, day and night, and physics provided evidence that children consistently use one of these mental models to explain the shape of the world regardless of the contextual difference and use of different data gathering techniques (Vosniadou, Skopeliti, & Ikospentaki, 2004, 2005).

Although some researchers have argued that “mental models” are a function of the way Vosniadou and Brewer (1992) gathered and analyzed their data (Schoultz, Saljo, & Wyndhamn, 2001) and that learners’ conceptual understandings cannot be described as well-organized cognitive structures (diSessa, 1993), several studies corroborated the notion that learners have a few well-developed mental models they use to explain and make sense of the natural phenomena (Christidou & Hatzinikida, 2006; Diakidoy & Kendeou, 2001; Lin & Chiu, 2007; Trundle et al., 2002).

Intentional Conceptual Change

The intentional conceptual change perspective is a relatively recent model of learning that aims to explain how students restructure their conceptual understandings. It utilizes the concept of intentional learning, which can be simply defined as “cognitive processes that have learning as a goal rather than an incidental outcome" (Bereiter & Scardamalia, 1989, p.363), to explain the self-regulated dimension of conceptual change.

The foundation of intentional conceptual change perspective has been established by Pintrich et al. (1993) in a seminal article where they criticized the initial conceptual change theory (Posner et al., 1982) for describing the change process as a solely rational enterprise and neglecting the role of affective factors in conceptual change. In light of a body of research literature that investigated the relationship between cognitive, metacognitive, and motivational variables and student learning, advocates of the intentional conceptual change perspective postulated that conceptual change depends not only on cognitive factors but also depends on metacognitive, motivational, and affective processes (Sinatra & Pintrich, 2003). Arguing that conceptual change requires learners to be aware of their existing conceptual understanding and have deliberate goal orientation to learn and understand the material, Sinatra and Pintrich (2003) described intentional conceptual change as "the goal-directed and conscious initiation and regulation of cognitive, metacognitive, and motivational process to bring about a change in knowledge" (Sinatra & Pintrich, 2003, p.6). More specifically, the intentional conceptual change perspective suggests that to successfully engage in conceptual change, learners must be aware of the need for change, be able to know what to change, have a willingness to change, and be able to regulate their change process using cognitive and metacognitive strategies (Luques, 2003).

The intentional conceptual change perspective does not offer an alternative explanation for the source and nature of cognitive structures and the mechanism of conceptual change. Therefore, the intentional conceptual change theory might be considered as a complementary perspective to conceptual change that utilizes the findings of intentional learning and self-regulated learning studies to explain the condition and the process of conceptual change. Although, the intentional conceptual change perspective can be easily synthesized with any conceptual change model, particularly with the models that are based on cognitive psychology, the framework theory (Vosniadou, 1994a) seems to be the more compatible model.

The conceptual change theory proposed by Vosniadou (1994a) and utilized in several studies that investigated the learners' conceptual understanding of astronomical phenomena appears to be very useful in describing and explaining learners' conceptual understanding and change (Trundle et al., 2002, 2007a). Therefore, considering the dependent variable of the current study (change in conceptual understanding of the cause of moon phases) and its compatibility with the intentional conceptual change perspective, Vosniadou's conceptual change model was utilized in the present study. The theoretical framework of this study, which is based on the framework theory (Vosniadou, 1994a), previous studies on lunar concepts (Trundle et al., 2002, 2007a), and the intentional conceptual change perspective (Pintrich, 1999; Pintrich et al., 1993), can be outlined as follows:

1) Preconceptions constructed prior to formal instruction are mostly alternative conceptions and they can either facilitate or inhibit conceptual change.

2) Alternative conceptions are usually coherent mental structures embedded in a wider conceptual framework, thus, they can be highly resistant to change if based on entrenched ideas.
3) Misconceptions are products of learners' attempts to integrate novel knowledge into their existing conceptual understanding without restructuring the latter.
4) Enrichment and revision are the mechanisms of conceptual change. Alternative conceptions are transformed into scientific conceptions through enrichment or revision of existing conceptual structure.
5) Conceptual change can be a gradual process and may require a considerable amount of instructional time.
6) Learners' motivational beliefs, their cognitive and metacognitive strategy use, and metacognitive awareness play important roles in the conceptual change process.

Constructs of the Study

Motivational Beliefs

The purpose of the following section is to illustrate and discuss the role of three motivational constructs (e.g., self-efficacy, mastery goal orientation, and task value) in the process of conceptual change. Seminal works on these three motivational constructs and recent studies that investigated the relationship among those three constructs and conceptual change will be discussed.

Self-efficacy

The concept of self-efficacy is the core concept of social cognitive theory, which assumes that human behavior, environment, and personal factors mutually interact and serve as determinants of one another (Bandura, 1997). According to Bandura, efficacy belief is the foundation of human agency, because people have little incentive to act if they do not believe that they can accomplish a given task. Bandura (1986) called this efficacy beliefs perceived self-efficacy and defined it as “people’s judgments of their capabilities to organize and execute courses of action required to attain designated types of performances” (p.391). Efficacy judgments are not concerned with the quantity of the skill one has but with what one believes one can do with those skills. Judgments of self-efficacy determine the amount of effort and persistence a learner will put forth when faced with an obstacle, and it is also related to the investment of cognitive effort to achieve a task (Bandura, 1982). Thus, self-efficacy can explain both the choice and level of activity engaged in and the likelihood of successful completion (Tuckman & Sexton, 1990).

In learning contexts, self-efficacy beliefs can be defined as learners’ beliefs about their capabilities to learn or perform an academic task at designated levels (Schunk & Zimmerman, 1997). A body of research indicates a positive link between self-efficacy and academic achievement (Schunk, 1990; Tuckman, 2003; Zimmerman, Bandura, & Martinez-Pons, 1992). Pajares and Miller (1994) found that self-efficacy was more predictive of problem solving than other personal variables such as self-concept, perceived usefulness, task related prior experience, and gender.

Several studies provided evidence that learners’ self-efficacy belief influences their academic performance by determining the amount of cognitive effort and persistence learner put forth (Greene, Miller, Crowson, Duke, & Akey, 2004; Schunk, 1990; Tuckman, 2003). Conceptual change requires learners to invest a great amount of cognitive effort and be persistent in understanding the differences between their alternative models and scientific models. Hence, learners' self-efficacy belief might be an important factor that influences their level of conceptual change. In the following subsection the relationship between self-efficacy and conceptual change will be discussed.

Self-efficacy and Conceptual Change

According to Bandura (1989), self-efficacy beliefs may influence cognitive activity in two ways: self-aiding or self-hindering. Similarly, self-efficacy is believed to have both direct effects on conceptual change and indirect effects via behavioral and cognitive engagement. The effect of self-efficacy for conceptual change might vary depending on how self-efficacy is conceptualized. If self-efficacy is defined as one's confidence in one's knowledge of what is being learned, self-efficacy may be detrimental to the conceptual change process because students might have such confidence in their prior beliefs that they are unwilling to change them (Linnenbrink & Pintrich, 2003; Pintrich, et al., 1993). Indeed, a recent case study with three high school students provided evidence that this might be the case. In this study, students with high self-efficacy for learning science exhibited resistance to change their alternative ideas if they had low metacognitive skills. In contrast, students with low self-efficacy belief but with high metacognitive skills were more likely to change their alternative ideas (Anderson & Nashon, 2007).

Another way to perceive the relation of self-efficacy to conceptual change is the confidence students have in their capabilities to change, organize, integrate, and synthesize scientific concepts. From this perspective, self-efficacy would be the students' confidence in their ability to use the scientific way of thinking or detect inconsistencies between their prior knowledge and newly introduced knowledge. High self-efficacy should enhance conceptual change in that students will feel confident that they can alter their prior theories or construct theories based on new ideas. Self-efficacy may also influence conceptual change via cognitive and behavioral engagement, since a high level of self efficacy is associated with increased persistence and effort, whereas low levels of efficacy are related to decreased persistence and effort (Linnenbrink & Pintrich, 2003; Pintrich, 1999; Pintrich, et al., 1993).

Although a considerable amount of literature has been published on the relationship between efficacy beliefs and academic achievement in various domains, few studies have focused on the relationship between learners' self-efficacy beliefs and their engagement in conceptual change. Some of these studies reported a significant relationship between students' efficacy beliefs for learning science and their conceptual understandings of density and buoyancy concepts (Yin, 2005) and electricity concept (Olson, 1999). Results of these studies seem to support the assertion that higher self-efficacy for science learning may facilitate the students' engagement in conceptual change. However, some other studies found no significant relationship between self-efficacy beliefs and conceptual understandings (Barlia, 1999; Kang, Scharmann, Noh, & Koh, 2005). Moreover, in a recent study with high school students, self-efficacy belief was found to be an obstacle in changing alternative ideas if students have low metacognitive skills (Anderson & Nashon, 2007).

Self-efficacy beliefs determine the amount of persistence and cognitive effort learners invest to complete a learning task successfully (Bandura, 1982). Conceptual change is a learning task that requires learners to invest a great amount of effort, be persistent in trying to understand when scientific concepts contradict their prior knowledge, and use deep cognitive strategies (such as elaboration and organization) to process and construct scientific concepts (Pintrich, 1999). Therefore, it seems logical to anticipate learners with high self-efficacy to engage in conceptual change more easily. However, additional studies are needed to provide evidence for the hypothesized positive relationship between the self-efficacy beliefs and conceptual change.

Mastery Goal Orientation

Goal orientation theory, which focuses on learners' intentions for engaging, choosing, and persisting at different learning tasks, is another way to understand why and how students engage in particular academic activities (Meece et al., 2006). Goal orientation theory is based on the assumption that individuals' goals provide meaning, direction, and purpose to all actions. According to achievement goal theory, students' interpretation and reaction to learning tasks are controlled by their learning goals. That is, goals influence the amount of time and cognitive effort students invest in an academic task (Covington, 2000). There are two main goal orientations: mastery or learning goal orientation, also called intrinsic goal orientation, and performance goal orientation, also called extrinsic goal orientation (Linnenbrink & Pintrich, 2003; McWhaw & Abrami, 2001).

The mastery goal orientation is related to increasing competency, mastering skills and understanding learning materials, whereas performance goal orientation is related to outperforming or demonstrating a high ability relative to others (Covington, 2000; Meece et al., 2006). Mastery oriented students choose challenging tasks, in contrast to performance oriented students who chose tasks that they are sure they can do (Eccles & Wigfield, 2002). Thus, mastery oriented students are more likely to have a desire to develop their competence, have more optimistic perceptions of task difficulty, and set higher goals even in difficult classes (Horvath, Herleman, & McKie, 2006).

Mastery goals increase the amount of time spent on learning a task, persistence in the face of difficulty, and the quality of engagement in learning by activating the use various cognitive strategies for information processing (Ames, 1992). Goal orientation and learning strategies have been reported being correlated in several studies. In those studies performance orientation was often found to be related to the use of surface-level strategies, such as memorizing, whereas mastery orientation was found to be related to the use of deep-level strategies and self-monitoring (Covington, 2000; Meece et al., 2006; Vermetten, Lodewijks & Vermunt, 2001). Results of these studies suggest that students with mastery goal orientation engage in more self-regulated learning (Linnenbrink & Pintrich, 2003; Pintrich, et al., 1993) and deep-level processing (Ames & Archer, 1988; Vermetten et al., 2001). Thus, they gain higher grades than their peers (Schunk, 1996).

Learners' goal orientation has been reported to be associated with their achievement mediating through their use of cognitive and metacognitive strategy use and the amount of time they invest in studying (Linnenbrink & Pintrich, 2003; Vermetten et al., 2001). Since, mastery goal orientated students frequently use cognitive and metacognitive strategies, which are required to engage in conceptual change, having mastery goal orientation might facilitate conceptual change. In the next section, research studies that investigated the relationship between learners' goal orientation and conceptual change learning will be discussed.

Mastery Goal Orientation and Conceptual Change

Students with a mastery goal might be more likely to engage in conceptual change as mastery goals are mainly associated with metacognitive awareness, self-regulatory strategies, positive affects, and persistence (Linnenbrink & Pintrich, 2002; Pintrich, et al., 1993). The mastery goal orientation and use of deeper cognitive strategy have been reported as being correlated, and deeper processing reportedly increased the probability of conceptual change and understanding in several studies (Kang et al., 2005; Kowalski & Taylor, 2004; McWhaw & Abrami, 2001; Pintrich, 1999). Therefore, it seems quite likely that mastery-oriented students engage in the type of cognitive processing necessary for conceptual change to occur. In addition, mastery oriented students are more likely to see new information as an opportunity to meet their goal of learning and advance their understanding of the topic; consequently, they might be more open to the conceptual change process (Linnenbrink & Pintrich, 2003; Pintrich, et al., 1993).

Few studies have investigated the relationship between adoption of mastery goal orientation and conceptual change. These studies provided evidence that a mastery goal orientation is indirectly related to conceptual change (Alao & Guthrie, 1999; Kang et al., 2005; Yin, 2005; Zusho & Pintrich, 2005), and it is highly related to learners' engagement and use of deep-level cognitive strategies (Alao & Guthrie, 1999; Barlia, 1999; Lee & Anderson, 1993; Zusho & Pintrich, 2005). In general, results of these studies suggest that the adoption of a mastery goal orientation facilitates conceptual change by enhancing learner's task engagement and promoting their use of deep-level cognitive processing (Linnenbrink & Pintrich, 2002; 2003; Pintrich, 1999; Pintrich et al., 1993).

Task Value

Task value is another motivational construct related to academic performance. Unlike goal orientation, which refers to the reason for participating in the task, task value refers to the evaluation of the task itself in the sense of how interesting, important, and useful the task is (Pintrich et al., 1991). Learners engage in learning tasks that have utility value and attainment value. Utility value refers to how well a task relates to accomplishment of short or long-term goals. Utility value is the usefulness of a task for achieving learning goals. Attainment value, on the other hand, refers to the level of importance learners place on doing well on a task (Eccles & Wigfield, 2002). Utility value and attainment value can merge in some cases where competent performance is necessary for a task to be useful or where competent performance can help the learner work toward a more ideal self-concept. Therefore, researchers tend to combine both utility and attainment value and refer to the combined construct as task value (Durik, Vida & Eccles, 2006).

Task value can be perceived as a personal characteristic of learners that they bring to different tasks rather than features of the task itself. Task value refers to the student's perception of the importance of the content or task to him or her. Although task value does not have a direct effect on academic performance, it is related to students' choice of becoming cognitively engaged in a task or course and their willingness to persist at the task (Pintrich, 1999). Students' task values have been reported as being related to their use of cognitive and metacognitive strategies and their willingness to persist at a learning task (Pintrich et al., 1993; Pokay & Blumenfeld, 1990). Task value indirectly influences academic performance by promoting students' use of cognitive and metacognitive strategies and their engagement with a learning task.

Studies have shown that self-efficacy belief and task value are related constructs. Initially children's self-efficacy and task value are independent of each other. However, over time children begin to value the activities that they perform well. Thus, self-efficacy and task value become positively related to each other (Eccles & Wigfield, 2002). Although the two constructs are related, perceived self-efficacy belief has been found to be the better predictor of academic performance, whereas task value is a better predictor of behavioral decisions in most studies (Bong & Skaalvik, 2003; Durik et al., 2006).

Since task value increases attention and engagement in learning, students with high task value for a course or a learning task are expected to utilize all the cognitive and affective resources they possess to understand the course content. Therefore, valuing yet-to-be-learned science content might increase the likelihood of conceptual change by ensuring high attention to and engagement with course materials or a learning task and use of various cognitive strategies to process them. The following section examines studies on the role of high task value in conceptual change learning within science classrooms.

Task Value and Conceptual Change

Very few studies have focused on the relationship between task value and conceptual change in the literature. From their case analysis study, which might be the first study that examined the relationship between students' task value and conceptual change, Barlia and Beeth (1999) reported that personal interest in learning science is an important factor that positively influences students' conceptual change. Barlia and Beeth concluded that if the content of the course was important or useful to students' daily life and the course was required for graduation, conceptual change was more likely to occur. In their school life, students do not always enroll in the courses in which they are interested. Rather, the course may be required for the degree they pursue or as a graduation requirement. In this case, students' perception of task value, perceived importance of the course for the goal (utility value), may compensate for the lack of interest and facilitate the conceptual change process. In a more recent study with college students, task value also was found to be a significant predictor of course performance in an introductory chemistry course. Task value was the second best predictor of course performance after self-efficacy in the study (Zusho & Pintrich, 2003).

Although the above two studies provided evidence for the hypothesized relationship between the task value beliefs and conceptual change in the literature, Olson (1999) found no significant relationship between the task value and conceptual change. More specifically, there was no difference among students in the high, moderate, and low conceptual change groups in terms of the utility value. The results of Olson's study suggest, at least in some cases, that utility value alone might not be prevailing enough to activate the necessary cognitive resources to engage in conceptual change.

In sum, conceptual change requires students to maintain their cognitive engagement to understand alternative views to restructure their existing conceptual understandings. Task value beliefs may facilitate learners' use of cognitive and behavioral resources and thus promote conceptual change whereas a lack of task value may constrain conceptual change (Pintrich, 1999). Due to the very limited number of previous studies and the inconsistency in the results of those studies, more studies clearly are needed to describe the relationship between task value and conceptual change.

Cognitive Strategies

The aim of the following section is to describe the major cognitive strategies students use and discuss the role of using cognitive strategies in the process of conceptual change.

Deep-level Cognitive Strategies

A cognitive strategy refers to "the cognitive, affective and behavioral process people apply to achieve their goals and to evaluate the outcomes of their actions" (Heikkila & Lonka, 2006, p.102). In a learning environment, cognitive strategies can be defined as any cognitive processes or operations learners employ to carry out an academic task or to acquire, retain, and retrieve different kinds of knowledge and performance (Pressley et al., 1995). They can also be defined as the procedures students use to select, organize, and integrate novel information with their existing knowledge (Weinstein & Mayer, 1986). Researchers identified several cognitive strategies learners employ to carry out an academic task, and several researchers proposed categories to classify these strategies (Vermunt &Vermetten, 2004).

According to Marton and Saljo (1976a, b), cognitive strategies can be divided into two categories: surface strategies and deep strategies. Learners who adopt surface strategies study learning material linearly without asking in-depth questions. They show minimal interest in understanding the subject in its entirety and learn by relying on memory rather than understanding. In contrast, learners who adopt deep strategies study various aspects of the learning material to obtain the entire picture. They can relate new information to previously acquired knowledge and search for a connecting point between the novel information and their prior knowledge. Learners who use deep strategies also tend to use metacognitive skills (Biggs, 1984).

Elaboration and organization strategies are two deep-level strategies. Elaboration strategies involve paraphrasing, identifying important points, making analogies and generalizations, making connections, and expanding on the material that has been presented. Organization strategies involve making outlines, charts, and concept maps. Distinguishing important information from unimportant information, trying to figure out how new information fits with what one already knows, and monitoring one's understandings are characteristics of elaboration and organization strategies (VanderStoep & Pintrich, 2003). Since deep strategies are more useful to integrate new information with previous knowledge, they seem to be more crucial for conceptual change.

Elaboration strategies require learners to create a more sophisticated schema than what is presented, whereas organization strategies require students to link concepts and ideas in a particular order so that students can reorganize their own schemata (Lyke & Kelaher Young, 2006). Deep strategies are more likely than surface strategies to lead to understanding and retention of meaningful material. Learners who use deep cognitive strategies are likely to be more engaged with the material than are students who use surface strategies (Nolen, 1988).

The effective use of deep-level cognitive strategies has been reported as a critical variable in successful academic learning. A learner's ability to select and use cognitive strategies adaptively plays an important role in the outcome of a learning task. Several studies reported that there is a considerable difference between successful and less successful learners regarding their cognitive strategy use (Nolen, 1988; Thomas & Rohwer, 1986). Successful learners tend to select and use learning strategies matched with the demands of different tasks, whereas less successful learners either do not have effective strategies in their repertoires or did not choose to employ them at appropriate times.

Deep-level Cognitive Strategies and Conceptual Change

Conceptual change requires learners to monitor and compare their current conceptions with the one presented in a class. It also requires learners to make connections between what they know and what has been presented to them (Sinatra & Pintrich, 2003; Vosniadou, 2003). Therefore, it seems likely that the use of deep-level strategies will lead learners to engage in conceptual change. Indeed, the use of deeper processing strategies has been reported as increasing the probability of conceptual change and understanding (Kang et al., 2005; Kowalski & Taylor, 2004; Linnenbrik & Pintrich, 2002; McWhaw & Abrami, 2001).

For instance, Alao and Guthrie (1999) reported that the use of monitoring and elaboration strategies explained 4% of the variance in fifth-grade students' conceptual understanding of ecological concepts. Similarly, the use of an elaboration strategy was found to be related to conceptual change in a study with 110 undergraduate students in a physics class. In this study the use of an elaboration strategy alone explained 4% of the variance in change in physics understanding (Linnenbrik & Pintrich, 2002). In another study with 194 students in grades four through six, cognitive strategy use was found to be related to the high level of student engagement in an academic task and success in science class (Blumenfeld & Meece, 1988). These studies have shown that the use of cognitive strategies significantly contributes to students' course performance and conceptual understanding.

Metacognition

The purpose of this section is to describe the concept of metacognition and to discuss the role of metacognitive strategy use and metacognitive awareness in conceptual change.

Defining Metacognition

The concept of metacognition has been studied for over thirty years. Yet, there is no commonly agreed upon definition of this concept among the researchers (Borkowski, 1996; Flavell, 1979). However, most researchers agreed that the terms cognition and metacognition refer to qualitatively two different phenomena: the former refers to skills that are necessary to perform a cognitive task and the latter refers to skills that are necessary to monitor and control how the task is performed (Schraw, 1998).

There are various definitions of the metacognition in the literature reflecting the different frameworks of the researchers who study it. Flavell (1987, p.21) who coined the term metacognition defined it as “knowledge and cognition about cognitive objects, that is, about anything cognitive.” Brown (1987) suggested a similar definition focusing on the regulatory aspect of the metacognition. According to Brown (1987, p.66) metacognition is “one’s knowledge and control of own cognitive system.” Other researchers emphasized a different aspect of the metacognition, which is awareness. According to these researchers, metacognition refers to “awareness and understanding of various aspect of thought” (Berk, 2006, p.296) or “awareness and management of one’s own thought” (Kuhn & Dean, 2004, p.270). Several researchers have perceived awareness as a crucial condition for cognitive processing to work efficiently (Berk, 2006).

In fact, Flavell (1986) introduced the term “metaconceptual” to describe the mental state where one’s knowledge is available for one’s conscious reflection and verbal elaboration. He further explained that it is the learners’ ability to “talk about their own and other people’s mental events” (p.424). Kuhn et al. (1988) described this mental state as “thinking explicitly about a theory one holds (rather than only thinking with it)” (p.7). Following these descriptions of the mental state in which learners think about and reflect on the knowledge they have, it would appropriate to assume that metacognitive activity largely depends on learners' awareness.

Although there are several definitions of metacognition in the literature, these definitions contain several common aspects, which are: (a) knowledge about cognition, (b) control and regulation of cognitive activities, and (c) awareness of mental activities and contents (concepts).

Metacognitive Strategies and Conceptual Change

Metacognitive strategies should be distinguished from cognitive strategies. A cognitive strategy is used to reach a cognitive goal, such as summarizing the main point of a reading passage to process it better. A metacognitive strategy, on the other hand, is used to check or monitor to see if the cognitive strategy had been executed efficiently to reach the goal. Cognitive strategies are used to make cognitive progress, whereas metacognitive strategies are used to control and monitor the cognitive progress (Flavell, 1987). More specifically, metacognitive strategies are used to select proper strategies and resources to perform a cognitive task and to screen and assess the task performance (Schraw, 1998; Schraw & Mosham, 1995).

Several studies reported that metacognition plays a crucial role in selecting and using cognitive strategies demanded by various learning tasks. For example, in a study with 366 undergraduate students, metacognitive monitoring was reported as being highly related to students' use of deep-level cognitive strategies (Heikkila & Lonka, 2006). A moderate relationship between metacognitive monitoring, metacognitive control, and use of deep cognitive strategies was reported from another study with 88 ninth and tenth grade students (Wolters, 1999). Romainville (1994) found that students with high metacognition were aware of the cognitive strategies they used and were able to describe the cognitive process in which they engaged. These studies indicate that being aware of the cognitive strategies that are available and being able to use them in an appropriate time and way seems to be a function of metacognition.

Studies suggest that learners adapt and change their cognitive processing based on the information provided by metacognitive activities (Pintrich, Wolters, & Baxter, 2000). Metacognitive strategies are used to plan, monitor, and regulate the cognitive process (Pintrich & Schrauben, 1992; Pintrich et al., 1993). Therefore, learners with high metacognitive strategy use might be more likely to efficiently regulate their cognitive processing and thus restructure their alternative conceptual understandings.

Metacognitive Awareness and Coherency of Conceptual Understandings

Studies of students' understanding of various astronomy concepts, such as shape of the earth, the day and night cycle, and the cause of the moon phases, revealed that students may construct various conceptual understandings with different level of coherency (Trundle et al., 2002: 2007a; Vosniadou & Brewer, 1992). These studies showed that while some learners construct internally coherent conceptual understandings, conceptual understandings that include a single mental model, others construct incoherent conceptual understandings of astronomical phenomena, conceptual understandings that include more than one mental model. For example, Trundle and colleagues (2002, 2007a) identified six types of conceptual understandings of the cause of the moon phases, two of which seem to be different from others in terms of their internal coherency: scientific with an alternative fragment and alternative fragments. Students who construct either of these two types of conceptual understandings use more than one contradictory, inconsistent mental model. These students seem not to be aware that the explanations they provide are not only scientifically inaccurate and they lack coherency.

Recent studies by Oliva (1999, 2003) suggest a relationship between the level of structural coherency of the conceptions and the characteristic of conceptual change in which learners engage. Oliva reported that students with a high level of formal reasoning ability change their alternative conceptions more easily if their initial conceptions are highly structured. In contrast, students with concrete reasoning change their alternative conceptions more easily if their initial conceptions are less structured. Likewise, Trundle et al. (2007a) contended that students with a single coherent explanation for a given phenomenon before the instruction might be more likely to benefit from the instruction and engage in conceptual change. These results suggest not only a relationship between individual differences and the mechanism of conceptual change but also a relationship between the coherency of initial conceptions and the types of conceptual understandings learners hold after instruction.

The reason some learners construct internally coherent conceptions while others do not might be understood by perceiving the term metacognition in following way. Metacognition, or metacognitive awareness, can also be perceived as the learners' awareness of contradiction or conflict in the specific theory they use to construct mental models. Learners who are aware of the contradiction within the information their specific theory provides in order to construct a mental model might be more likely to select this information more carefully to construct a conceptual understanding that is internally consistent. Being metacognitively aware does not necessarily mean that the conceptual understanding constructed is consistent with the scientific explanation for the given phenomenon, rather it means constructing a conceptual understanding that is coherent and free of internal inconsistency. A coherent conceptual understanding can be scientific or alternative, but always include a single causal explanatory framework.

Students who have concepts that are categorized as scientific with an alternative fragment conceptions or alternative fragments might not be metacognitively aware that the conceptual understanding they use to explain the given phenomenon includes explanations/mental models that are not consistent with each other. Seeing internal consistency in conceptual understanding might be a function of metacognitive ability. That is, students who are metacognitively aware might be more likely to construct a conceptual understanding that is coherent, while students who are not metacognitively aware might be more likely to construct a conceptual understanding that is not coherent.

Thorley (1990) used the term “metaconceptual” to refer to the kind of awareness that permits learners to reflect on the content of their conceptions. His analysis of several discourses that took place in science classes provides examples of how metaconceptual awareness allowed students to recognize the inconsistencies in their reasoning and conceptions. Several researchers also used the term “metaconceptual awareness” to describe the learners' awareness of the difference between their alternative ideas and the scientific concepts (Vosniadou, 1994a, 2007; Vosniaodu & Ioannides, 1998) and the awareness of the changes in their concepts as a result of instruction (Mason & Boscolo, 2000). Although these researchers did not establish a link between the metacognitive awareness and the coherency of conceptual understanding, they suggested that students with metacognitive awareness might be able to recognize inconsistencies between their prior knowledge and the new knowledge presented to them in science classes (Kowalski & Taylor, 2004; Pintrich et al. 1993; Vosniadou, 1994a, 2007).

"Metacognition is the notion of thinking about one's own thought or thinking process" (Hennessey, 2003, p.104). For conceptual change to occur, individuals might need to be aware of the need to change and to be able to know what to change as well as to be able to construct a conceptual understanding that is coherent and consistent. This might be possible through awareness of the contradiction in one's explanation or recognizing that the learner is entertaining more than one explanation for a given phenomenon (Luques, 2003). Metacognition seems to play a vital role in learners' awareness of this contradiction as well as the conceptual understanding they construct.

Metacognition and Durability of Conceptual Change

One of the problems in conceptual change learning is the permanency of the change students experienced during the instruction. Georghiades (2000) used the term "durability of conceptions" to refer to the stability of newly constructed scientific mental models within the learners' conceptual system. Students who reverted to their alternative mental models after successfully engaging with conceptual change have been reported in several studies (Georghiades, 2004a; Trundle et al., 2007a; Tytler & Peterson, 2004). Georghiades (2000) described this situation as "conceptual decay" and Tytler (1998) described it as "regressing in thinking."

Trundle and her colleagues (Trundle et al., 2007a) speculated that a lack of metacognitive awareness, the learners' inability to detect inconsistencies in their conceptual understanding, might be the reason some students in their study reverted to their alternative mental models several months after instruction. Georghiades (2004a) also offered metacognitive awareness as a condition for durability of conceptual change. In his quasi-experimental study with 60 fifth grade students, students in the experimental groups who received the instruction on electricity through the metacognitive instance approach retained their scientific understanding longer than the students in the control groups. The findings of these studies suggest that students without metacognitive awareness, even after they engaged in successful conceptual change, are more likely to revert back to their previous alternative mental models. It appears that metacognitive awareness might not only play an important role in constructing coherent conceptual understanding but also ensure the stability of those scientific mental models once constructed.

Derivations of the Research Hypotheses

Three sets of research hypotheses were generated to address three main research questions posed in this study. In the following subsections each hypothesis is presented and the theoretical bases for the hypotheses are provided.

A Hypothesized Model of Intentional Conceptual Change

The first set of research hypotheses tests the predictive ability of the hypothesized model of intentional conceptual change and includes the following seven hypotheses:

Hypothesis 1: Preservice teachers' motivational beliefs will have a direct influence on their use of metacognitive strategies.

Motivational beliefs, such as self-efficacy, mastery goal orientation, and task value, promote learners' use of various metacognitive strategies. Studies have reported that students with high motivational beliefs are more likely to control and regulate their cognitive processing using metacognitive strategies (Linnenbrink & Pintrich, 2002; 2003; Pokay & Blumenfeld, 1990; Zusho & Pintrich, 2003). Therefore, the hypothesized model includes a direct influence of motivational beliefs on metacognitive strategies.

Hypothesis 2: Preservice teachers' motivational beliefs will have a direct influence on their use of deep-level cognitive strategies.

Motivational beliefs influence the amount of cognitive effort learners put forth. Studies indicated that students with high motivational beliefs tend to use deep-level cognitive strategies such as elaboration and organization that promote conceptual understandings of scientific concepts (Ames, 1992; Pintrich et al., 1993; Vermetten et al., 2001). Therefore, the hypothesized model includes a direct influence of motivational beliefs on deep-level cognitive strategies.

Hypothesis 3: Preservice teachers' use of metacognitive strategies will have a direct influence on their use of deep-level cognitive strategies.

A growing body of literature suggests that metacognition aids learners in selecting and using cognitive strategies demanded by various learning tasks (Romainville, 1994).

Metacognition helps learners to activate, monitor and regulate necessary cognitive resources to solve problems (Antonietti, Ignazi & Perego, 2000; Bielaczyc, Pirolli, & Brown, 1995; Flavell, 1979; Swanson, 1990) and facilitates students' use of deep-level cognitive strategies such as elaboration and organization (Heikkila & Lonka, 2006; Wolters, 1999). Therefore, the hypothesized model includes a direct influence of metacognitive strategies on deep-level cognitive strategies.

Hypothesis 4: Preservice teachers' use of metacognitive strategies will have a direct influence on their level of conceptual change.

Previous studies have shown that by using metacognitive strategies learners control and regulate their cognitive processing and monitor the content of their conceptual understandings (Georghiades, 2000, 2004a,b; Yuruk, 2007). Thus, learners who frequently use various metacognitive strategies in learning scientific concepts might be more likely to restructure their alternative conceptual understandings as a result of heightened and efficient cognitive processing of course materials. Consequently, the hypothesized model includes a direct influence of metacognitive strategies on conceptual change

Hypothesis 5: Preservice teachers' use of deep-level cognitive strategies will have a direct influence on their level of conceptual change.

The use of deep-level cognitive strategies has been reported to increase the probability of conceptual change in several studies (Kang et al., 2005; Kowalski & Taylor, 2004; Linnenbrik & Pintrich, 2002; McWhaw & Abrami, 2001). These studies have shown that the use of deep-level cognitive strategies, such as elaboration and organization, helps learners to make connections between prior knowledge and new knowledge and integrate new information with previous knowledge, thus, promote conceptual understandings of scientific concepts. Therefore, the hypothesized model includes a direct influence of deep-level cognitive strategies on conceptual change.

Hypothesis 6: Preservice teachers' motivational beliefs will have an indirect effect on their level of conceptual change through their influence on metacognitive strategies and deep-level cognitive strategies.

Research studies suggest that motivational beliefs do not directly influence learners' academic performance but motivational beliefs are associated with students' learning mediating through their use of cognitive and metacognitive strategy use and the amount of time they invest in studying (Linnenbrink & Pintrich, 2003; Vermetten et al., 2001). Research studies suggest that the adoption of a mastery goal orientation, high self-efficacy and task value may influence the level of students' cognitive processing, thus facilitating conceptual change (Linnenbrink & Pintrich, 2002; 2003; Pintrich, 1999; Pintrich et al., 1993). Therefore, the hypothesized model includes an indirect of motivational beliefs on conceptual change through cognitive and metacognitive strategies.

Hypothesis 7: The hypothesized model of intentional conceptual change will have an acceptable predictive ability in predicting change in preservice teachers' conceptual understandings from pre to post-interviews.

The hypothesized model of intentional conceptual change is grounded in the conceptual change and educational psychology literature and it is expected to demonstrate a high predictive ability in predicting change in participants' conceptual understandings of the cause of the moon phases. Figure 2.1 illustrates the hypothesized model of intentional conceptual change that is tested by the first set of research hypotheses in the study.

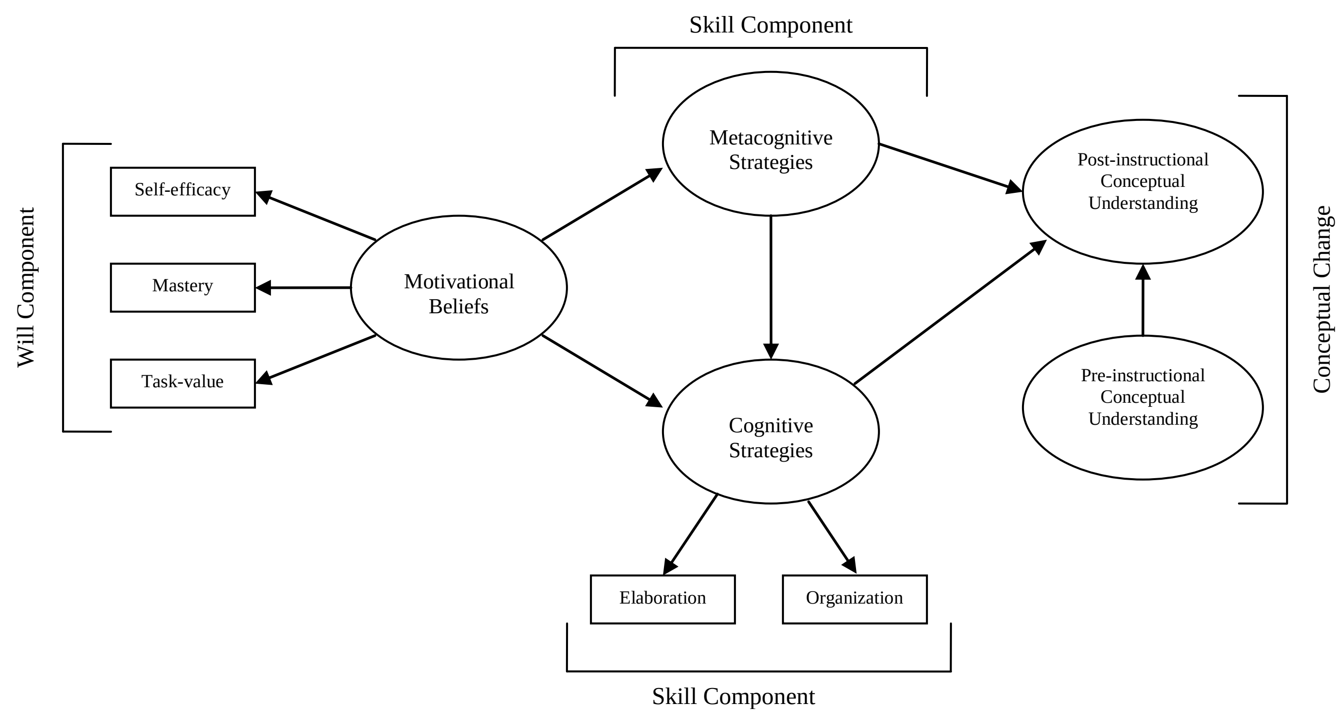

Figure 2.1 A hypothesized model of intentional conceptual change

Metacognition and the Coherency of Conceptual Understandings

The second set of research hypotheses deals with the relationship between the coherency of participants' conceptual understandings, their level of metacognitive strategy use, and the type of conceptual understandings they hold after instruction. The second set of hypotheses includes the following two hypotheses:

Hypothesis 8: Preservice teachers' use of metacognitive strategies will have a direct influence on the coherency of their post-instruction conceptual understandings.

Research literature suggests that learners with high metacognition are more likely to reflect on the knowledge presented in science classes and check possible inconsistencies in their causal explanations (Kuhn, 1999; Pintrich et al. 1993; Thorley, 1990; Vosniaodu & Ioannides, 1998). Consequently, they might be more likely to construct a coherent conceptual understanding. This relationship is tested by a direct influence of a metacognitive strategies variable on participants' coherency of post-instruction conceptual understandings (see figure 2.2).

Hypothesis 9: The coherency of preservice teachers' pre-instruction conceptual understandings will have a direct influence on the type of post-instruction conceptual understandings.

Learners who construct a coherent conceptual understanding before instruction, whether scientific or alternative, might be more likely to benefit instruction and restructure their alternative understandings (Oliva, 1999; 2003; Trundle et al., 2007a). Therefore, they might be more likely to have a scientific conceptual understanding after instruction. This relationship between the structure of the initial conceptual understandings and the type of post-instruction conceptual understandings is tested by a direct influence of the coherency of pre-instruction conceptual understandings variable on the type of post-instruction conceptual understanding variable (see figure 2.2).

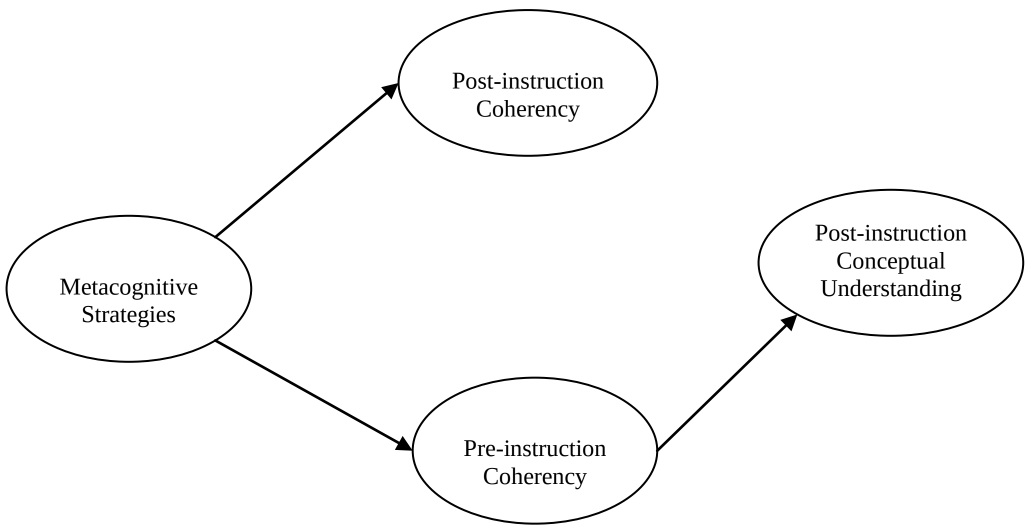

Figure 2.2 Metacognitive strategies and the coherency of conceptual understandings

Metaconceptual Awareness and the Change and Durability of Conceptual Understandings

The third set of research hypotheses addresses the role of metacognitive awareness in the change and the stability of conceptual understandings and includes the following three hypotheses:

Hypothesis 10: There will be a statistically significant difference in metaconceptual awareness scores of preservice teachers in different conceptual profile groups.

Previous studies indicated that metaconceptual awareness might play a significant role in the trajectory of learners' conceptual understandings of scientific phenomena (Georghiades, 2004a; Trundle et al., 2007a). More specifically, literature suggests that learners who restructure their alternative conceptual understandings and maintain their scientific conceptual understandings long after instruction are more likely to have high metaconceptual awareness than learners who don't restructure their alternative conceptual understandings and/or regress in their conceptual understandings. Therefore, a statistically significant difference is expected in metaconceptual awareness score of the participants in three conceptual understanding profiles in this study.

Hypothesis 11: Preservice teachers' level of metaconceptual awareness will have a direct influence on their level of conceptual change.

Metaconceptual awareness promotes learners' reflection on the content of their conceptual understandings, thereby facilitating their recognition of the differences between alternative ideas and the scientific concepts (Thorley, 1999; Vosniadou, 1994a, 2007; Yuruk, 2007). Learners with high metaconceptual awareness, therefore, might be more likely to restructure their alternative conceptual understanding and construct a scientific conceptual understanding as a result of instruction. Consequently, the hypothesized model of conceptual change and durability (figure 2.3) includes a direct influence of the metaconceptual awareness variable on the post-instruction conceptual understanding variable.

Hypothesis 12: Preservice teachers' level of metaconceptual awareness will have a direct influence on the durability of conceptual change.

Recent studies have shown that metaconceptual awareness also might play an important role in the retention of scientific conceptual understandings (Georghiades, 2000; 2004a; Trundle et al., 2007a; Yuruk, Beeth, & Anderson, 2009). These studies suggest that a restructuring of a conceptual understanding tends to be more successful and durable when it is purposeful and involves conscious evaluation and comparison of the content of the alternative conceptual understandings. Therefore, the hypothesized model of conceptual change and durability illustrated in figure 2.3 includes a direct influence of the metaconceptual awareness variable on the delayed post-instruction conceptual understanding variable.

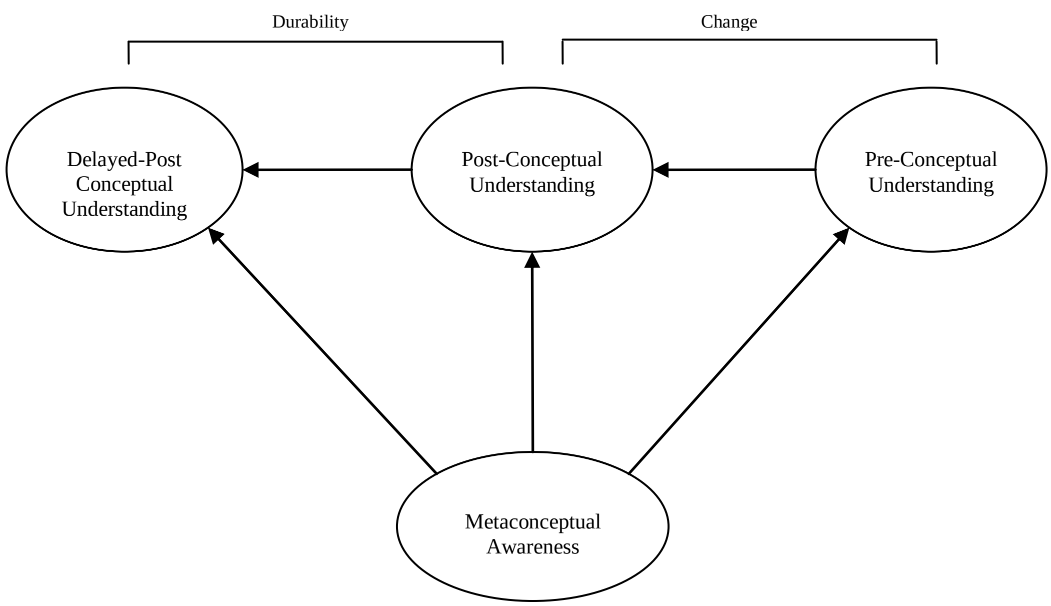

Figure 2.3 A hypothesized model of metaconceptual awareness and the change and the durability of conceptual understandings

A Review of the Lunar Literature

This section presents the research literature related to students' conceptual understandings of the cause of the moon phases. Studies are organized under two subtitles. First, the results of the descriptive studies are provided, followed by a discussion of the results of instructional studies.

Conceptual Understandings of the Cause of the Lunar Phases

A large and growing body of literature has investigated children's and adults' conceptual understandings of the cause of the moon phases since the original work of Piaget (1972a). These studies have shown that although children, even at early ages are aware that appearance of moon changes in time (Piaget, 1972a; Trundle, Atwood, & Christopher, 2007b; Za'rour, 1976), they have various alternative ideas about the mechanism that produces the change in the appearance of the moon.

For example, some young children believe that when the moon's appearance changes in shape, it really changes in size also (Za'rour, 1976). The sources of the causal explanations young children provide to explain the change of the moon's appearance seem to change by age. While children see human action and supernatural forces as being responsible for the change in moon shape at very early ages (e.g., the moon is born, cut by people, fairies change the moon's appearances) children's explanations involve natural forces such as wind and clouds as they get older (Haupt, 1950; Piaget, 1972a).

When children begin to realize that what changes is the moon's appearance not the size, most children construct a mental model based on the idea that something must be blocking the light from reaching the moon in explaining the changes in the appearance of the moon. Baxter (1989) reported four explanations that are based on this idea from his study with 120 children aged between 9 and 16. Children believe that a cloud, a planet other than earth, the sun, or earth causes moon phases by blocking the moon's light from reaching earth. The idea that the shadow of the earth causes moon phases was reported as the most common explanation among the participants in Baxter's study. Indeed, this alternative conception, which is often called the eclipse model, was reported as the most common alternative conception among elementary school children (e.g. Barnett & Morran, 2002; Dunlop, 2000; Roald & Mikalsen 2001). Other common alternative conceptions elementary children have regarding the cause of the moon phases are provided in Table 2.1.

Studies investigating middle and high school students' understanding of the cause of the moon phases reported results very similar to the findings with elementary students. The eclipse model was found to be the most commonly held alternative conception in these studies (e.g. Baxter, 1989; Taylor, Barker, & Jones, 2003; Trumper, 2001a; 2001c; Trundle, Atwood, Christopher, & Sackes, 2010).

Alternative Conceptions	Elementary School	Middle and High School	College
Earth's shadow on moon (eclipse model)	Barnett & Morran, 2002; Baxter, 1989; Broadstock, 1992; Dai, 1991; Dunlop, 2002; Hobson, Trundle, & Sackes, 2010; Roald & Mikalsen, 2001; Schoon, 1992; Trundle et al., 2007b	Baxter, 1989; Bisard, Aron, Francek, & Nelson, 1994; Chae, 1992; Dai, 1991; Sadler, 1987; Schoon, 1992; Taylor et al., 2003; Trumper, 2001a; 2001c; Trundle et al., 2010;	Bell & Trundle, 2008; Bisard et al., 1994; Callison & Wright, 1993; Dai & Capie, 1990; Lindell, 2001; Ogan-Bekiroglu, 2007; Parker & Heywood, 1998; Schoon, 1995; Targan, 1988; Trumper, 2000; 2001b; 2001c; Trundle et al., 2002; 2007a; Trundle & Bell, 2010; Zeilik et al., 1999
Planet's (other than earth) or sun's shadow on moon	Baxter, 1989	Baxter, 1989; Trumper, 2001a; 2001c; Trundle et al., 2010	Bell & Trundle, 2008; Lindell, 2001; Ogan-Bekiroglu, 2007; Trumper, 2001c; Trundle et al., 2002; Trundle & Bell, 2010
Earth's rotation on its axis	Barnett & Morran, 2002; Stahly, Krockover, & Shepardson, 1999	Trundle et al., 2010	Bell & Trundle, 2008; Targan, 1988; Trundle et al., 2002; 2007a ; Trundle & Bell, 2010
Earth's tilt		Trundle et al., 2010	Callison & Wright, 1993; Trundle et al., 2002
Clouds	Barnett & Morran, 2002; Baxter, 1989; Dunlop, 2000; Haupt, 1950; Roald & Mikalsen, 2001; Stahly et al., 1999	Baxter, 1989; Bisard et al., 1994; Dunlop, 2000; Roald & Mikalsen, 2001; Trundle et al., 2010	Bell & Trundle, 2008; Bisard et al., 1994; Callison & Wright, 1993; Trundle et al., 2002
Observers point of view (geographic location)	Roald & Mikalsen, 2001; Stahly et al., 1999	Roald & Mikalsen, 2001; Trundle et al., 2010	Callison & Wright, 1993; Ogan-Bekiroglu, 2007; Trundle et al., 2002; 2007a
Varying distance between earth and moon, and sun and moon	Dunlop, 2000; Stahly et al., 1999	Dunlop, 2000; Trundle et al., 2010	Bell & Trundle, 2008; Ogan-Bekiroglu, 2007; Trundle et al, 2002; Trundle & Bell, 2010
Size change of the moon	Roald & Mikalsen, 2001; Za'rour, 1976	Roald & Mikalsen, 2001	

Table 2.1 Common Alternative Conceptions

Particularly, Baxter's (1989) study of 120 students, ages 9 through 16 years, Chae's (1992) study of 151 students in grades 6, 8, and 10, and Bisard et al.'s (1994) study with middle school students all found that a majority of students held alternative conceptions about the cause of moon phases and the eclipse model as the most common alternative conception. Roald and Mikalsen's (2001) study with 26 deaf and 13 hearing students also indicated the eclipse model as the most common alternative conception among students from ages 7 to 17 years. These studies have shown that middle and high school students have alternative conceptions which are similar to those of elementary students. However, there was one unique alternative conception, the earth's tilt, which appeared at these grade levels (Trundle et al., 2010). Other common alternative conceptions held by middle and high school students are provided in Table 2.1.

Research studies targeting college students' understanding of the cause of the moon phases obtained results very similar to the findings with elementary, middle and high school students (e.g. Ogan-Bekiroglu, 2007; Trumper, 2000; Trundle et al., 2002; Trundle, Atwood, & Christopher, 2006; 2007a; Zeilik, Schau, & Mattern, 1998). Results of these studies indicate that students across a wide range of ages and grade levels have difficulty understanding the cause of moon phases (Trundle et al., 2002; 2007a).

More specifically, these studies indicate that most college students, including preservice teachers, do not understand the cause of the moon phases. For example, in their study with 42 preservice teachers Trundle and colleagues (2002) found that 90.5% of participants had an alternative explanation for the cause of the moon phases before the instruction. Callison and Wright (1993), in a study of 76 elementary preservice teachers, found that before the instruction 93.4% of the participants held alternative understandings of moon phases. Similarly, 82% of the 122 elementary preservice teachers surveyed by Schoon (1995) held alternative understandings about the cause of the moon phases, and Dai and Capie (1990) reported similar results in their survey of 174 preservice teachers. In a study with 61 college nonscience majors, Targan (1988) found that 98.4% of the students had alternative understandings before the instruction. Zeilik et al. (1999) reported from their study with 498 college astronomy students that about 62% of the students had alternative models for the cause of the moon phases before instruction. Trumper (2001c) also reported similar result from his survey of 483 preservice teachers' understanding of astronomy concepts that more than half of the participants had alternative ideas about the cause of the moon phases.

From elementary school through college levels the eclipse model was found to be the most commonly held alternative conception. Other common alternative conceptions that college students and preservice teachers have regarding the cause of the moon phases are provided in Table 2.1.

Instructional Studies

The cause of the moon phases is a complex astronomical phenomenon that requires an understanding of other science concepts (e.g., the shape of the earth, orbits, light and reflection) and the ability to think in three dimensions and from two different perspectives (Suzuki, 2002; Vosniadou, 1991). Therefore, the concept of the cause of the lunar phases is considered developmentally inappropriate for very young children because learning of this concept might place a considerable amount of burden on their cognitive processing capacities (Hobson et al., 2010; National Research Council [NRC], 1996). Indeed, some instructional studies reported that the cause of the moon phases is a very difficult astronomy concept for elementary students to grasp (Dunlop, 2000; Jones & Lynch, 1987; Sharp & Kuerbis, 2006; Stahly et al., 1999).

Some previous instructional studies with elementary students revealed that none of the children had a scientific understanding of the cause of the moon phases before instruction (Dunlop, 2000; Sharp & Kuerbis, 2006; Stahly et al., 1999). Although some children appeared to benefit from instruction, the instruction was not effective in helping most children to restructure their alternative conceptual understandings. Among other astronomy concepts that were taught in these studies, cause of the moon phases was the most difficult concept for elementary students to understand (Dunlop, 2000; Sharp & Kuerbis, 2006).

On the other hand, some recent studies that investigated the effect of instruction on the elementary students' understanding of the cause of the moon phases revealed that adequately designed instruction can help children in restructuring their alternative conceptual understandings. For example, Barnett and Morran (2002) reported that fifth grade students could develop sophisticated understandings of astronomy concepts as a result of instruction. While none of the children had a scientific understanding before instruction, more than three-fourth of the children developed full or partial scientific understandings after instruction. A similar positive outcome was reported from another recent study with fourth graders (Trundle et al., 2007b). In this study not only the mainstream children but also children with special needs benefited from the instruction in that 8 out of 10 children held a scientific conceptual understanding after instruction. In a more recent study, an instructional intervention that was supported with computer technology was found to be effective in helping young elementary children develop a conceptual understanding of the cause of the moon phases (Hobson et al., 2010). More than half of the children held a scientific understanding of the cause of the moon phases after instruction in the study.

Few studies aimed to modify alternative conceptual understandings of the cause of the moon phases at the middle and high school level. In an earlier study with high school students, Sadler (1987) found that 37% of the students surveyed understood the cause of moon phases before instruction, whereas 60% held a scientific understanding after instruction. From a study with 67 students aged 7 to 14 years, Dunlop (2000) reported that none of the students held a scientific understanding of the cause of the moon phases before instruction and only 29% held a scientific understanding after instruction. Similarly, in another study with 31 seven and eight year students, Taylor et al. (2003) found that none of the students surveyed understood the cause of moon phases before instruction and only 16% understood the concept after instruction. In a more recent study with eighth graders, Trundle et al. (2010) found that 2.8% of the students had a scientific understanding of the cause of the moon phases before instruction and most students (73%) held a scientific understanding of the cause of the moon phases after instruction.

Most previous instructional studies designed to change college students' alternative conceptions of the cause of the moon phases have met with limited success, except some recent studies (Trundle et al., 2002). In these studies very few students appeared to have a scientific conceptual understanding of the cause of the moon phases before instruction (Callison & Wright, 1993; Ogan-Bekiroglu, 2007; Targan, 1988; Trumper, 2006; Zeilik et al., 1999). The percentage of change from alternative conceptual understandings to scientific conceptual understanding generally was not substantial and ranged from 16% to 31%. Researchers reported that among other astronomy concepts the cause of moon phases was the one of the most difficult concepts for college students to understand (Ogan-Bekiroglu, 2007; Trumper, 2006).

Results of some recent instructional studies are more encouraging. The Trundle et al., (2002) study with college students majoring in elementary education provided evidence that students' conceptual understanding can be successfully changed by instruction. In their study, of 42 preservice teachers who received instruction, almost 67% of participants held a complete scientific understanding after instruction. In their follow-up study conducted with 12 participants from the original study, Trundle et al., (2007a) found that of the 12, four students showed regression in their thinking, whereas eight students showed continuous growth or stability in their conceptual understandings. In a similar study, Bell and Trundle (2008) investigated the effect of using computer simulation on pre-service teachers' conceptual understandings of standard-based lunar concepts. While none of the participants had a scientific conceptual understanding before instruction most participants (82%) developed a scientific conceptual understanding of the cause of the moon phases after instruction in the study.

Results of these studies indicate that children and adults have various alternative conceptions about the cause of lunar phases (e.g. Barnett & Morran, 2002; Chae, 1992;

Dai, 1991; Trundle et al., 2002). The eclipse model was the most commonly held alternative conception by students regardless of their grade levels. Several researchers investigated the effectiveness of instructional activities on changes in students' conceptual understandings of cause of lunar phases (e.g. Dunlop, 2000; Ogan-Bekiroglu, 2007; Stahly et al., 1999; Targan, 1988; Taylor et al., 2003). Recent studies reported that conceptual change oriented technology enhanced instructional activities can be effective in promoting conceptual change even with young elementary school children (e.g. Hobson et al, 2010; Trundle et al., 2007b). Although studies identified and tested elements of effective instructional strategies in addressing learners' alternative conceptions described in the literature, individual factors that help learners benefit most from conceptual change orientated instruction have been rarely examined. Therefore, the present study is aimed to identify the factors that help preservice teachers benefit most from an empirically tested conceptual change orientated instruction.

Chapter 3: METHODOLOGY

Introduction

This chapter describes the design of the study, participants and context, instruction, and data collection and analysis procedures for both qualitative and quantitative data.

Design of the Study

This study was based on a within-stage mixed model research design, which utilizes both quantitative and qualitative research approaches in at least one of the three major research stages including the research objective, data collection, and data analysis (Johnson & Christensen, 2004; Johnson & Onwuegbuzie, 2004). The current study was designed based on quantitative research objectives and involved collection of both qualitative and quantitative data with corresponding analyses to test the research hypotheses.

The present study involved four data collection points, resulting in four phases. In the first (before instruction) and the third phase (one to two weeks after instruction) of the study, the data were collected via a semi-structured interview, which was designed to reveal participants' conceptual understandings of lunar concepts. In order to assess participants' motivational beliefs and their use of cognitive and metacognitive strategies, the data in the second phase (immediately after instruction) were collected via a self-report instrument. In the fourth phase (13 to 15 weeks after instruction), the data were collected via semi-structured interviews, which were designed to reveal the durability of participants' conceptual understandings of lunar concepts as well as their metaconceptual awareness. An outline of the study design is shown in Table 3.1.

Phases	1 Before instruction	2 Immediately after instruction	3 1 to 2 weeks after instruction	4 13 to 15 weeks after instruction
Type of Instrument	Pre interview (Protocol A)	MSLQ	Post interview (Protocol A)	Delayed-post interview (Protocol A and B)
Participants	Preservice teacher (n=52)	Preservice teacher (n=52)	Preservice teacher (n=52)	Preservice teachers (n=16)

Table 3.1 Design of the study

Participants and Context

A convenience sampling technique, which is a nonrandom sampling technique, was used to select participants (Johnson & Christensen, 2004). The original sample consisted of 55 preservice early childhood education teachers at a major Midwestern research university. However, three participants were removed from the sample because during the administration of the self-report instrument these participants did not appear to read the questions, they appeared to randomly select responses, and they completed the instrument much faster than other participants. Due to possible response bias, those three participants were removed from the study sample.

The remaining 52 preservice teachers were the actual sample of the study. Participants were enrolled in a science method course, which was part of the early childhood education program. Most participants were female (98%) and there was only one male participant (2%) in the study. Forty-nine participants (94%) were European-American, two participants (4%) were African-American, and one participant (2%) was Asian-American. The number of college science credits that participants had completed before joining the study ranged from 9 to 35 quarter hours, with a mean of 15 hours. Nineteen participants previously completed one astronomy course and four participants had completed two astronomy courses.

The current study recruited participants from an ongoing research project, Moontech, which aimed to investigate the use of a computer simulation to promote the scientific understanding of lunar concepts. Participants in the current study gave permission for use of their pre- and post-interview records from the Moontech study, and additional data also were gathered. Interviews were conducted in interview rooms located in the same building where the participants were taking their science method course. The self-report instrument was administered in the classroom during the science method course with the permission of the instructor.

Instruction

The instruction on lunar concepts integrated the *Starry Night Backyard* software with instruction on moon phases from *Physics by Inquiry* by McDermott (1996). The instruction was identical to that of previous investigations by Trundle et al. (2002, 2006, 2007a, b) and Trundle and Bell (Bell & Trundle, 2008; Trundle & Bell, 2010) with a few minor differences. Participants' moon observations were collected from the *Starry Night Backyard* software rather than actual observations of the moon, and participants collected moon data from images that were projected onto a screen using a projector and a computer for the entire class.

Participants received instruction while enrolled in a science method course designed for preservice early childhood teachers. The science method course was a part of the Masters of Education initial licensure program for early childhood education (Pre-K-3). The science method course was offered the quarter before student teaching and focused on teaching science content knowledge through inquiry based activities and pedagogy appropriate for young children.

Four class sessions, with a total of six hours instruction, were devoted to instruction of the lunar concept. The instruction consisted of three parts: (1) gathering, recording, and sharing moon data, (2) analyzing moon data by looking for patterns in the data, and (3) modeling the cause of moon phases.

Participants recorded daily moon observations from the *Starry Night Backyard* software during class time. The *Starry Night Backyard* software screen was projected onto a large projection screen and the instructor guided participants to gather and record their moon observations. Participants made their moon observations individually by recording the shapes of the moon, percentage of disc illumination, the angular separation between moon and sun, the direction of the moon, and the date and time of observation on a calendar, which had a circle for each day where the participants sketched the shape of the moon. Participants collected nine weeks of data during portions of only four class sessions. Volunteers shared their data by replicating their sketches on posters hung on the chalkboard and recording the dates, times, angular separation, and cardinal directions for the observation during class sessions. Then the participants looked for and discussed any anomalies in the shared data.

After the two class sessions of data sharing, participants worked in small groups consisting of no less than three but no more than four students to analyze their moon data by looking for and discussing patterns, then modeling the cause of moon phases through psychomotor modeling activity. This part of the instruction consisted of five tasks: (1) identifying observable shapes and patterns of moon phases, (2) determining the length of the lunar cycle, (3) sequencing the moon phases, (4) applying new concepts and scientific labels, and (5) modeling the cause of moon phases through psychomotor modeling activity. The summary of above instructional activities is provided in Table 3.2.

The instructional strategy used in the study has been used in several other studies with students from different educational levels (Bell & Trundle, 2008; Hobson et al., 2010; Trundle et al., 2002, 2006, 2007a, b; Trundle & Bell, 2010). These studies have provided evidence that the instructional strategy used to teach lunar concepts is effective to promote conceptual change in lunar concepts. The main purpose of the current study was to test the predictive ability of a learning model in predicting participants' conceptual change rather than how effective the instruction was. Therefore, to control the possible confounding effect of instruction with unknown effectiveness, the instructional strategy that has been reported being effective in promoting conceptual change in several studies was selected.

Targeted Concepts	Summary of Activities
Shapes and Patterns of moon phases	1. Identify and describe patterns. 2. Describe the rate of change (i.e., gradual or abrupt). 3. Draw an observed sequence of moon shapes. 4. Identify when the sky was clear but the moon could not be observed.
The length of the lunar cycle	1. Number the data from day 1 to day 63. 2. Select a distinctive shape, and list the number of the day that the shape first appeared and list the number of the second and third days when the shape reappeared. 3. Repeat with 3 additional shapes. 4. Estimate how much time passed before each shape reappeared.
The sequence of moon phases	1. Sequence a series of drawings of 8 representative phases in the pattern observed.
New concepts and scientific labels	1. Use the scientific term "new moon" to describe when the moon could not be observed during the moon cycle. 2. Use the scientific term "synodic period" to describe the time interval from new moon to full moon and back to new moon. 3. Apply scientific labels (e.g., waxing gibbous) to each shape.
Cause of moon phases (Psychomotor modeling activity)	1. Place a bright, exposed light bulb at eye level to represent the sun in a darkened room. 2. Use a Styrofoam ball as a model for the moon. 3. Hold the ball in front of body at arm's length. 4. The student's head is the earth, move the ball around their heads. 5. Note the appearance of the lit portion of the ball and determine how much of the moon is lit at any one time 6. Use the models to reproduce all the phases in the order they were observed. 7. Write and orally explain their understandings of the causes of moon phases.

Table 3.2. Summary of instructional activities (Trundle et al., 2010)

Data Collection Procedure

Two data gathering techniques were used to collect the data from participants in this study: a self-report instrument and structured interviews. In the following subsections qualitative and quantitative data collection procedures and the instruments will be described.

Qualitative Data

To reveal the participants' conceptual understandings of moon phases and their metaconceptual awareness, semi-structured interviews were conducted using two sets of interview questions. The first set of questions, Interview Protocol A, aimed to reveal the participants' conceptual understanding of moon phases, and it was used before and after the instruction and in the delayed-post interviews. Participants' pre and post interview data were collected for an ongoing research project that aimed to investigate the use of computer simulation to promote the scientific understanding of lunar concepts (Trundle & Bell, 2010). The permission to use these previously collected pre and post interviews and access the participants of that study to gather additional data was obtained for the current study.

The second set of questions, Interview Protocol B, aimed to reveal the participants' level of metaconceptual awareness. This interview protocol was used only in the delayed-post interviews immediately after Interview Protocol A, and was specifically collected for the current study. A detailed description of pre, post and delayed-post interviews will be provided in the following subsections.

Pre- and Post-Interviews

To reveal the participants' conceptual understandings of moon phases semi-structured interviews were conducted before and after instruction using a set of interview questions (Interview Protocol A). This interview protocol was developed and used by Trundle et al. (2002) in various conceptual change studies with participants who have similar characteristics to the participants in this study.

Interview Protocol A included three tasks that aimed to reveal the participants' understandings of the cause of the moon phases (Task 1 and 2) and sequence (Task 3). In pre and post-interviews participants were initially asked to verbally explain what they thought caused the moon phases (Task 1, pre and post). The three-dimensional model of the moon, earth and sun was provided to the participants to support their verbal explanations about the cause of the moon phases by demonstrating their ideas (Task 2, pre and post). Participants, then, were asked to sort a set of cards that depict eight primary moon phases in the proper sequence (Task 3, pre and post) (Trundle et al., 2002).

During the interview, the researcher first repeated what participants exactly said instead of paraphrasing their ideas to make sure that what the researcher recorded accurately reflected the students' explanations. Additional probing questions were asked such as "How is that happening?" "What do you mean?" and "Please explain a little more about that" to reveal the genuine conceptual understanding of the participants rather than accepting participants' initial responses (Trundle, et al., 2002, 2007a).

All participants (n=52) were individually interviewed in a quiet interview room. Pre-interviews lasted about 30 minutes and post-interviews lasted about 20 minutes.

Interviews were video-taped and notes were taken immediately after each interview. A copy of the interview protocol used to assess the participants' conceptual understandings of the lunar concepts, Interview Protocol A, can be found in Appendix A.

Delayed-post Interviews

The aim of the delayed-post interviews was to assess the durability of the participants' conceptual understanding of lunar concepts and their level of metaconceptual awareness. To assess the durability of participants' conceptual understanding, Interview Protocol A was used first. To reveal the participants' level of metaconceptual awareness, Interview Protocol B was used immediately after completing the Interview Protocol A.

Interview Protocol B consisted of six questions, such as "Do you remember what your ideas/responses were about the cause of the moon phases in the first interview?" "What happened when you first realized that your understanding was different from what we taught in class?" "What steps did you follow to change your understanding?", and were designed based on previous research on metacognition and conceptual change (Hennessey, 2003; Kowalski & Taylor, 2004; Luques, 2003; Vosniadou, 1994a, 2007).

A subset of participants (n=16) was selected using a stratified sampling procedure for the delayed-post interviews based on the metacognitive strategies scores they obtained from the *Motivated Strategies for Learning Questionnaire*. Participants were divided into four categories (highest, high, low, and lowest) based on their scores. Four participants were randomly selected from each category for the delayed-post interviews to ensure that participants who were interviewed represented the participants from different levels of metacognition. Participants were individually interviewed in a quiet interview room and each interview, including Interview Protocol A and B, lasted about 30 to 40 minutes. Interviews were video-taped and notes were taken immediately after each interview. A copy of interview protocol used to assess participants' metaconceptual awareness, Interview Protocol B, can be found in appendix B.

Quantitative Data

The *Motivated Strategies for Learning Questionnaire* (MSLQ) designed to measure motivation and use of learning strategies by college students was used to assess the participants' level of motivation, and use of cognitive and metacognitive strategies (Pintrich, Smith, Garcia, & McKeachie, 1993). The MSLQ is a self-report instrument consisting of six motivation subscales (included 31 items), and nine learning strategies scales (included 50), for a total of 81-items. The motivation scales target three areas: (1) value (intrinsic and extrinsic goal orientation, task value), (2) expectancy (control beliefs about learning, self-efficacy); and (3) affect (test anxiety). The learning strategies section consists of nine scales which can be divided into three areas: cognitive, metacognitive, and resource management strategies. The cognitive strategies scales include (a) rehearsal, (b) elaboration, (c) organization, and (d) critical thinking. Metacognitive strategies are assessed by one large scale that includes planning, monitoring, and regulating strategies. Resource management strategies include (a) managing time, and study environment; (b) effort management, (c) peer learning, and (d) help-seeking. Subscales of MSLQ have reliability coefficients ranging from .52 to .93 and have good factor structure (Duncan & McKeachie, 2005; Pintrich et al., 1993).

The following motivational belief subscales of MSLQ were used in the study: intrinsic goal orientation, task value, and self-efficacy. To assess the participants' use of cognitive strategies elaboration and organization subscales were used; and to assess the participants' metacognition, metacognitive self-regulation subscale that include planning, monitoring, and regulating strategies were used.

The MSLQ was administered during the science method course with the permission of the instructor. Participants took approximately 15 minutes to complete the instrument. Participants were reminded that participation in completing the scale was voluntary, the scale was not an exam, and it would not affect their course grade.

Data Analysis

Qualitative Analysis

Constant Comparative Method

The constant comparative method (CCM) was used to analyze the qualitative data obtained through Interview Protocol A and Interview Protocol B in the study. Constant comparative methodology utilizes the inductive method to generate a data driven theory (Glaser, 1965). The method integrates two general approaches to the analysis of qualitative data: testing a hypothesis through quantifying the qualitative data with theoretical categories previously established, and generating a hypothesis by establishing theoretical categories through the initial inspection of the data (Bogdan & Biklen, 1982; Glaser, 1965; Glaser & Strauss, 1967).

The constant comparative method consists of four stages: comparison of incident with incident to form properties of a category, comparison of incident with properties of a category to integrate and refine categories, the delimitation of theory constructed based on a small set of concepts derived from the data, and the formulation and presentation of the theory (Glaser, 1965; Glaser & Strauss, 1967). These stages of the constant comparative method suggest that the method mainly involves category coding through induction and simultaneous comparison of all incidents to reach a theory that emerges from the data. By comparing and contrasting the incidents, researchers develop codes to represent properties of categories, define and refine categories establishing inclusion and exclusion criteria for categories until the categories are theoretically saturated, and assign incidents to categories using codes and find negative incidents that do not fit the established categories. This process allows researchers to discover qualitative similarities and differences between incidents through the use of categories with high discriminative power (Boeije, 2002; Kinach, 1995).

Although the constant comparative method is a component of grounded methodology, it can be used separately from grounded methodology as a strategy for analysis of any type of qualitative data (Coombe, 1995). Indeed, the method has been widely used in several research fields including sociology, psychology, business management (Boeije, 2002; Coombe, 1995) and in studying conceptual change in several science content areas such as tides (Ucar, Trundle, & Krissek, in press), the particulate nature of matter (Adadan, Trundle, & Irving, 2010), seasons (Wild & Trundle, 2010) and moon phases (Trundle et al., 2002, 2007a,b). These studies showed that the constant comparative method of analysis is a useful technique in describing learners' conceptual understandings of scientific phenomena. Therefore, CCM was used to analyze the qualitative data collected in this study.

Establishing a Partial Framework

The framework of codes developed by Trundle et al. (2002, 2007a,b) in previous lunar concepts studies, which was developed using the constant comparative method (Glaser, 1965; Glaser & Strauss, 1967), was used to analyze the participants' conceptual understanding of the cause of the moon phases, (Interview Protocol A), in the current study. This framework of codes served as a partial framework that helped researchers to identify and describe a scientific mental model and the possible alternative mental models participants might have (Trundle et al., 2002). A partial framework of codes was an open coding system that allowed any additional codes that emerged during data analysis to be included in the framework. Table 3.3 shows the description of the codes used to code participants understanding of the cause of the moon phases.

Code	Meaning of Code
Sci Half	Half of the moon illuminated by the sun
Sci See	Part of the illuminated half we see determines the phase
Sci EMS	Relative positions of earth, sun and moon determine the part we see
Sci Orb	Moon orbits earth
Alt Eclipse	Dark part of moon in earth’s shadow; phases caused by earth’s shadow
Alt Rot	Earth’s rotation on axis causes phases
Alt Helio	Moon orbits the sun (independent of the Earth) causes phases.
Alt Geo	Moon phases due to a viewer’s geographic position on earth. Sun and moon orbit the earth, causing moon phases
Alt Clouds	Cloud causes moon phases by covering the different portion of the moon.
Alt Planets	Other planet's shadow on moon causes moon phases
Alt Distance	Varying distance between sun and moon causes moon phases.
Alt ETilt	Tilt of the earth on its axis causes moon phases.
Alt Oth	Reason other than any of above given alternative conceptions.

Table 3.3. Codes key for interview protocol A (Based on Trundle et al., 2002, 2007a)

A framework of codes was also developed based on previous research studies to analyze the metaconceptual awareness of 16 participants who participated in delayed-post interviews (Beeth, 1998a; Hennessy, 2003; Thorley, 1990; Trundle et al., 2007a; Yuruk, 2007). This initial framework of codes served as a partial framework and allowed any additional codes that emerged during data analysis to be included. It helped the researcher to identify and describe the levels and types of metaconceptual awareness shown by the participants. Table 3.4 shows the description of the codes used to code the participants’ metaconceptual awareness. A detailed explanation of the criteria that were used to create coding scheme was provided in the following pages.

Code	Meaning of Code
MAC Initial	Metaconceptual Awareness of Contradiction: States initial ideas about the cause of the moon phases.
MAC UnSci	Metaconceptual Awareness of Contradiction: Explains how she/he realized that her initial ideas were not scientific.
MAU Change	Metaconceptual Awareness of Change in Understanding: Explains how initial ideas changed.
MAS Exp	Metaconceptual Awareness of Strategies and Experience: Gives specific examples about personal experience in learning lunar concepts.
MAS Step	Metaconceptual Awareness of Strategies and Experience: Explains the specific steps taken to change initial ideas or construct scientific understanding of the cause of the moon phases.
M Other	Metaconceptual Awareness Other: Other than above given indicators of awareness.

Table 3.4. Codes key for interview protocol B

Coding and Comparison of Qualitative Data

Based on the partial framework, Trundle et al. designed a coding sheet to organize and standardize the analysis of data collected through Interview Protocol A. The coding sheet was an open coding sheet that allowed new codes that might emerge during data analysis to be incorporated into the coding system (Trundle et al., 2002). Video-taped interviews (Interview Protocol A) were analyzed using this coding sheet. A copy of the coding sheet can be found in Appendix C.

A coding and scoring sheet was also designed based on the partial framework of codes developed to code participants' metaconceptual awareness to organize and standardize the analysis of Interview Protocol B. This coding sheet was an open coding sheet that allowed new codes that might emerge during data analysis to be incorporated to the coding system. Video-taped interviews (Interview Protocol B) were scored and analyzed using this coding sheet. A copy of the coding sheet can be found in Appendix D.

Comparison is the main analytical tool of the constant comparative method (Tesch, 1990). Making the type of comparisons explicit is recommended in using the constant comparative method because it enhances the internal validity of the findings (Boeije, 2002). Although the types and numbers of comparisons made vary depending on the nature of the data and the research questions, the following comparisons are suggested as a guideline: "(a) comparing different people, (b) comparing data from the same individuals with themselves at different points in time, (c) comparing incident with incident, (d) comparing data with category, and (e) comparing a category with other categories" (Charmaz, 2000, p.515).

In the present study, the following comparisons were made to analyze the participants' conceptual understanding of the cause of the moon phases: (1) comparison of data within a single interview to coding scheme, (2) comparison of codes within a single interview to types of mental models, (3) comparison of mental models within a single interview to types of conceptual understanding, (4) comparison of types of conceptual understanding among participants, (5) comparison of types of conceptual understanding before and after instruction, and (6) comparison of types of conceptual understanding three weeks after the instruction and 13 to 15 weeks after the post-interviews for 16 participants. The detailed explanation of the comparisons made and the purpose of these comparisons was provided in Table 3.5.

Comparison	Purpose of Comparison
Data within a single interview (verbal responses, use of models, card sorting) were compared to coding scheme	Code transcripts and add new, emergent codes to the coding framework
Codes within a single interview were compared to types of mental models	Determine consistency of responses within the interview and assign participants to mental models such as the eclipse model or heliocentric model.
Mental models within a single interview were compared to types of conceptual understanding.	Assign participants to types of conceptual understanding such as scientific, scientific fragment, and alternative.
Types of conceptual understanding among participants in the group were compared	Summarize overall types of conceptual understanding among the group
Types of conceptual understanding were compared from before to after instruction for each participant	Distinguish conceptual change
Types of conceptual understanding were compared from after to 13-15 weeks after instruction for 16 participants.	Determine the durability of conceptual change

Table 3.5. Comparisons made for the data obtained by interview protocol A (Ucar et al, in press)

Several comparisons were also made in the analysis of participants' metaconceptual awareness. To analyze 16 participants' metaconceptual awareness, the following comparisons were made in the data collected through Interview Protocol B: (1)

comparison of data within a single interview to the coding scheme, (2) comparison of codes within a single interview to the types of metaconceptual awareness, (3) comparison of the level and types of metaconceptual awareness within a single interview to the categories of metaconceptual awareness, (4) comparison of the metaconceptual awareness among 16 participants, (5) comparison of the types of conceptual understanding to the level of metaconceptual awareness. The detailed explanation of the comparisons made and the purpose of the comparisons was provided in Table 3.6

Comparison	Purpose of Comparison
Data within a single interview were compared to coding scheme	Code transcripts and add new, emergent codes to the coding framework
Codes within a single interview were compared to types of metaconceptual awareness	Determine consistency of responses within the interview, and the level and types of metaconceptual awareness participants have
Level and types of metaconceptual awareness within a single interview were compared to categories of metaconceptual awareness	Determine and quantify participants' overall level of metaconceptual awareness
Metaconceptual awareness among 16 participants were compared	Summarize metaconceptual awareness among the 16 participants
Types of conceptual understanding were compared to level of metaconceptual awareness for each participant	Determine the relationship between conceptual change and metaconceptual awareness

Table 3.6. Comparisons made for the data obtained by interview protocol B

Analysis of Interview Protocol A: Conceptual Understanding

Immediately after each interview notes were taken about participants' conceptual understanding using the codes that are provided in Table 3.3. The video-taped interviews were reviewed in their entirety and coded again by the researcher using the coding sheet (Appendix C). After all video-taped interviews were coded; the mental models participants used to explain the cause of the moon phases were identified. Then, based on the mental models they used, participants' responses were assigned to one of the six conceptual understanding categories including scientific, scientific fragments, scientific with alternative fragments, alternative with scientific fragments, alternative, and alternative fragments (Trundle et al., 2002, 2007a, b).

Participants' conceptual understandings were categorized as "scientific" if they exhibited an understanding of all critical elements that are required for a scientific understanding. Participants' conceptual understandings were categorized as "scientific fragment" if they contained understanding of some but not all the scientific elements without including any alternative model or elements of an alternative model. Conceptual understandings that include understanding of all the scientific elements but also include one or more alternative mental model were categorized as "scientific with alternative fragment." Conceptual understandings were categorized as "alternative with scientific fragment" if they included an alternative mental model along with three or less elements of a scientific understanding. Conceptual understandings were categorized as "alternative" if they did not exhibit any of the scientific elements and explained the cause of the moon phases with an explanation alternative to a scientific explanation. Participants' conceptual understandings that included more than one alternative mental model were categorized as "alternative fragments." Table 3.7 shows the types of conceptual understanding and mental models used to identify participants' conceptual understanding in this study (Trundle et al., 2002, 2007a, b).

To make the statistical analysis possible, participants' conceptual understandings were scored with a rubric which was designed for this study. After participants' conceptual understandings of the cause of the moon phases were assigned into one of the conceptual categories, participants received a score between 0 to 10 based on the number of scientific elements their conceptual understandings included and the number of alternative mental models they had. A detailed description of the rubric used to score participants' conceptual understanding of the cause of the moon phases assessed in the pre, post and the delayed-post interviews is provided in Appendix D.

Type of Conceptual Understandings	Criteria and Codes
Scientific	All four scientific criteria included: • Half of the moon is illuminated by the sun [Sci Half] • The portion of the illuminated half seen from earth varies over time [Sci See] • The relative positions of the earth, sun, and moon determine the portion of the lighted half seen from earth [Sci EMS] • The moon orbits earth [Sci Orb]
Scientific Fragment	Included a subset but not all of the four scientific criteria
Scientific with Alternative Fragments	Met all four scientific criteria, but also indicated held one of the alternative fragments listed below
Alternative with Scientific Fragments	Included an alternative mental model along with a subset but not all of the four scientific criteria
Alternative	
Eclipse	The earth's shadow causes the moon phases [Alt Eclipse]
Earth's Rotation	The earth's rotation on its axis causes the moon phases [Alt Rot]
Heliocentric	Moon orbits the sun but not earth. In other words, the moon and earth orbit the sun independently of each other. When the sun gets between the earth and moon, the moon is in the new moon phase [Alt Helio]
Geocentric	Sun and moon orbit the earth, causing moon phases [Alt Geo]
Clouds	Cloud cover causes moon phases [Alt Clouds]
Planet	Planet's (other than earth) shadow on moon causes moon phases [Alt Planets]
Distance between the Moon and Sun	Varying distance between sun and moon. When moon is closer to sun the moon is full. When it is further away from the sun, the moon is in the new moon phase [Alt Distance]
Earth's Tilt	Tilt of the earth on its axis causes moon phases [Alt ETilt]
Other	Reason other than any of above given [Alt Oth]
Alternative Fragments	Included a subset or subsets of alternative mental models

Table 3.7. Types of conceptual understanding (Trundle et al, 2002)

Analysis of Interview Protocol B: Metaconceptual Awareness

Immediately after each interview, notes were taken about participants' metaconceptual awareness. To assess participants' metaconceptual awareness video-taped interviews of 16 randomly selected participants based on their MSLQ metacognition scores were reviewed and coded. Then, the level of metaconceptual awareness that participants exhibited was determined using the coding and scoring sheet designed for the study.

The coding and scoring sheet included three types of metaconceptual awareness: (1) the metaconceptual awareness of contradiction, (2) the metaconceptual awareness of change in understandings, and (3) the metaconceptual awareness of strategies and experience. The metaconceptual awareness of contradiction involves participants' awareness of their initial mental models about the cause of the moon phases and their awareness of differences between their initial mental models and scientific mental models. The metaconceptual awareness in change in understanding involves participants' awareness of how their initial mental models changed over the course of the instruction. The metaconceptual awareness of strategies and experience involves participants' awareness of the cognitive and metacognitive strategies they use to learn lunar concepts, and the awareness of how their learning experience influences their conceptual understanding. These three major types of metaconceptual awareness were identified through the review of previous studies that examined conceptual change and metacognition (Beeth, 1998a, b; Hennessy, 2003; Thorley, 1990; Trundle et al., 2007a; Yuruk, 2007). Table 3.8 shows the description of the types of metaconceptual awareness.

Type of Metaconceptual Awareness	Criteria
Metaconceptual Awareness of Contradiction	• Participant states her/his initial ideas about the cause of the moon phases. • Participant explains how she/he realized that her/his ideas were not scientific.
Metaconceptual Awareness of Change in Understanding	• Participant explains how her/his initial ideas changed over the course of the instruction.
Metaconceptual Awareness of Strategies and Experience	• Participant explains/gives specific examples about her/his experience in learning lunar concepts. • Participant explains the specific steps she/he took to change her/his initial ideas or construct the scientific understanding of the cause of the moon phases.

Table 3.8 Types of metaconceptual awareness and identification criteria

The participants' responses to the Interview Protocol B were coded and scored using the coding and scoring sheet (Appendix E). Participants were given two points if their responses reflected a thorough metaconceptual awareness for a given indicator of the type of metaconceptual awareness. If participants' responses reflected fragmented awareness they were given one point, and if the responses reflected no metaconceptual awareness, they were given 0 points.

Based on the score they obtained, the participants' responses were assigned into three metaconceptual awareness categories: high metaconceptual awareness, moderate metaconceptual awareness, and low metaconceptual awareness. Participants who obtained higher than seven points were assigned to the high metaconceptual awareness category, participants who obtained five to seven points were assigned to the moderate metaconceptual awareness category, and those participants who obtained less than five points were assigned to the low metaconceptual awareness category. A copy of the coding and scoring sheet used to score and assign the participants to the metaconceptual awareness categories can be found in Appendix E.

Establishing Inter-rater Reliability

The inter-rater reliability was established to demonstrate the dependability of the coding of the data. Since there were more than two conceptual understandings categories into which participants' conceptual understandings could be assigned, Cohen's weighted kappa statistic was utilized in calculating reliability of the coding (Cohen, 1968). All video-taped interviews were coded and analyzed by the researcher. A total of 33% of the pre-interviews and 23 % of the post-interviews were randomly selected and coded by another researcher who was experienced in analysis of this type of data. The inter-rater agreement for the pre interviews was 0.83 and for the post interviews was 0.93, indicating high inter-rater agreements.

Inter-rater reliability also was established for the scoring of the metaconceptual awareness interviews by calculating an intra-class coefficient using a two-way mixed model with absolute agreement. A total of 50% of the metaconceptual awareness interviews were randomly selected and scored by another researcher. The intra-class correlation coefficient for the scoring of the metaconceptual awareness interviews was 0.80 (0.28-0.96, F=8.264, p=0.006), indicating high inter-rater agreement (McGraw & Wong, 1996).

Quantitative Analysis

Participants' scores from the subscales of the MSLQ were calculated to determine variations in the preservice teachers' self-reported level of metacognitive strategy use, motivational beliefs, and use of cognitive strategies. To obtain the reliability estimate of the measurements, the analysis of internal consistency, using a Cronbach's alpha, was performed for each subscale. The Pearson product-moment coefficients were computed to determine the relationships among the variables. A nonparametric test, Kruskall-Wallis, was used to determine whether there is a statistically significant difference in metaconceptual awareness scores of participants in different conceptual profile groups.

The hypothesized model of intentional conceptual change was tested using a partial least squares path modeling with latent variables technique. The relationship between the metacognitive strategy use and the coherency of conceptual understandings, conceptual understandings that include single mental model, as well as the relationship between the metaconceptual awareness and the change and the durability of conceptual understandings were analyzed using PLS-PM with observed variables technique. A more detailed description of the PLS-PM analysis is provided in the next section.

Partial Least Squares Path Analysis (PLS-PM)

The predictive utility of the hypothesized model of intentional conceptual change was evaluated using a partial least squares path modeling with latent variable technique (Wold, 1982). Partial least square path modeling (PLS-PM) is a member of structural equation modeling approach, which allows researchers to model and test the relationship between observed and latent variables (Joreskog & Wold, 1982; Lohmoller, 1989). Unlike more well known structural equation modeling approaches, which commonly use maximum-likelihood method of estimation to analyze covariance matrix such as “linear structural relationship” (LISREL) (Jorekog & Sorbom, 1993) and “analysis of moment structures” (AMOS) (Arbuckle, 1994), PLS-PM employs partial least square method of estimation to analyze variance matrix and it utilizes principal component analysis rather than common factor analysis in estimating latent variable scores (Lohmoller, 1989; Falk & Miller, 1992). Therefore, structural equation modeling techniques that typically use maximum-likelihood method of estimation to analyze covariance-matrix are usually referred to as covariance-based SEM and the techniques that use partial least square method are referred to as variance-based SEM in the literature (Chin & Newsted, 1999; Gefen, Straub, & Boudreau, 2000; Haenlein & Kaplan, 2004).

Covariance-based SEM models are theory confirmation-oriented. They are more suitable for theory testing as they assume that the model under investigation meets the conditions of a closed system. That is, no relevant independent variable is omitted from the model (Chin & Newsted, 1999; Falk & Miller, 1992). In contrast, PLS-PM is oriented to prediction or theory-building and it aims to express theoretical ideas rather than to explain causality (Falk & Miller, 1992; Henseler, Ringle, & Sincovics, 2009). Although PLS-PM can also be used in theory confirmation, the technique is more suitable for research conditions where there is high complexity but low theoretical information about the extent of the model (Chin, 1998; Joreskog & Wold, 1982; Wold, 1989). Although these two approaches to structural equation modeling are based on different algorithms, as research conditions approach to optimal situations (e.g. multivariate normality, large sample size and indicators for the latent variables) both techniques produce similar estimates. According to Joreskog and Wold “the numerical difference between the two estimates cannot or should not be substantial” (p. 266). Indeed several studies reported high correlation between maximum-likelihood and partial least squares based estimations (Chin & Newsted, 1999; Fornell & Bookstein, 1982).

Covariance-based SEM aims to find functionally indeterminate parameters that describe the relationship between observed and latent variables (Falk & Miller, 1992). Covariance-based SEM techniques make strong assumptions about measurements, distributions, and theory in generating such knowledge of relationship. Therefore, covariance-based SEM techniques are often considered as “hard modeling” techniques. PLS-PM, on the other hand, utilizes an iterative least square technique as an estimation method to determine the best set of predictors of the relationship between variables and tries to account for as much variance as possible between the observed and latent variables. PLS-PM does not make the stringent assumptions as covariance-based SEM techniques do. Because PLS-PM makes fewer assumptions, it is often referred as a“soft modeling" technique (Joreskog & Wold, 1982). Table 3.9 compares the maximum likelihood and partial least squares approaches to structural equation modeling.

Criteria	Covariance-based SEM	PLS-PM
Objective of Analysis	• Explanation • Theory-confirmation • Estimate invariant structural parameters	• Prediction • Theory-building. • Estimate the best prediction of a specified set of variable relationship
Hypothesis Testing	• Tests whether covariance matrix can be reproduced	• Tests the null hypothesis of no effect for path coefficients and loadings
Assumptions		
Theoretical	• All relevant variables included • No specification error • Well developed theory	• Does not require well developed theory • Misspecification has less influence
Distributional	• Parametric • Requires multivariate normal distribution and independent observations	• Nonparametric • Does not make distributional assumptions
Measurement	• Typically at least interval level	• Minimal demands on measurement scale
Latent Variables	• Typically include reflective indicators	• Can be reflective or formative
Model Complexity	• Small to moderate complexity	• Large complexity
Sample Size	• Large sample size, minimum of 200 • 10 times of the number of parameters estimated in the model.	• Small sample size • 10 times of the number of indicators in the largest block

Table 3.9. Comparison of approaches to structural equation modeling. Based on Chin & Newstend (1999) and Falk & Miller (1992).

According to Joreskog and Wold (1982) maximum likelihood and partial least squares approaches to structural equation modeling are not competitive but complementary approaches. Researchers could utilize either approach based on theoretical (e.g. research questions, complexity of the model) and empirical considerations (e.g. sample size, distribution of the data). Wold (1989) stated that PLS-PM was specifically designed for social science research as the models developed in social science studies are often complex, open-systems, and researchers usually analyze data from small samples. The main purpose of this study was to test the predictive ability of the hypothesized intentional conceptual change model in predicting conceptual change in astronomy. Considering the exploratory and predictive purposes of the study, open-system nature of the hypothesized model, and the small sample size, the PLS-PM technique was employed as the main statistical analysis tool for the study.

Chapter 4: ANALYSIS OF DATA

Introduction

This chapter presents the results of the analysis of qualitative and quantitative data. Results are presented in two sections: Qualitative findings and quantitative findings.

Qualitative Findings

This section reports the analysis of the pre, post, and the delayed-post interviews that were conducted to assess participants' conceptual understanding of the cause of the moon phases (interview protocol a) and their level of metaconceptual awareness (interview protocol b, delayed-post only). As described in chapter three, constant comparative method of analysis was used to analyze the data obtained through interviews. Initially all video-taped interviews were coded to identify the type of mental models participants used to explain the cause of the moon phases. Then, participants' mental models of the cause of moon phases were assigned into one of six predetermined conceptual understanding categories identified in previous studies (Trundle et al., 2002; 2007a).

A similar procedure was followed for the analysis of the metaconceptual awareness interviews, which were conducted with only a subset of participants (16 of the 52 participants) in the delayed-post interviews. Participants' responses were coded and scored first, and then, based on their scores participants' metaconceptual awareness were grouped into three groups: low, moderate, and high metaconceptual awareness.

Types of Conceptual Understandings Identified in the Study

This section presents the type of conceptual understandings participants held in the pre, post, and the delayed-post interviews. Criteria used in categorizing participants' conceptual understanding as well as an example for each type of conceptual understanding in the form of excerpts from the participants' interviews are provided.

Scientific

Participants' conceptual understandings of the cause of the moon phases were identified as scientific if they included all four critical elements that define a scientific conceptual understanding. Those elements are: 1) the moon orbits the earth (SciOrbit); 2) half the moon is always illuminated by the sun (SciHalf); 3) the portions of the illuminated half, as seen from earth, varies over time (SciSee); 4) and the relative positions of the earth, sun, and moon determine the portion of the lighted half seen from earth (SciEMS) (Trundle et al., 2002).

Only six of the 52 participants (12%) demonstrated a scientific conceptual understanding of the cause of moon phases in the pre-interviews. The number of participants who demonstrated a scientific understanding increased to twenty-five (48%) in the post-interviews. Nine of the 16 participants' (56%) conceptual understandings were categorized as scientific in the delayed-post interviews. The following excerpt from one participant's responses in the post-interview assessment provides an example of a scientific understanding.

> R: What do you think causes the phases of the moon?
>
> 283807: **Umm the moon phases are caused by how much of the lighted part of the moon we see (SciSee). Only half of the moon is lit at any given time (SciHaf)** because

> that is the half that facing the sun. And then, **as it moves around us (SciOrb) whatever angle umm earth is at with the moon and the sun that is the portion that we see (SciEMS).**
>
> R: Okay. Why don't you give a specific example and explain how that works? Pick out a specific moon phases and tell me how that works?
>
> 283807: Okay, one of the specific moon phases that we talked about was the half moon, which they called quarter moon. So, if the sun is in front of me where the camera is and I am earth, the moon would be positioned right here where my fist is [*Holding her left fist up parallel to her body*]. And **only this half of the moon is going to be lit from the sun (SciHaf)** [*pointing with her right hand to the side of her left fist that faces to the camera*] but since we are here [*Pointing her head that faces to the her left fist*], earth, **we only see like that half part (SciSee)** [*Pointing to the side of her left fist that towards to the left side of her head*].

The above excerpt shows that the participant was able to explain the cause of the moon phases by exhibiting all the elements of scientific mental model. Because the responses included all the elements of scientific mental model and included no sign of an alternative mental model, the type of conceptual understanding was categorized as scientific.

Scientific Fragments

Participants' conceptual understandings of the cause of the moon phases were identified as scientific fragments if they included some but not all four of the scientific elements and include no alternative model or elements of an alternative model within the responses. Only two of the 52 participants (4%) held scientific fragments as their type of conceptual understanding in the pre-interviews. In the post-interviews 13 of the 52 participants' (25%) type of conceptual understandings were categorized as scientific fragments, and three of the 16 participants (19%) held this type of conceptual understanding in the delayed-post interviews. The following excerpt from one participant's responses in the post-interview assessment provides an example of a conceptual understanding that was categorized as scientific fragments.

> R: What do you think causes the phases of the moon?
>
> 488658: Umm, **the orbit of the moon around the earth causes the phases (SciOrb)** based on the amount of the light that from the sun which comes at an angle, so that depending of the how much sun light is available where **the position of the moon is in orbit around the earth is how much of the moon we see (SciEMS)**.

As the excerpt illustrates, the participant's verbal explanation and use of models included only two elements of scientific understanding (SciOrb and SciEMS), and participant did not include alternative mental model or elements of an alternative mental model in the explanation of the cause of the moon phases. Therefore, this response was categorized as scientific fragments.

Scientific with Alternative Fragment

Participants' conceptual understandings were categorized as scientific with an alternative fragment if they included all four elements of scientific understanding and they included an element of an alternative mental model within their mental model. None of the participants' conceptual understandings from the pre-interviews were categorized as scientific with an alternative fragment. Only one of the 52 participants (2%) held this type of conceptual understanding in the post interviews and one of the 16 participants

(9%) in the delayed post interviews. Following excerpt illustrates a participant's responses in post-interview.

> R: What do you think causes the phases of the moon?
>
> 300809: So, we have the earth, and **the moon is rotating around the earth (SciOrb)**, and the earth is rotating one days the earth rotating, and the moon takes a month to rotate around the earth and that what cause the phases. Day and night are caused by the earth rotating, that's when you see the moon and when you don't. And then the moon rotates around the earth and it takes one month to fully rotate, so **the phases you see of the moon are based on where the moon is in relation to the earth during that month (SciEMS)**….
>
> R: Now show me another phase, such as a phase where we can't see the moon?
>
> 300809: Okay [*Participant moved the moon component between the earth and the sun component*]. This is the new moon.
>
> R: Okay, why this is the new moon?
>
> 300809: Every month there will be a full moon and no moon… Okay, I don't remember why, but I know that this is the full moon [*Participant moved the moon component to a full moon position*] and this is the new moon [*Participant moved the moon component to a new moon position*].
>
> R: By looking at the model what you can tell me for the reason we can't see the moon.
>
> 300809: We can't see the moon because it is orbited kind of… **Half the moon is always illuminated (SciHaf)**, but depending on what phase you are in and where the sun is **will determine how much of that half you can see (SciSee)**. So, here this side of the moon is lit, but we can't see that [*Pointing the side of the moon component that faces the sun component*].
>
> R: Okay, we can't see that, because?

> 300809: **Because we are blocking it (AltEcl)** [*Pointing the earth component*]. **We are blocking the sun illuminating this half of the moon (AltEcl)** [*Pointing the side of the moon that faces the earth component*].

The participant's verbal responses and her manipulation of the models indicated that she included all four of the scientific elements within her responses. However, in addition to holding a scientific mental model, participant also included an alternative idea (AltEcl) within her mental model of the cause of the moon phases. Therefore, her response was categorized as scientific with alternative fragments.

Alternative with Scientific Fragments

Responses that included some but not all four elements of scientific understanding within an alternative mental model were categorized as alternative with scientific fragments. Eight of the 52 participants' (15%) conceptual understandings were in this category in the pre-interviews, whereas 10 of the 52 participants' (19%) conceptual understandings were categorized as alternative with scientific fragments in the post-interviews. None of the participants demonstrated this type of conceptual understanding in the delayed-post interviews. The following excerpt is from one participant's responses in pre-interview assessment, which was identified as alternative with scientific fragments.

> R: What do you think causes the phases of the moon?
>
> 769205: Umm, the sun shines only on the certain part of the moon. And then, what you see on earth is different. So as the moon turns like it moves, the sun goes behind it and illuminates it. And then, from the earth you usually **see the part that is illuminated (SciSee)**…
>
> R: Okay, this is what we called a full moon. Orange areas represent what we can of the moon. Can you arrange the model so that we would have this drawing?

769205: **I think it looks like this (AltEcl)** [*Participant moved the moon component to a new moon position*].

R: Why do you think it looks like that?

769205: **Because the sun is shining through all of the moon and is directly in line with the earth (AltEcl).**

R: Okay, this is a new moon. Can you arrange your model to a new moon position?

769205: We are gonna switch them like this [*Participant moved the moon component to a full moon position*]; **because it is on the opposite site, so the sun does not hit the moon (AltEcl)**.

R: Why the sun does not hit the moon?

769205: Because, the sun is hitting this side of the earth [*Pointing the side of the earth component that faces to the sun component*] **and not this side (AltEcl)** [*Pointing to the side of the earth component that is away from the sun component*].

Although the participant exhibited one of the four elements of scientific understanding, an alternative mental model, eclipse model, was in the center of her conceptual understanding. Therefore, this synthetic conceptual understanding, which is a combination of a fragmented scientific mental model and an alternative mental model, was categorized as alternative with scientific fragments.

Alternative

Participants' conceptual understandings were categorized as alternative if they did not exhibit any of the scientific elements and they explained the cause of the moon phases with a single alternative mental model that was contrary to a scientific explanation. More than half of the participants (52%) held alternative conceptual understanding in the pre-interviews and only one participant held (2%) alternative conceptual understanding in the post-interview. None of the participants exhibited this type of conceptual understanding in the delayed-post interviews. The eclipse model was the most common alternative mental models participants held in pre-interview (27%). Earth's rotation model (13%), heliocentric model (10%), and geocentric model (2 %) were other alternative mental models participants held. The following excerpt provides an example of one participant's responses in pre-interview that exemplifies the most commonly held alternative mental model.

> R: What do you think causes the phases of the moon?
>
> 302868: It's the different positioning of the sun as it relates to the earth and the moon, and the how the earth's rotation around the sun.
>
> R: So, could you elaborate on it?
>
> 302868: Like the position of the sun. Because the sun would be here [*Holding her right hand as a sun*], the earth [*Holding her left hand in front of her right hand that represents the sun*] and the moon revolving around the earth [*Swiftly circling the finger point of her left hand*]. So I would say that it has to do with where we are in relation to revolving around the sun [*Holding her right hand and moving her left hand around it as she talks*]. It would have an effect, because **the earth will be blocking the different portion (AltEcl)**...
>
> R: Could we see a moon that looks like this? (A drawing representing a crescent moon phase provided)
>
> 302868: It would just be barely around the corner [*Positioning the moon component behind the earth component in waxing gibbous phase*], **see you would only see just the small portion of the side (AltEcl)** [*Pointing the right corner of the moon component that faces the sun component. The remaining portion of the moon component is behind the earth component*]. So there are light coming on the side kinda hedges that small crescent

> [*Pointing the right corner of the moon component that faces the sun component*] but not enough to show half or all of the moon.

This participant's conceptual understanding included a single alternative mental model, eclipse model, and she consistently used this alternative model to explain the cause moon phases during the interview. The participant maintained that the earth blocks the sun light from reaching the moon, thus, produce different phases of the moon. The portion of the moon that is observable from the earth is the part that is not covered by the earth's shadow. Therefore, this participant's response was categorized as alternative.

Alternative Fragments

Participants' conceptual understandings that included more than one alternative mental model were categorized as alternative fragments. While nine of the 52 participants' (17%) conceptual understandings were categorized as alternative fragment in the pre-interviews, the number of participants who held alternative fragments conceptual understanding was two (4%) in the post-interviews. Three of the 16 participants' (19%) conceptual understandings were categorized as alternative fragments in the delayed-post interviews. Following excerpt illustrates a participant's responses in pre-interview.

> R: Okay. I would like for you to use this model and explain to me and show me while you're explaining what you think causes the phases of the moon.
>
> 612050: I think probably in the fall we see more full moon because the earth is in the different position. **There is something about the fall that makes it a full moon (AltSeason).** At night you can see it clear because the sun is down. You can see the whole circle instead of the crescent.
>
> R: During the fall we can see a full moon

612050: More commonly a full moon.

R: Why is that?

612050: I don't know **may be the season**. **May be something about the sun's location. That it is not too cold not too hot or something. May be in the summer it is so bright so you can't see the whole circle (AltSeason).** In the winter, I don't know…

R: Use the model to show me what happens as the moon goes through one complete cycle of phases.

612050: **As the earth turns** [*Turning the earth component in clockwise direction*], **it changes what you can see (AltRot)**, but when it is at this point this is a full moon [*Holding the moon component above the earth in full moon position*]. As the earth turns the moon would change too [*Moving the moon component around the earth component*], but when it comes to this position we would see a full moon [*Turning the earth component around itself as moving the moon component around the earth component. Stops at full moon position, the moon component is above the earth*].

R: What happens as the earth turns around its self?

612050: **The moon phase change (AltRot).**

Throughout the interview the participant used two alternative mental models simultaneously to explain what she thinks causes the phases of the moon. Although the earth's rotation model is one of the most common alternative mental models reported in the literature, the season model is a novel alternative mental model identified in this study. This participant asserted that we observe different phases of the moon depending on the season. The moon is not visible during the summer due to excessive amount of light, and the moon is fully visible during the fall. The participant also explained the cause of the moon phases using earth's rotation model suggesting that earth's rotation around its axis also involve causing moon phases. Therefore, the participant's conceptual understanding, which is a combination of two alternative mental models, was categorized as alternative fragments.

Summary of Conceptual Understandings: Findings for Pre, Post, and Follow-up Interviews

Before instruction participants' conceptual understandings were mainly categorized as alternative and alternative fragments (69%). After the instruction the majority of the participants' conceptual understandings was categorized as scientific or scientific fragment (73%). There was a substantial increase in participants' conceptual understanding scores from the pre- to the post-interviews. The results of the delayed-post interviews were similar to the post-interviews that the majority held scientific or scientific fragment conceptual understandings (12 of the 16 participants; 75%) suggesting participants tend to maintain their scientific understanding 13 to 15 weeks after the instruction. Table 4.1 presents the results of the qualitative analysis of the pre-, post, and the delayed-post interviews.

Type of Conceptual Understanding	Participants Expressing This Conceptual Understanding		
	Pre-interview (n=52)	Post-interview (n=52)	Delayed-post Interview (n=16)
Scientific	6 (12%)	25 (48%)	9 (56%)
Scientific Fragments	2 (4%)	13 (25%)	3 (19%)
Scientific with Alternative Fragment	0 (0%)	1 (2%)	1 (6%)
Alternative with Scientific Fragments	8 (15%)	10 (19%)	0 (0%)
Alternative	27 (52%)	1 (2%)	0 (0%)
Alternative Fragments	9 (17%)	2 (4%)	3 (19%)

Table 4.1 Profiles of participants' conceptual understanding

Levels of Metaconceptual Awareness

Sixteen of the 52 participants were randomly selected based on their scores from the metacognitive strategy use subscale for the delayed-post interviews. The selected participants were interviewed 13 to 15 weeks after the post-interviews to assess their level of metaconceptual awareness and the durability of conceptual understandings of the cause of the moon phases. Metaconceptual interviews (interview protocol B) targeted three types of metacognitive awareness: (1) the metaconceptual awareness of contradiction, (2) the metaconceptual awareness of change in understanding, and (3) the metacognitive awareness of strategies and experience.

The participants' responses were scored using a coding and scoring sheet (Appendix E), which was designed for the study. Scores in the coding and scoring sheet ranged from 0 to 10. Based on the total score obtained, participants' responses were assigned into three metaconceptual awareness categories: high metaconceptual awareness (>7 points), moderate metaconceptual awareness (5 to 7 points), and low metaconceptual awareness (5< points). In the following subsections characteristics of each metaconceptual awareness level are presented along with an example for each level.

High Metaconceptual Awareness

Seven of the 16 participants' (44%) responses were categorized as high metaconceptual awareness. These participants tend to aware of their initial mental models about the cause of the moon phases and the differences between their initial mental models and the scientific mental model. They were able to articulate how their initial mental models had changed over the course of the instruction and describe the cognitive and metacognitive strategies they used to learn lunar concepts. Participants with high metaconceptual awareness also were able to explain how their learning experience influenced their conceptual understanding. The following excerpt provides an example of one participant's responses that exemplifies the high metaconceptual awareness category.

> R: Do you remember what your ideas/responses were about the cause of the moon phases in the first interview? What did you think was the cause of the moon phases?
>
> 285840: I guess **what I thought causes the moon phases was the reflection of the sun off the moon**. **I did not consider anything about the moon's orbit really (MAC_Initial)**, I think I thought about it more as, I knew that the moon orbited around the earth, but **I think I thought of it more as like the earth rotating around and that's how the phases coming up (MAC_Initial)**. **Like a full rotation of the earth, but that would have been a day (MAC_UnSci.)**. I don't know why I would have thought of it that way. I suppose from cartoons sun is coming up like that.

R: What happened when you first realized that your understanding was different from what the instructor taught in the class?

285840: **Using the software taught me that my original thoughts were not sound (MAC_UnSci.)**. Using the moon software and then documenting each day helped me to see different phases.

R: How did you realize that what you think was not scientifically acceptable response for the cause of the moon phases?

285840: Basically **with the help of software**. **And we did an experiment where we had the flashlights and the moon (MAC_UnSci.)**. I got the see all the phases as they were occurring rather than just looking at specific date and time and writing that down.

R: How did your ideas change over the course of the instruction?

285840: **I no longer thought the moon stayed stationary and that was earth doing all the rotating. I began to see that the moon is rotating around the earth and that played a part (MAU_Change).**

R: What did you do to change your understanding of the cause of the moon phases? How did you study? What did you pay attention to during instruction? Was there a moment when you realized and suddenly understood the cause of the moon phases? Can you describe it?

285840: **How we kept the, the Starrynight software program, we kept it at the same time every day (MAS_Step.)**. We were seeing different portions of the moon. **Because I think if I kept it the way I was thinking you would see the same portion of the moon at the same time every day (MAC_UnSci & MAU_Change).** With the way I was having it rotate. **And then, with the software helped me see that at six am ever day we don't necessarily see the same portion, so something else had to be affecting that (MAS_Exp.). Recording data everyday helped me see that the moon's rotation around the earth did have something to do with it. Because when I first started I was thinking the moon is stationary so the earth was the one rotating (MAS_Exp.)**. **But, that means that you would see the same portion of the moon at the same time everyday and that's not true (MAC_UnSci)**. So, realizing that obviously something else was playing in there and it is the moon that was moving as well that affected. So you might not see the same portion at the same time.

R: Was there a moment when you realized and suddenly understood the cause of the moon phases? Can you describe it?
285840: Yeah, **the activity with the styrofoam ball. It helped me to see the different cycle by being able to hold those objects. Because I was the earth I could actually see the view (MAS_Exp.)**. And that made the cycles of the moon made a lot more sense, why they were occurring. **Whereas Starynight helped me see that you would not see the same portions of the moon same time every day. I could see it in the software but it did not help me much understand the whole cycle process (MAS_Exp.).**

R: What steps did you follow to change your understanding?
285840--- What steps I took were all in class. As a class when **we did the hands on, actually with flashlight and styrofoam ball and the talked as class. Those helped and the Starrynight also supported that (MAC_Step)**.

As the excerpt illustrates, the participant was aware of her initial understanding of the cause of the moon phases and the elements of scientific understanding she did not consider previously. She was able to articulate why her initial understanding did not provide a plausible explanation for the cause of the moon phases, thus, she was aware of the elements of her initial mental model that were not working in constructing a plausible explanation for the cause of moon phases. She explained the elements of her mental model that were restructured during the course of the instruction. She was also aware of the elements of the instruction that helped her in restructuring her initial mental model and constructing a scientific understanding of the cause of the moon phases. his participant exhibited high metaconceptual awareness, and thus, her responses were given a score of eight and categorized as high metaconceptual awareness.

Moderate Metacognitive Awareness

Six of the 16 (38%) participants' responses were categorized as moderate metaconceptual awareness. These participants, to some extent, tend to be aware of their initial mental models about the cause of the moon phases and the differences between their initial mental models and scientific mental model. They were able to fairly articulate how their initial mental models changed over the course of the instruction and somewhat describe the cognitive and metacognitive strategies they used to learn lunar concepts. Participants with moderate metaconceptual awareness also, to some extent, were able to explain how their learning experience influenced their conceptual understanding. The following excerpt is from one participant's responses, which was categorized as moderate metaconceptual awareness.

> R: Do you remember what your ideas/responses were about the cause of the moon phases in the first interview? What did you think was the cause of the moon phases?
> 289802: I don't remember that much. Probably said **something how the earth's orbit around the sun mattered. Now that I am thinking it probably does not (MAC_Initial)**. Because I kinda remember making a list of things that affect moon phases and **I don't think the earth's orbit was on there (MAC_UnSci)**.
> R: How did you realize that what you think was not scientifically acceptable response for the cause of the moon phases?
> 289802: I think the only time I realized that was when we did the list Dr. Trundle doing that styrofoam ball experiment. **I think still throughout I thought earth' rotation have something to do with it. I am sure we talked about that it did not (MAC_UnSci.).**
> R: Until that time you were thinking earth's orbit somehow involve causing moon phases?
> 289802: Yeah, until you know she explained it well, I don't remember How she explained it, I said o yeah of course.

R: How did your ideas change over the course of the instruction?

289802--- Maybe **more cognizant of what was going on** (**MAU_Change**).

R: What did you do to change your understanding of the cause of the moon phases? How did you study? What did you pay attention to during instruction? Was there a moment when you realized and suddenly understood the cause of the moon phases? Can you describe it?

289802: Probably the **styrofoam ball activity**. That's, uumm, since I am such a visual learner. you could see it on the computer program what it look like. You could not actually see the 3D model and see the darker part and compare it. But the **styraform ball and the light you walk around you can see okay this is the lit part over there you can see the dark part. So that was helpful to me (MAS_Exp).**

R: What steps did you follow to change your understanding?

289802: Actually, **on the month cart seeing the progression and change**, Ohh yeah there is that pattern. Seeing it laid out and **you can see the pattern, see the angles things like that (MAS_Step)**, days between you know 29 to 30 days something to complete the cycle. Just watching as everything kinda revealed itself, getting that enlightenment, Aha moment.

The participant was aware of her initial understanding of the cause of the moon phases, that is, she was aware that initially she considered earth's orbit around the sun as the cause of lunar phases. She did not explain the elements of her mental model that were restructured during the course of the instruction. However, she was able to describe the elements of the instruction that helped her in restructuring her initial mental model and constructing a scientific understanding of the cause of the moon phases. Therefore, the participant's responses were given a score of six and categorized as moderate metaconceptual awareness.

Low Metacognitive Awareness

Three of the 16 participants' (18%) responses were categorized as low metaconceptual awareness. These participants exhibited very limited awareness of their initial mental models about the cause of the moon phases and the differences between their initial mental models and scientific mental model. Their articulations of how their initial mental models had changed over the course of the instruction and descriptions of the cognitive and metacognitive strategies they used to learn lunar concepts were also fairly limited. Participants with low metaconceptual awareness, to some extent, were able to explain how their learning experience influenced their conceptual understanding. The following excerpt from one participant's responses provides an example of low metaconceptual awareness.

> R: Do you remember what your ideas/responses were about the cause of the moon phases in the first interview?
> 290809: Probably as clueless as I am now.
>
> R: Do you remember specifically?
>
> 290809: **No, I don't (MAC_Initial).**
>
> R: What happened when you first realized that your understanding was different from what the instructor taught in the class?
> 290809: I still don't really know. I know what the phases are and I know things rotate around each other, but **I don't really know (MAC_Initial).**
> R: How did you realize that what you think was not scientifically acceptable response for the cause of the moon phases?
> 290809: **Probably because I had no idea, so I am sure it is not scientific (MAC_Unsci).**
> R: How did your ideas change over the course of the instruction?
> 290809: Probably **it was just clarified (MAU_Change)**. I am sure a lot of thing I have heard. You know you hear them and you forget them. Really I just got the phases. **I remember doing the whole modeling thing**, but, **I did not completely understand it**. We did it in one day. So, when we did the phases things whole time, so **I probably needed more (MAS_Exp.).**
> R: What did you do to change your understanding of the cause of the moon phases? How did you study? What did you pay attention to during instruction?

290809--- I remember the day we did it with our stray foam balls and light and we moved around. Remember doing that and **paying attention to that and trying to understand that (MAS_Exp).**

R: Was there a moment when you realized and suddenly understood the cause of the moon phases? Can you describe it?

290809: **No, there was no big aha (MAS_Exp.)**.

R: What steps did you follow to change your understanding?

290809--- I just did what we did in the class. **I did not do anything extra. It probably shows (MAS_Step).**

As the excerpt illustrates, the participant was not able to articulate the content of her initial conceptual understanding of the cause of the moon phases. She also failed to provide any description of a recognition or awareness of the differences between the alternative mental model of the lunar phases she had and the scientific model provided during instruction. Although the participant did not provide a detailed account of the elements of her mental model that were restructured during the course of the instruction, she was able to describe some elements of the instruction and suggested that she needed more help in understanding the cause of the moon phases. This participant also recorded that she did not experience any major changes in her conceptual understanding. Therefore, her responses were given a score of two and categorized as low metaconceptual awareness.

Summary of Metaconceptual Awareness Interviews

Sixteen of the 52 participants were interviewed 13 to 15 weeks after the post-interviews to assess their level of metaconceptual awareness. Interviews were analyzed and scored using a rubric designed for the study. Seven of the 16 participants' (44%) responses were categorized as high metaconceptual awareness. These participants tend to aware of the content of their pre-instructional mental models about the cause of the moon phases as well as the differences between their initial mental models and scientific mental models. They were able provide a detailed account of the change in their initial mental models over the course of the instruction and describe the cognitive and metacognitive strategies they used to process knowledge and concepts provided in the instruction. Participants with high metaconceptual awareness also were able to explain how their learning experience influenced their conceptual understanding.

Six of the 16 participants' (38%) responses were categorized as moderate metaconceptual awareness. These participants, to some extent, were aware of the content of their initial mental models about the cause of the moon phases as well as the differences between their initial mental models and the scientific mental model. They were able to fairly articulate how their initial mental models changed over the course of the instruction and somewhat describe the cognitive and metacognitive strategies they used to learn lunar concepts. Participants with moderate metaconceptual awareness also, to some extent, were able to explain how their learning experience influenced their conceptual understanding.

Three of the 16 participants' (18%) responses were assigned to the low metaconceptual awareness category. These participants exhibited fairly limited awareness of the content of their initial mental models about the cause of the moon phases. They appeared to have a lack of recognition of the differences between their initial mental models and the scientific model of the cause of the moon phases. Their articulation of how their initial mental models changed over the course of the instruction and descriptions of the cognitive and metacognitive strategies they used to learn lunar concepts also were fairly limited. Participants with low metaconceptual awareness, to some extent, were able to explain how their learning experience influenced their conceptual understanding.

Quantitative Findings

This section reports the results of the quantitative analysis. SmartPLS version 2.0M3 software package (Ringle, Wende, & Will, 2005) was used to perform partial least square path analyses. Statistical Program for the Social Sciences (SPPS Version 17.1 for Windows) was used to calculate descriptive statistics and conduct nonparametric tests. An alpha level of 0.05 was set for the all statistical analyses performed in the study.

Data Screening and Evaluation

Data screening and preparation for model testing was performed using SPSS version 17.0 (SPSS for Windows, 2008). The percentage of missing data value was less than 2% with no apparent pattern. Therefore, the missing data was imputed using a regression estimation method. Examination of possible outliers revealed that none of the cases was three standard deviations away from the mean of its distribution. Thus, all cases were retained for the analysis. The distributional characteristics of the data set were inspected using graphical methods (histograms and Normal Q-Q plots). Two distributions showed a sign of skewness. The distribution of the pre-conceptual understanding scores was skewed to the right and the distribution of the post-conceptual understanding scores was slightly skewed to the left. Given that the PLS-PM analysis is robust with regard to violation of normality and it makes no distributional assumption, analyses were performed on the raw data without making any transformation.

Descriptive Statistic for the Subscales of MSLQ

Participants' scores from the subscales of the MSLQ were calculated to determine means and standard deviations of their self-reported level of metacognition, motivation, and use of cognitive strategies. Participants tended to report relatively high levels of deep-level cognitive strategies (elaboration and organization) and metacognitive strategies. Participants also reported relatively high levels of self-efficacy and task value, and they tended to adopt a mastery goal orientation. Table 4.2 presents the mean scores and standard deviations for each subscale of the MSLQ.

Subscales of MSLQ	N	Mean Score	Standard Deviation
Metacognition	52	51.33	11.0
Elaboration	52	27.67	6.43
Organization	52	14.83	5.24
Self-efficacy	52	47.93	5.44
Mastery Goal	52	21.42	3.22
Task value	52	34.37	5.38

Table 4.2 Descriptive statistics of the subscales of MSLQ

Reliability of the Subscales of MSLQ

Cronbach's alpha was calculated to assess internal consistency for each subscale of the MSLQ used in this study. In the present study, reliability coefficients of subscales ranged from 0.58 to 0.90. Table 4.3 presents the Cronbach's alpha for each subscale.

Subscales of MSLQ	N	Number of items	Alpha
Metacognition	52	12	.84
Elaboration	52	6	.80
Organization	52	4	.72
Self-efficacy	52	8	.90
Mastery Goal	52	4	.58
Task value	52	6	.87

Table 4.3 Reliability estimates for subscales of MSLQ

Previous studies reported that subscales of the MSLQ have acceptable reliability coefficients ranging from 0.52 to 0.93 (Duncan & McKeachie, 2005; Pintrich et al., 1993). Reliability of measures obtained in this study were very similar to those reliability coefficients previously reported in the literature. All reliability coefficients were within the acceptable limit except the coefficient of mastery goal orientation subscale. Although the mastery goal orientation subscale had a low reliability coefficient, it was very close to the lenient cut-off value of 0.60.

Quantification of the Qualitative Data: Conceptual Understanding

To make statistical analysis possible, participants' pre-, post-, and delayed-post conceptual understandings were scored with a scoring rubric (Appendix D), which was designed for this study. Chi (1997) suggested that mental models can be quantifiable for statistical analysis based on their level of sophistication and coherency. Other researchers also quantified mental models and used parametric statistical analysis techniques to analyze their data (Chi, 1997; Vosniadou et al., 2005). In this study participants' responses were given scores ranging from 0 to 10 based on the number of scientific elements and alternative mental models included in their conceptual understanding. Table 4.4 presents the means and standard deviations of participants' conceptual understandings scores that were generated using the scoring rubric. These scores were used in the statistical analysis performed in the study.

Conceptual Understanding	N	Mean Score	Standard Deviation
Pre-interview	52	3.15	2.8
Post-interview	52	7.81	2.92
Delayed-post Interview	16	7.75	3.53

Table 4.4 Means and standard deviations of the conceptual understanding scores

Correlations between Independent and Dependent Variables

The relationship between the independent variables and their correlations with conceptual understanding scores was examined using a Pearson product-moment correlation coefficient. There was a strong positive relationship between the metacognitive strategy use variable and the deep-level cognitive strategy use variables. Participants who were high in metacognitive strategy use also were more likely to use deep-level cognitive strategies (elaboration and organization). The self-efficacy, task value, and mastery goal variables were moderately related to the metacognitive strategy use variable. Participants who reported that they frequently use metacognitive strategies were more likely to have high self-efficacy for learning science and they also were more likely to value the course and adopt mastery goal orientation. Likewise, participants with high self-efficacy, task value, and mastery goal orientation were more likely to use deep level strategies (elaboration and organization). Participants with high self-efficacy also were more likely to have high mastery goal orientation and task-value.

Metacognitive strategy use, use of deep level strategies (elaboration and organization), and high task value were moderately related to post-conceptual understanding scores. The relationship between the cognitive, metacognitive, and motivational beliefs variables and the pre-conceptual understanding variable was low and did not reach statistical significance. However, there was a moderate significant relationship between the pre-conceptual understanding and the post-conceptual understanding scores. Table 4.5 presents the zero-order correlations between the independent variables utilized in this study and the pre and post-conceptual understanding scores.

Variables	1	2	3	4	5	6	7	8
1. Metacognition	1.0							
2. Elaboration	.72**	1.0						
3. Organization	.65**	.55**	1.0					
4. Self-efficacy	.38**	.56**	.23	1.0				
5. Mastery Goal	.50**	.52**	.31*	.62**	1.0			
6. Task value	.48**	.53**	.43**	.57**	.71**	1.0		
7. Pre-Conceptual	.22	-.01	.10	.12	.06	.09	1.0	
8. Post-Conceptual	.46**	.43**	.29*	.23	.31*	.41**	.38**	1.0

Table 4.5 Correlations between the subscales of MSLQ

** Correlation is significant at the .01 level (2-tailed)

* Correlation is significant at the .05 level (2-tailed)

Partial Least Square Path Analysis: Testing of Hypothesized Model

Partial least square path analysis (PLS-PM) was used in the current study to test the predictive power of the hypothesized model. PLS-PM analysis was performed using the SmartPLS software (Ringle et al., 2005). The software computes the estimates of standardized regression coefficients of the paths of the model, the factor loadings for the indicators of the latent variables, and the amount of variance account for the dependent variables. Thus, the software makes it possible to test hypothesized relationships between independent and dependent variables depicted in the model.

Because PLS-PM makes no distributional assumption, the statistical significance of the path coefficients and loadings are estimated using a bootstrap procedure. In the bootstrap procedure, a large number of random samples with replacement are drawn from the actual data and path coefficients and loadings are estimated for each sample. Means and standard deviations of the path coefficients and loading are calculated from the bootstraped samples, and then these values are used in calculation of the t values for the path coefficients and loadings of the actual data. The SmartPLS software application also computes several reliability (Cronbach’s alpha and composite reliability coefficient) and validity (convergent and divergent) statistics, which can be used to assess the quality of the model.

In structural equation modeling, a model is typically evaluated following a two-step procedure (Hair, Black, Babin, Anderson, & Thaham, 2005). Likewise, the results obtained from a PLS-PM model are analyzed and evaluated in two stages. In the first stage reliability and the validity of the measurement model, also called outer model, is assessed. This step ensures the quality of the measurement model prior to hypothesis testing. In the second stage the structural model, also called inner model, the hypothesized relationship between independent (exogenous) and dependent (endogenous) variables is assessed. A detailed evaluation of the inner and outer model is provided in the subsequent sections.

Sample Size Consideration

In determining the sample size, Chin (1998) suggests considering either (A) the latent variable with the largest number of formative indicators, a type of measurement model where indicators are hypothesized as the cause of the latent variable, or (B) the dependent latent variable with the largest number of independent variable impacting it. Ideally the sample size should be 10 times of either the situation (A) or (B), whichever is the greater. In the present study all measurement models were reflective. That is, latent variables were hypothesized to be the cause of the observed indicators. Therefore, situation A was not applicable in deciding the minimum sample size required for the analysis. The post conceptual understanding variable was the dependent variable with the largest number of independent variables connected to it. Three variables, deep-level cognitive strategies, metacognitive strategies, and pre conceptual understanding, were connected to the post conceptual understanding. Therefore, the minimum sample size required for the analysis was 30. Considering the actual sample of the study (n=52), the sample size for the present study was large enough to perform PLS-PM analysis.

Power of the Statistical Analysis

Researchers suggest calculating power of the statistical analysis to determine whether the study has a power to reject the null hypothesis when the null hypothesis is indeed incorrect. Traditionally a power level of at least 0.80 is suggested to detect medium effect size (Cohen, 1988). In the present study a post hoc power of the statistical analysis was computed using G*Power version 3.0.1 software application (Faul, Erdfelder, Lang, & Buchner, 2007). Based on the sample size of the study (n=52), the latent variable with the greatest number of predictors (i.e. 3), the predetermined alpha level of 0.05, and the observed effect size of 0.42, the post-hoc power of the study was found to be 0.93, which was higher than the suggested level.

Evaluation of the Measurement Model (Outer Model)

A PLS-PM consists of two sub-models. The first model is referred to as the outer model. Also referred to as the measurement model, the outer model describes the relationship between the observed variables and the latent variables (Tenenhaus, Vinzi, Chatelin, & Lauro, 2005). This relationship could be either reflective, where the latent variable is hypothesized to be the cause of the observed variables, or formative, where the observed variables are hypothesized to be cause of the latent variable. In either mode, the partial least square estimation procedure creates latent variables that are linear functions of their indicators (Chin, 1998; Tenenhaus et al., 2005). When a reflective mode is used, indicators of a latent variable (path lines from a latent variable to observed variables) are calculated using a principal component analysis. When a formative mode is used, indicators of a latent variable are calculated using regression weights (Chin, 1998; Chin

& Newsted, 1999). In this study, all measurement models were reflective. In other words, latent variables were hypothesized to be the cause of the observed variables.

In assessing the quality of the measurement model, the following criteria were used: reliability of the latent variables, loadings and cross-loadings of the observed variables, and average variance extracted by latent variables from their indicators (observed variables) (Chin & Newsted, 1999). These statistics are used to evaluate the convergent and discriminant validity of the measurement model.

Reliability of the Latent Variables

Internal-consistency of the indicators (observed variables) is calculated to assess the construct validity of the measurement model. Cronbach's alpha coefficient for the latent variable of motivational beliefs was $\alpha=0.71$ and the latent variable of deep-level cognitive strategies was $\alpha=0.84$. Cronbach's alpha is influenced by the number of indicators used to measure a latent variable. Therefore researchers suggest using an alternative measure of reliability, composite reliability (Dillon–Goldstein's p coefficient), which utilizes loadings of indicators in calculating a reliability coefficient for the measurement models in structural equation modeling (Chin & Newsted, 1999; Werts, Linn, & Joreskog, 1974). Composite reliability is not influenced by the number of indicators, thus, it provides a better estimate of the reliability for the measurement model (Chin & Newsted, 1999). In the present study, the composite reliability of motivational beliefs was 0.90 and the composite reliability of the deep-level cognitive strategies was 0.87. Cronbach's alpha and composite reliability coefficients were above the value suggested in the literature.

The PLS-PM analysis does not provide direct evidence for unidimensionality of the observed variables that are connected to a latent variable. High internal consistency coefficients (Cronbachs' alpha and composite reliability) are typically seen as evidence of unidimensionality of the latent variables (Tenenhaus et al., 2005). Although high internal consistency is necessary for undimensionality, it is not a sufficient indicator. In the present study unidimensionality of the latent variables were examined using principal component analysis to provide further evidence for the unidimensionality of the latent variables. SPSS version 17.0 was used to perform principal component analysis. Results indicated that unidimensionality was viable for the latent variables of motivational beliefs and deep-level cognitive strategies as there was only one factor with eigenvalue larger than 1 for both latent variables (Motivational beliefs: eigenvalue= 2.267, variance explained= 75.6%; deep-level cognitive strategies: eigenvalue=1.55, variance explained=77.7%). The results provided strong evidence that the two latent variables in the model were unidimensional.

Loadings and Cross-loadings of the Observed Variables

Loadings between the latent variable and its indicators of observed variables should be equal or larger than 0.55. A loading of 0.55 suggest that about 30% of the variance in the observed variable is explained by its latent variable (Falk & Miller, 1992). A more conservative approach recommends 0.70 as a cut off value for acceptable loading, suggesting that a latent variable should at least explain about half of the variance in its indicator variables (Henseler et al., 2009). In the present study loadings of the indicators of the latent variables ranged from 0.82 to 0.91 ($p<.001$), providing strong evidence for the convergent validity of the model.

Cross-loadings, correlations between latent variable component scores and other observed variables besides its own block, are used to assess the discriminant validity of the measurement model. If an observed variable loads higher with other latent variables than the one it is intended to measure, the observed variable should be reconsidered or even removed from the model. In the present study none of the observed variables loaded higher with other latent variables than the one they were intended to measure. The results provided evidence for the discriminant validity of the measurement model. Table 4.6 provides loadings and cross-loadings of the observed variables to the latent variables.

Variables	Deep-level Cognitive Strategies	Metacognition	Motivational Beliefs	Pre Conceptual Understanding	Post Conceptual Understanding
Elaboration	**0.91**	0.72	0.62	-0.01	0.43
Organization	**0.85**	0.65	0.39	0.10	0.29
Metacognitive Str.	0.78	**1.00**	0.52	0.22	0.46
Mastery Goal	0.48	0.50	**0.90**	0.06	0.31
Self-efficacy	0.47	0.38	**0.82**	0.12	0.23
Task-value	0.55	0.48	**0.89**	0.09	0.41
Pre Conceptual	0.04	0.22	0.10	**1.00**	0.38
Post Conceptual	0.41	0.46	0.37	0.38	**1.00**

Table 4.6 Loadings and cross loadings of the observed variables

Correlations among the Constructs (Average Variance Extracted)

The average variance extracted (AVE) refers to the amount of variance that a latent variable extracts from its indicators relative to the amount due to a measurement error error (Chin, 1998; Chin & Newsted, 1999). An AVE value greater than 0.50 is desirable as this suggests that 50% or more variance of the observed variables is accounted for by its respective latent variable. In this study the AVE value was 0.76 for the motivational beliefs and 0.78 for the deep-level cognitive strategies. In other words, motivational beliefs accounted for more than three-fourths of the variance in its indicators of self-efficacy, task-value, and mastery orientation. Similarly, the deep-level cognitive strategies accounted for more than three-fourths of the variance in its indicators of elaboration and organization strategies. These results provided further evidence for the convergent validity of the measurement model.

The AVE values could also be used as a means of evaluating divergent validity of the latent variables (Chin, 1998). The AVE's of the latent variables should be greater than the square of the correlations among the latent variables, which indicates that more variance is shared between the latent variable components representing a different block of indicators. Table 4.7 shows that the AVE of the motivational beliefs and cognitive strategies was greater than the square of the correlations among the latent variables providing further evidence for the validity of the measurement model.

Constructs	1	2	3	4	5
Metacognition	-				
Deep-level Cognitive Strategies	0.61	**0.78**			
Motivational Beliefs	0.27	0.33	**0.76**		
Pre Conceptual Understanding	0.05	0.002	0.01	-	
Post Conceptual Understanding	0.21	0.17	0.14	0.14	-

Table 4.7 Correlation among construct scores (AVE extracted in diagonals)

Evaluation of the Structural Model (Inner Model)

The second step in the evaluation of the PLS-PM analysis is the evaluation of the structural model. The structural model, also called the inner model, describes the hypothesized predictive or causal relationship between the latent variables in the model (Tenenhaus et al., 2005). The relationships between the exogenous and the endogenous latent variables are represented through single-headed arrows. Variables that have arrows pointed toward them are called endogenous variables and variables that do not receive any arrow are called exogenous variables. When an arrow is pointed from variable A to variable B, it suggests that the variable A is a predictor or cause of the variable B. This situation effect of variable A on variable B is called a direct effect. If the effect of variable A on variable B is mediated by another variable, for instance variable C, this effect is referred to as an indirect effect. An indirect effect is a product of all path coefficients in a given relationship. For the above example, the indirect effect of A on B through C is calculated by multiplying the path coefficient of variable A to C with the path coefficient of variable C to B. The partial least square estimate procedure generates path coefficients for each arrow in the inner model. These path coefficients are equivalent to standardized βs in a regression analysis, and they are used to interpret the magnitude and the direction of the relationships among the variables.

In assessing the quality of the measurement model, the following criteria are used: magnitude and significance of the path coefficients, magnitude of R^2, effect size for R^2 change, and global goodness of fit indices.

Assessment of Path Coefficients (The First Set of Hypotheses)

The SmartPLS software computes path coefficients for the hypothesized relationships between the variables in the model. As described previously, a bootstrap procedure typically is used to calculate corresponding t-values for each path coefficient to determine whether a given path coefficient is statistically significant. To evaluate the significance of the path coefficients in this study, a bootstrap procedure using 1000 random samples with replacement from the actual dataset was employed. The significance levels of all hypothesized paths (direct effect) were assessed using two-tailed tests. Path coefficients with t-statistics equal or larger than ± 1.96 are declared as statistically significant. The statistical significance of indirect effects is assessed using Sobel test (Hoyle & Kenny, 1999; Preacher & Hayes, 2008). Chin (1998) suggests that path coefficients (direct effect) should be higher than 0.20 to indicate predictive ability. Therefore, a path coefficient larger than the 0.20 criterion is used to assess the practical significance of the hypothesized paths. This criterion also is used in model trimming along with theoretical consideration.

The first six research hypotheses were tested and the results are reported in this section. The following paragraphs provide the results of each research hypothesis that were tested to evaluate the significance of the postulated relationship between the variables in the model.

Hypothesis 1: Preservice teachers' motivational beliefs will have a direct influence on their use of metacognitive strategies. The direct effect of the motivational beliefs on metacognitive strategies was statistically significant ($\beta=0.52$, $t=4.70$, $p<0.001$). Therefore, the null hypothesis of no effect was rejected.

Hypothesis 2: Preservice teachers' motivational beliefs will have a direct influence on their use of deep-level cognitive strategies. The direct effect of motivational beliefs on deep-level cognitive strategies was statistically significant ($\beta=0.23$, $t=2.68$, $p<0.001$). The model also included an indirect effect of motivational beliefs on deep-level cognitive strategies that was mediated by metacognitive strategies. This indirect effect of motivational beliefs on deep-level cognitive strategies was statistically significant ($\beta=0.35$, $t=4.34$, $p<0.001$). The total effect of motivational beliefs, which includes the direct and indirect effects, on deep-level cognitive strategies also was statistically significant ($\beta=0.58$, $t=5.18$, $p<0.001$). Based on these results, the null hypothesis of no effect was rejected.

Hypothesis 3: Preservice teachers' use of metacognitive strategies will have a direct influence on their use of deep-level cognitive strategies. The direct effect of metacognitive strategies on deep-level cognitive strategies was statistically significant ($\beta=0.66$, $t=11.43$, $p<0.001$). Therefore, the null hypothesis of no effect was rejected.

Hypothesis 4: Preservice teachers' use of metacognitive strategies will have a direct influence on their level of conceptual change. The direct effect of metacognitive strategies on conceptual change was not statistically significant ($\beta=0.18$, $t=0.97$, $p>0.05$) when the direct effect of cognitive strategies on conceptual change was controlled. The path coefficient was smaller than 0.20. Therefore, the direct path from metacognitive strategies to conceptual change was removed from the model and the model was reanalyzed. In this trimmed model, the indirect effect of metacognitive strategies on conceptual change, which was mediated by cognitive strategies, was statistically significant ($\beta=0.26$, $t=3.21$, $p=0.001$). Results indicated that the alternative hypothesis of direct effect was untenable. Therefore, the null hypothesis of no effect was retained.

Hypothesis 5: Preservice teachers' use of deep-level cognitive strategies will have a direct influence on their level of conceptual change. The direct effect of deep-level cognitive strategies on conceptual change was not significant in the untrimmed model, the hypothesized model that included a path between the metacognitive strategies and conceptual change ($\beta=0.26$, $t=1.36$, $p>0.05$). However, the path coefficient was larger than 0.20 with larger t-statistics than the metacognitive strategies. Therefore, based on the empirical and theoretical reasons, the path between the metacognitive strategies and conceptual change was removed from the model and the path between the deep-level strategies and conceptual change was kept in the model. The analysis was conducted again on this trimmed model. The results indicated that the direct effect of cognitive strategies on conceptual change was statistically significant ($\beta=0.40$, $t=3.30$, $p<0.001$). Therefore, the null hypothesis of no effect was rejected for the trimmed model.

Hypothesis 6: Preservice teachers' motivational beliefs will have an indirect effect on their level of conceptual change through their influence on metacognitive strategies and deep-level cognitive strategies. The indirect effect of motivational belief on conceptual change that is mediated by deep-level cognitive strategies was statistically significant ($\beta=0.09$, $t=2.08$, $p=0.037$). Likewise, the indirect effect of motivational beliefs on conceptual change through metacognitive strategies and deep-level cognitive strategies was statistically significant ($\beta=0.14$, $t=2.63$, $p<0.01$). The total indirect effect of motivational beliefs on conceptual change also was statistically significant ($\beta=0.23$, $t=2.45$, $p<0.01$). Based on these results, the null hypothesis of no indirect effect is rejected. Table 4.8 presents the direct, indirect, and total effect statistics for the variables in the model

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Independent Variables	Direct Effect			Indirect Effect			Total Effect			Dependent Variables
	β	t	p	β	t	p	β	t	p	
Deep-level Cognitive Strategies										
	0.40	3.30	<0.001	-	-	-	0.40	3.30	<0.001	Post Conceptual Understanding
Metacognitive Strategies										
	0.66	11.43	<0.001	-	-	-	0.66	11.43	<0.001	Deep-level Cognitive Strategies
	-	-	-	0.26	3.21	<0.001	0.26	3.21	<0.001	Post Conceptual Understanding
Motivational Beliefs										
	0.52	4.70	<0.001	-	-	-	0.52	4.70	<0.001	Metacognitive Strategies
	0.23	2.68	<0.001	0.35	4.34	<0.001	0.58	5.18	<0.001	Deep-level Cognitive Strategies
	-	-	-	0.09	2.08	0.037				
							0.23	2.45	<0.01	Post Conceptual Understanding
	-	-	-	0.14	2.63	<0.01				
Pre Conceptual Understanding										
	0.36	4.72	<0.001	-	-	-	0.36	4.72	<0.001	Post Conceptual Understanding

Table 4.8 Direct, indirect, and total effects

Amount of Variance Explained and Effect Size Estimates

The amount of variance explained in endogenous (dependent) latent variables by the exogenous (independent) latent variables is another criterion that is used to assess the quality of structural model. Unlike a multiple regression analysis, a latent variable in structural equation modeling can be both an independent and a dependent variable. There were two exogenous variables that did not receive any arrows from other variables in the model: motivational beliefs and pre-conceptual understanding. The endogenous variables of the model were: metacognitive strategies, cognitive strategies, and post conceptual understanding.

Researchers suggest that the variance explained by an endogenous variable should be equal to or higher than 10% (Falk & Miller, 1992). The amount of variance accounted for in metacognitive strategies by motivational beliefs was almost 28%. Motivational beliefs and metacognitive strategies together accounted for 65% of the variance in deep-level cognitive strategies. While pre-conceptual understandings accounted for 13% of the variance, deep-level cognitive strategies accounted for 17% of the variance in the post-conceptual understandings. Pre-conceptual understandings and deep-level cognitive strategies together predicted 30% of the variance in the post-conceptual understandings.

The change in R^2 in a dependent latent variable with the inclusion of an independent variable can be used to test whether the impact of that independent variable on the dependent variable is substantial. In this study, the effect size estimate of f^2 was calculated to evaluate the contribution of each independent variable in the amount of variance explained in the dependent latent variables, except for the control variable of pre conceptual understanding. Note that the pre-conceptual understanding variable was included in the model so that the residuals of the post conceptual understanding variable could be considered as a measure of conceptual change. Residual change scores are suggested as an alternative to gain scores to create change scores that are statistically independent of pre-test scores (Bauer, 2004; Cohen, Cohen, West, & Aiken, 2003; Hoyt, Leierer, & Millington, 2008). The use of residual change scores as an index of conceptual change allows researchers to identify individuals who engaged with conceptual change more or less than expected, regardless of their pre-conceptual understanding (Andre & Windschitl, 2003; Bode, Heinemann, Semik, & Mallinson, 2004) so that variables that contribute to the unexpected change in conceptual understandings can be determined (See Appendix F for residual change scores and raw change scores). The effect size estimate for the deep-level cognitive strategies variable in predicting post conceptual understanding was f^2=0.23. The effect size estimate for the motivational belief variable in predicting metacognitive strategies and deep-level cognitive strategies was f^2=0.39 and f^2=0.14 respectively. The effect size estimate for the metacognitive strategies variable in predicting deep-level cognitive strategies was f^2=0.86. These results indicated that the effect size estimates for the independent variables of the model ranged between medium effect to high effect (Cohen, 1988), indicating that the independent variables have a practical significance in predicting their respective dependent variables as well as a statistical significance.

Global Evaluation of the Hypothesized Model (Hypothesis 7)

The goodness of fit (GOF) index is considered as a global index for evaluating model quality in the PLS-PM analysis. Like χ^2 based indexes used in covariance-based SEM analysis, the GOF index provides a measure of global goodness of fit of a model. The GOF index ranges from 0 to 1 and higher values indicate that the model has a high predictive power (Tenenhaus et al., 2005). A GOF value of 0.50 and higher is considered as an indicator of a highly predictive model. Two GOF indices were used to evaluate the predictive power of the hypothesized model in the study: absolute GOF and relative GOF. The absolute GOF index is the geometric mean of the average communalities (measurement model) and the average R^2 of latent variables. The relative GOF index is the comparison of actual communalities and coefficients of determination to their respective eigenvalues and canonical correlation. The results of the hypothesis test are provided below.

Hypothesis 7: The hypothesized model of intentional conceptual change will have an acceptable predictive ability in predicting change in preservice teachers' conceptual understandings from pre to post-interviews. Two GOF indices were evaluated to test the hypothesis. In this study the absolute GOF index was 0.608 and the relative GOF index was 0.935, indicating that the hypothesized model was able to take into account almost 94% of its achievable maximum. Both the absolute and relative GOF indices suggest that the model has a predictive ability. Therefore, the null hypothesis of no predictive ability is rejected and the alternative hypothesis is retained.

Summary of the Results for the First Set of Hypotheses (Hypotheses 1 to 7)

All research hypotheses, except the hypothesis that suggested a positive direct effect of metacognitive strategies on conceptual change, were supported by the data. The hypothesized model was respecified by removing the nonsignificant direct effect of metacognitive strategies on conceptual change. In this trimmed model, all direct and indirect effects were statistically significant. Also, the path coefficients (direct effects) were all larger than the recommended value of 0.20 with medium to high effect size. The absolute and the relative GOF indices indicated that the hypothesized model has a predictive ability in predicting change in participants' conceptual understandings from pre to post-interviews. Figure 4.1 illustrates the results of the PLS-PM analysis for the trimmed model.

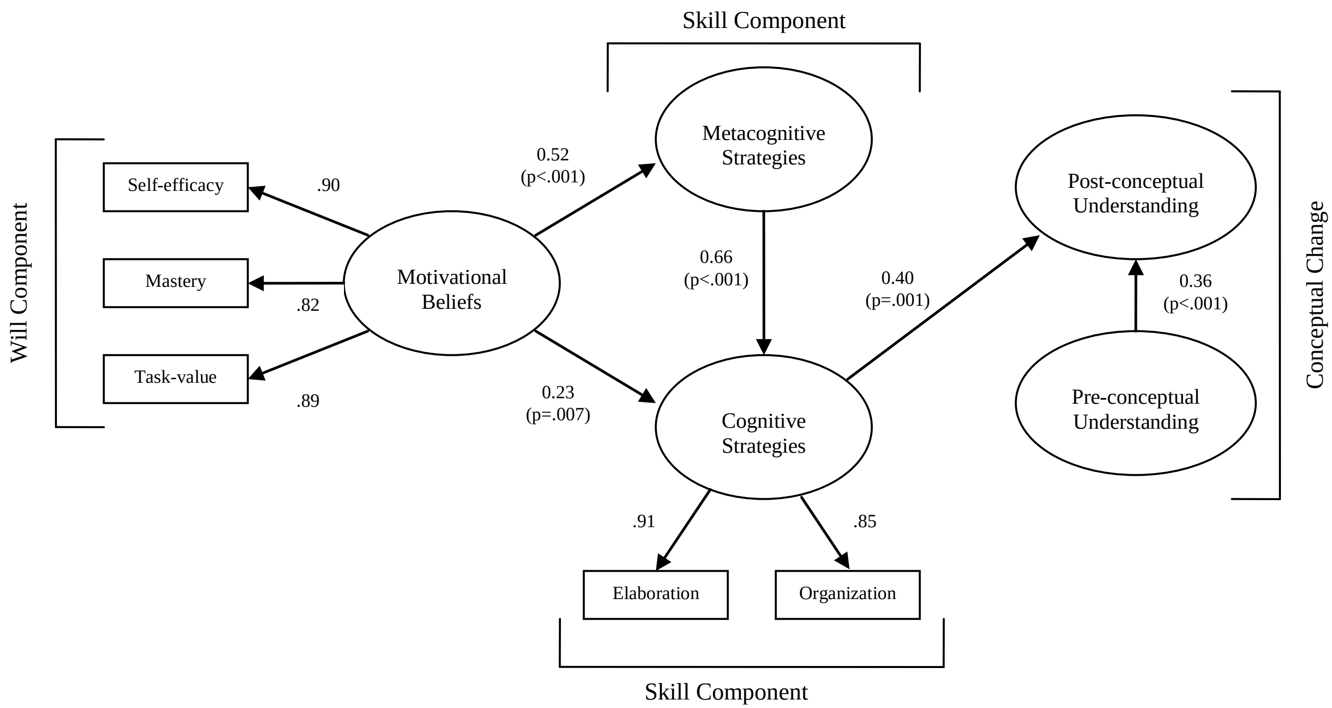

Figure 4.1 The trimmed model of intentional conceptual change

Coherency of Conceptual Understandings (The Second Set of Hypotheses)

A PLS-PM analysis with observed variables was conducted to test the second set of research hypotheses that dealt with the relationship between the coherency of participants' conceptual understandings and their level of metacognitive strategy use.

For the current study, coherency of conceptual understanding was defined as having a single mental model within a conceptual understanding. Based on the number of mental models they included, participants' conceptual understandings were assigned into either coherent conceptual understanding (single mental model) or incoherent conceptual understanding (more than one mental model) category. Group membership was identified through dummy coding. The group that contained participants with incoherent conceptual understanding was chosen as a reference group. The results of each hypothesis test are provided below.

Hypothesis 8: Preservice teachers' use of metacognitive strategies will have a direct influence on the coherency of their post-instruction conceptual understandings. While the direct effect of metacognitive strategies on coherency of the participants' pre-conceptual understanding was not statistically significant ($\beta=0.186$, $t= 1.34$, $p=.186$), the direct effect of metacognitive strategies on the coherency of the post-conceptual understanding was statistically significant ($\beta=0.288$, $t= 2.12$, $p=.039$). These results supported the research hypothesis that metacognitive strategies are positively related to coherency of post-conceptual understandings, thus the null hypothesis of no effect was rejected.

The next hypothesis tested the relationship between the coherency of participants' initial conceptual understanding and the type of conceptual understanding participants constructed after the instruction.

Hypothesis 9: The coherency of preservice teachers' pre-instruction conceptual understandings will have a direct influence on the type of post-instruction conceptual understandings. The direct effect of the coherency of pre-conceptual understandings on the type of post-conceptual understandings was statistically significant ($\beta=0.53$, $t= 4.45$, $p<.001$). Therefore, the null hypothesis of no effect was rejected.

Summary of the Results of the Second Set of Hypotheses (Hypotheses 8 and 9)

A PLS-PM analysis with observed variables was performed to test the hypothesis that examined the relationship between metacognitive strategy use and the coherency of conceptual understandings. While the direct effect of metacognitive strategies on the coherency of pre-conceptual understandings was not statistically significant ($\beta=0.186$, $t= 1.34$, $p=0.186$), the direct effect of metacognitive strategies on the coherency of post-conceptual understandings was statistically significant ($\beta=0.288$, $t= 2.12$, $p=.039$). According to Cohen (1988) this is very close to a moderate effect.

A similar result was obtained for the hypothesis that tested the relationship between the coherency of participants' initial conceptual understanding and the type of conceptual understanding participants constructed after the instruction. The coherency of pre-conceptual understanding was statistically significant predictor of the type of conceptual understandings participants held after instruction ($\beta=0.53$, $t= 4.45$, $p<.001$). According to Cohen (1988) this is a strong effect. Figure 4.2 illustrates the results of the

PLS-PM analysis that was used to test the postulated relationships with hypotheses 8 and 9.

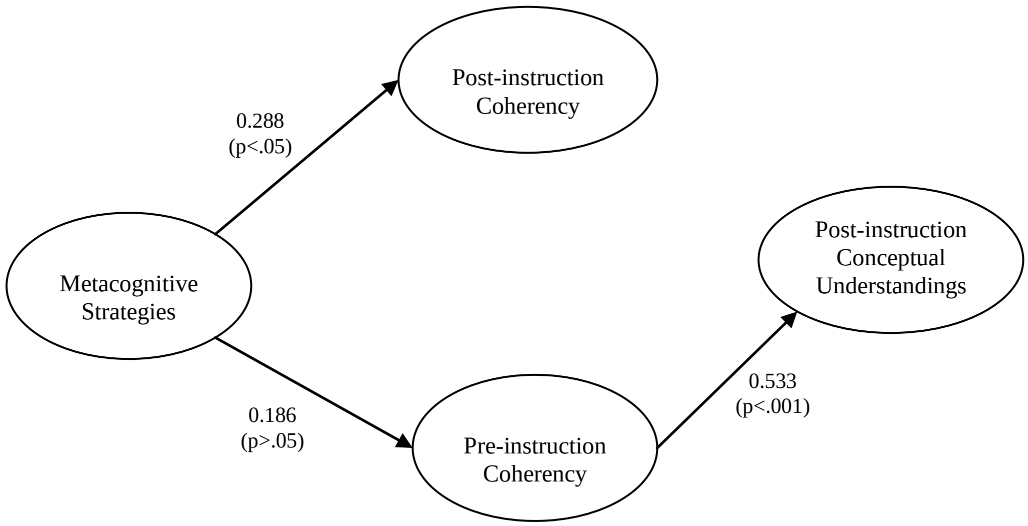

Figure 4.2 Metacognitive strategies and the coherency of conceptual understandings

The Change and the Durability of Conceptual Understandings (The Third Set of Hypotheses)

The third set of research hypotheses tested in this study addressed the role of metaconceptual awareness in the change and the stability of conceptual understandings. As described previously, 16 participants participated in the delayed-post interviews that were conducted 13 to 15 weeks after the post-interviews. In addition to their conceptual understanding of cause of the moon phases, participants' level of metacognitive awareness was also assessed using an interview protocol that was designed for the study. There was a strong positive relationship between the participants' metaconceptual awareness score and their metacognitive strategy use score ($r=.744$, $p=.001$) suggesting participants who frequently use metacognitive strategies were more likely to have high metaconceptual awareness or vice versa. The high correlation between those two variables also provided evidence for the convergent validity of the metaconceptual awareness protocol.

Based on the change and stability in participants' conceptual understanding from pre to post and from post to delayed-post interviews, participants' conceptual understandings were assigned into three groups that describe the profile of their long-term conceptual understandings (Trundle et al., 2007a). These groups were "*decay or stability*", "*continuous growth*", and "*growth and stability*". Participants who maintained their scientific conceptual understanding from pre to post and from post to delayed-post interview and participants who shifted from alternative conceptual understanding on the pre to scientific on the post interview and maintained their scientific understanding from post to the delayed-post interview were assigned into *growth and stability* group. Participants who exhibited continuous progression toward scientific or scientific fragment conceptual understanding from pre to post and from post to delayed-post interview were assigned into *continuous growth* group. Participants who maintained their alternative conceptual understanding or regressed from scientific or scientific fragment conceptual understanding to an alternative conceptual understanding were assigned to *decay or stability* group. Table 4.9 presents the profile of participants' conceptual understanding assessed in pre, post, and delayed-post interviews and their metaconceptual awareness score. Participants' level of metaconceptual awareness and the durability of the conceptual change in which they engaged were examined using a nonparametric tests and PLS-PM analysis with observed variables. The results of the hypothesis test are provided below.

Hypothesis 10: There will be a statistically significant difference in metaconceptual awareness scores of preservice teachers in different conceptual profile groups. A Kruskall-Wallis test, nonparametric equivalence of ANOVA, was performed to examine the differences in metaconceptual awareness scores of those participants in three conceptual profile groups described above. The results of the Kruskall-Wallis test indicated a statistically significant difference between the three groups ($H=8.27$, $p=.016$). A series of post-hoc test conducted using Mann-Whitney U procedure revealed a significant difference between the *decay or stability* group and the *growth and stability* group ($Z=2.62$, $p=.009$), and the *decay or stability* group and the *continuous growth* group ($Z=2.15$, $p=.032$). Participants in *growth and stability* and *continuous growth* groups had significantly higher metaconceptual awareness score than those participants in *decay or stability* group. The difference between the *continuous growth* group and the *growth and stability* group was not statistically significant ($Z=.65$, $p=.51$).

Hypothesis 11: Preservice teachers' level of metaconceptual awareness will have a direct influence on their level of conceptual change. In order to test this hypothesis a PLS-PM analysis was performed. The direct effect of metaconceptual awareness on the post-conceptual understandings scores was statistically significant ($\beta=0.50$, $t= 3.01$, $p=0.003$), indicating metaconceptual awareness is positively related to conceptual change. Therefore, the null hypothesis of no effect was rejected.

Group	Participant #	Pre	Post	Delayed-post	Metaconceptual Awareness Score
Decay or stability	1	Alt. Frg. (1)	Alt. Frg. (1)	Alt. Frg. (1)	3
	2	Alt. Frg. (1)	Scientific (10)	Sci. W. Alt. Frg. (6)	6
	3	Alt. Frg. (1)	Alt. W. Sci. Frg. (3)	Alt. Frg. (1)	2
	4	Sci. Frg. (8)	Sci. Frg. (8)	Sci. Frg. (7)	2
	5	Alternative (2)	Alt. W. Sci. Frg. (3)	Alt. Frg. (1)	4
	6	Alternative (2)	Scientific (10)	Sci. Frg. (9)	6
Growth and stability	7	Alt. W. Sci. Frg. (3)	Scientific (10)	Scientific (10)	6
	8	Alt. W. Sci. Frg. (3)	Scientific (10)	Scientific (10)	9
	9	Alt. W. Sci. Frg. (3)	Scientific (10)	Scientific (10)	8
	10	Scientific (10)	Scientific (10)	Scientific (10)	8
	11	Scientific (10)	Scientific (10)	Scientific (10)	9
	12	Alternative (2)	Scientific (10)	Scientific (10)	6
Continuous growth	13	Alt. Frg. (1)	Alt. W. Sci. Frg. (5)	Scientific (10)	8
	14	Alt. W. Sci. Frg. (3)	Alt. W. Sci. Frg. (5)	Sci. Frg. (8)	5
	15	Alternative (2)	Sci. Frg. (8)	Scientific (10)	10
	16	Alternative (2)	Sci. Frg. (9)	Scientific (10)	10

Table 4.9 Longitudinal profiles of participants conceptual understandings

Hypothesis 12: Preservice teachers' level of metaconceptual awareness will have a direct influence on the durability of conceptual change. A PLS-PM analysis was also performed to test the last hypothesis. The direct effect of metaconceptual awareness on the delayed-post conceptual understanding scores was statistically significant (β=0.38, t=2.46, p=.002), indicating metaconceptual awareness is positively related to the durability of conceptual change. Therefore, the null hypothesis of no effect was also rejected.

Summary of the Results of the Third Set of Hypotheses (Hypotheses 10, 11, and 12)

The differences between metaconceptual awareness scores of participants in three conceptual profile groups were tested using a Kruskall-Wallis test. On the other hand, the relationship between the participants' level of metacognitive awareness and the change in their conceptual understandings from pre to post (conceptual change) and from post to delayed-post (durability) interviews was examined using a PLS-PM analysis.

The results of Kruskall-Wallis test indicated that conceptual profile groups differ significantly in their metaconceptual awareness scores (H=8.27, p=.016). Mann-Whitney U test revealed a statistically significant difference between *decay or stability* group and *growth and stability* group (Z=2.62, p=.009). The effect size was *r*=.77, indicating a large effect. The difference between *decay or stability* group and *continuous growth* group also was statistically significant (Z=2.15, p=.032). The effect size was *r*=.68, suggesting a large effect. The difference between *continuous growth* group and *growth and stability* group was not statistically significant (Z=.65, p=.51).

The results of the PLS-PM analysis showed that the direct effects of metaconceptual awareness on conceptual change (β=0.50, t= 3.01, p=0.003) and the durability of conceptual change were statistically significant (β=0.38, t=2.46, p=.002). These results provided evidence for the alternative research hypotheses that suggest a positive relationship between metaconceptual awareness and the change and the durability of conceptual understandings. Figure 4.3 illustrates the results of the PLS-PM analysis that was used to test these postulated relationships with hypotheses 11 and 12.

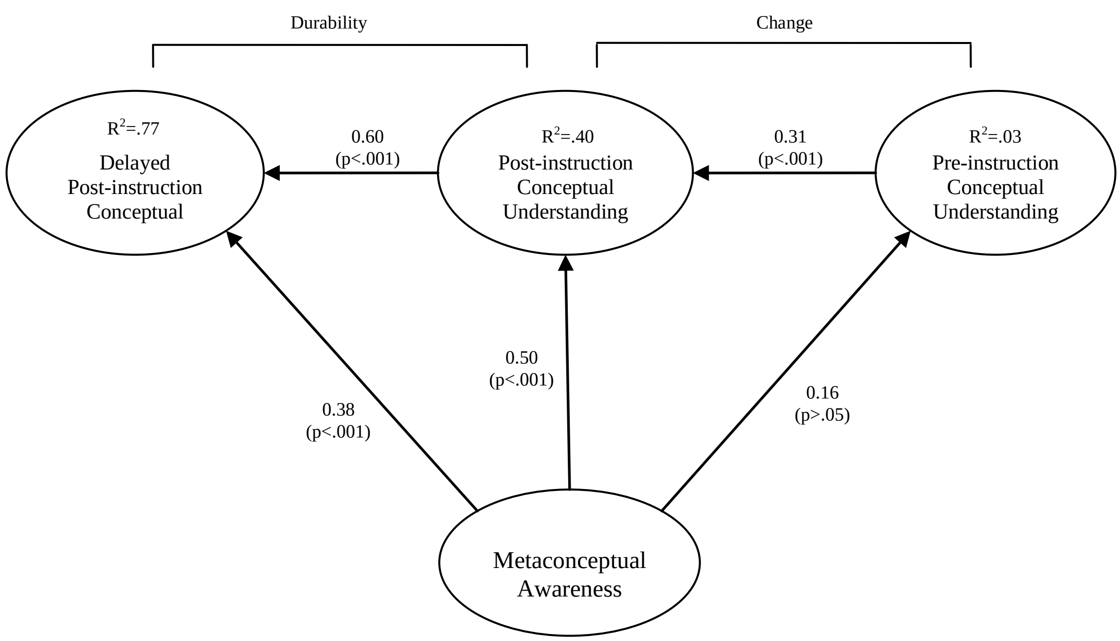

Figure 4.3 Metaconceptual awareness and the change and the durability of conceptual understandings

Chapter 5: DISCUSSION AND CONCLUSION

Introduction

The present study had three main research objectives: (1) to investigate the predictive ability of the hypothesized model in explaining change in pre-service early childhood teachers' conceptual understandings of the cause of moon phases, (2) to examine the relationship between the coherency of participants' conceptual understandings and their level of metacognitive strategy use and the type of conceptual understandings they construct after instruction, and (3) to explore the role of metaconceptual awareness in the change and the durability of conceptual understandings. In line with these aims, three sets of hypotheses, a total of 12 hypotheses, were generated based on the relevant literature and tested in the study.

In this chapter, results of the hypothesis tested are discussed based on the relevant literature and the theoretical framework utilized in the study. Implications of the findings for instructional practices and recommendations for future research also are presented.

Discussion of the Hypothesized Model

In order to test the predictive ability of the hypothesized model of intentional conceptual change, six research hypotheses were generated and tested using Partial Least Square Path Modeling (PLS-PM) analysis. Results supported all six research hypotheses, except the hypothesis that suggested a positive direct effect of metacognitive strategies on conceptual change. After the modification of the hypothesized model by removing the nonsignificant direct effect of metacognitive strategies on conceptual change, all direct and indirect effects became statistically significant. The absolute and the relative Goodness of Fit (GOF) indices indicated that the hypothesized model has a predictive ability in explaining change in participants' conceptual understandings from the pre to post-interviews.

Previous research studies suggest that metacognitive strategy use has a direct influence on conceptual understandings (Kowalski & Taylor, 2004; Pintrich et al. 1993; Vosniadou, 1994a, 2007; Vosniaodu & Ioannides, 1998). However, the path coefficient from metacognitive strategy use to conceptual change was not statistically significant in the present study. Results indicated that metacognitive strategy use indirectly influenced the conceptual change through its influence on deep-level cognitive strategies. Congruent with the previous studies, metacognitive strategies was a strong predictor of the use of deep-level cognitive strategies (Heikkila & Lonka, 2006; Pintrich et al., 2000; Romainville, 1994; Wolters, 1999). Results suggest that use of metacognitive strategies facilitated participants' use of deep-level cognitive strategies, which in turn promoted participants' conceptual understandings of the cause of the moon phases.

Use of deep-level cognitive strategies predicted 17% of the variance in post-conceptual understandings scores. Participants who frequently used elaboration and organization strategies were more likely to engage in conceptual change and construct a scientific understanding of the cause of the lunar phases. This finding is consistent with the other studies where the use of deep-level cognitive strategies reported to promote students' conceptual understandings of science concepts (Kang et al., 2005; Kowalski &

Taylor, 2004; Linnenbrik & Pintrich, 2002; McWhaw & Abrami, 2001).

Results also provided evidence for the hypothesized indirect effect of motivational beliefs on conceptual change. Motivational beliefs, self-efficacy, mastery goal orientation, and task-value had direct influences on participants' use of cognitive and metacognitive strategies. Participants with high motivational beliefs were more likely to use cognitive and metacognitive strategies. Thus, they were more likely to engage conceptual change as reported in other research studies (Kutza, 2000; Olson, 1999; Pintrich, 1999; Zusho & Pintrich, 2003).

Overall, results provided evidence for the predictive ability of the hypothesized model of intentional conceptual change in explaining change in conceptual understandings of the cause of the moon phases.

Discussion of the Coherency of Conceptual Understandings

The relationship between metacognitive strategy use and the coherency of conceptual understandings was tested using a PLS-PM analysis with observed variables. Although the direct effect of metacognitive strategies on the coherency of pre-conceptual understandings was not statistically significant, there was a statistically significant direct effect of metacognitive strategies on the coherency of post-conceptual understandings with a close to moderate effect size. These results suggest that participants with high metacognitive state were more likely to construct coherent mental models. In other words, these participants' conceptual understandings of the cause of lunar phases included a single, coherent, causal explanation. This finding seems to support the hypothesis proposed by previous studies that metacognition might play a vital role in learners' awareness of the contradictions in their causal explanations and it might facilitate the construction of coherent mental models (Luques, 2003; Mason & Boscolo, 2000; Vosniadou, 1994a, 2007).

The relationship between the coherency of participants' initial conceptual understanding and the type of conceptual understanding participants constructed after the instruction was also statistically significant with a strong effect size. The coherency of pre-conceptual understanding was a statistically significant predictor of the type of conceptual understandings participants held after instruction. This finding is consistent with the predictions of the previous studies (Oliva, 1999; 2003; Trundle et al., 2007a) and suggests that participants who held a coherent mental model of the cause of the lunar phases, whether scientific or not, were more likely to construct scientific conceptual understanding after instruction.

Discussion of the Durability of Conceptual Understandings

In order to examine the role of participants' metaconceptual awareness in the change and durability of their conceptual understandings nonparametric tests and PLS-PM analysis were performed. Based on the change and stability in participants' conceptual understanding from pre to post and from post to delayed-post interviews, participants' conceptual understandings were assigned into three groups that describe the profile of their long-term conceptual understandings (Trundle et al., 2007a). These groups were "*decay or stability*", "*continuous growth*", and "*growth and stability*".

Results of the nonparametric tests indicated a statistically significant difference in metaconceptual awareness scores of participants in different conceptual profile groups.

More specifically, the participants who maintained their scientific conceptual understandings (*growth and stability*) or progressed toward scientific conceptual understandings (*continuous growth*) throughout the study obtained significantly higher metaconceptual awareness scores than those participants who regressed in their conceptual understandings or maintained alternative conceptual understandings (*decay or stability*).

Results of the PLS-PM analysis demonstrated that the direct effects of metaconceptual awareness on conceptual change and the durability of conceptual change were both statistically significant. Participants with a high metaconceptual awareness score were more likely to change their alternative conceptual understandings after instruction and they also were more likely to retain their scientific conceptual understandings several months after instruction. The results provided evidence that metaconceptual awareness plays a significant role in the change and the durability of conceptual understandings. These results are consistent with the recent literature on the relationship between metacognition and conceptual change where the researchers provided evidence for the importance of the metaconceptual awareness in the durability of scientific conceptual understandings (Georghiades, 2004a; Trundle et al., 2007a; Tytler & Peterson, 2004). However, the findings of this study suggest that metaconceptual awareness might play a more crucial role in the restructuring of conceptual understandings than the durability of conceptual understandings. Metaconceptual awareness seems to aid learners in constructing a well organized, coherent mental model in the initial change process. These mental models probably are adequately situated within a larger conceptual framework, which makes it easy for learners to retrieve them when needed, hence, making the conceptual understandings more durable.

Implications for Instructional Practices

Findings of the present study indicate that use of deep-level cognitive strategies facilitates the restructuring of the alternative conceptual understandings. It appears that use of elaboration and organization strategies allowed learners to make connections between the elements of scientific conceptual understanding of the cause of lunar phases and process the course content more efficiently. Therefore, learners' use of elaboration and organization strategies should be promoted, explicitly taught, and modeled in science classes to promote scientific conceptual understanding.

In the present study participants who frequently use metacognitive strategies were more likely to use cognitive strategies that facilitate conceptual understanding. Likewise, participants with high metaconceptual awareness were more likely to have coherent conceptual understandings. They were also more likely to restructure their alternative conceptual understandings and retain their scientific conceptual understandings several months after instruction than participants with low metaconceptual awareness. These results suggest that learners' metacognitive strategy use and metaconceptual awareness should be promoted to help them engage in conceptual change. Previous studies indicate that metacognitive thinking can be taught and promoted with the teaching of science concepts (Beeth, 1998a, b; Hewson, Beeth, & Thorley, 1998). Likewise, the use of metacognitive strategies, such as planning, monitoring, and regulating, can be modeled and promoted in instructional strategies to increase the probability of students engaging in conceptual change.

Motivational beliefs were significant predictors of participants' level of cognitive and metacognitive strategy uses. Participants who believed that they could learn the course content, focused on understanding and mastering the course content, and highly valued the course were more likely to use cognitive tools to facilitate their learning of the cause of lunar phases. These results suggest that motivational beliefs influence the amount of cognitive effort learners put in understanding the cause of lunar phases. Therefore, instructional strategies designed to facilitate conceptual change should also incorporate strategies to promote learners' motivational beliefs.

Recommendations for Future Research

The sample of the study was homogenous, relatively small, and nonrandom. Participants of the current study were volunteers and the majority of the participants were white female who were approximately 23 years of age. Although the ratio of observations to independent variables was adequate for the statistical analysis employed in the study, it was not sufficient to perform covariance based structural equation modeling (Hair et al., 2006). Since the sample was not randomly selected from the population, the results of this study cannot be generalized to a broader population. Replication studies with larger sample sizes are needed to evaluate the generalizability of the results of the current study to the population of preservice teachers. The independent variables of the study were not manipulated. Since only the association between the independent variables and the dependent variable was observed, strong causal inferences cannot be made. Future studies with experimental designs, where the independent variables are manipulated through cognitive and metacognitive strategy use training, should be conducted.

The instrument used in the current study was not specifically developed to assess strategies and motivational beliefs learners employ in restructuring their existing conceptual understanding. According to Bandura (2005), an instrument to assess self-efficacy beliefs should be task specific. That is, it should be designed to assess learners' beliefs about their capacity to perform a given task at a designated level. Self-efficacy sub-scale of MSLQ was not designed to measure learners' beliefs about their capacity to restructure their conceptual understanding. Although the role of cognitive, metacognitive, and motivational factors in restructuring conceptual understanding has been a focus of conceptual change literature since the seminal work of Pintrich and colleagues (1993), researchers continue to use existing instruments in studying the role of these factors, and conceptual change specific instruments have yet to be developed. Therefore, future studies should focus on developing instruments that specifically assess the cognitive strategies, metacognitive strategies, and motivational beliefs that promote conceptual change learning.

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Appendix A: Interview Protocol A

Interview Protocol A

Cause of the Moon Phases and Sequence

Statements made to students are in bold.

Sequence:

- Introduction
- Consent
- Interview

Introduction:

Thank the student for participating.

The purpose of my research project is to help me improve the effectiveness of teaching about moon phases. As far as this interview goes, there are no right or wrong answers because I just want to understand what you think about moon phases. Your answers will not be considered in determining your grade in your science class.

During this interview, I will ask you questions to which you will respond. Your answers will be videotaped. Some of the questions will require you to use a model to explain your answers. Do you have any questions?

Interview Questions:

1. **You probably have noticed that the moon does not always look the same. For example, sometimes we can see what we call a "full moon" and at other times the moon is not full. What do you think causes the phases of the moon?**
2. Probe to get the student to explain what he/she thinks causes the phases of the moon. (e.g. **Explain to me how something could block the moon to cause the phases. What could be blocking the moon? Explain how that happens**.)
3. Provide students with components to build a model based on their explanation of the cause of moon phases. **These model components represent the sun, earth, and moon. For practical reasons, they are not to scale in size or relative distances from each other. I want you to use this model to explain to me, and show me while you are explaining what you think causes the phases of the moon.** If the student says that clouds cause the phases of the moon, a piece of cotton will be provided for the cloud component.
4. (Drawing provided to show what the full moon phase looks like. Orange areas represent what we see of the moon at that moon phase.) **Take the model and arrange it so that we would see a full moon. Why would the moon appear like this drawing?**
5. (Drawing provided to show what the new moon phase looks like.) **Now arrange them so that we would have a new moon. Why would the moon appear like this drawing?**
6. (Drawing provided to show what the crescent moon phase looks like. Show the drawing.) **Could we see a moon that looks like this? If so, arrange the model so**

that we would be able to see a moon that looks like this drawing. Why would the moon appear like this drawing? If not, why not?

7. (Drawing provided to show what the gibbous phase looks like.) **Could we see a moon that looks like this? If so, arrange the model so that we would be able to see a moon that looks like this drawing. Why would the moon appear like this drawing? If not, why not?**
8. (Drawing provided to show what the "false gibbous" phase looks like.) **Could we see a moon that looks like this? If so, arrange the model so that we would be able to see a moon that looks like this drawing. Why would the moon appear like this drawing? If not, why not?**
9. **Use the model to show me what happens as the moon goes through one complete cycle of phases.**
10. (Place the model components so that the phase of the moon is approximately at the first quarter phase). **Look how the model is arranged now. Could the sun, earth and moon be arranged like this? If not, why not? If yes, suppose that this straight pin is located where you are. With a very clear sky, what would you see when you looked at the moon if the sun, earth, and moon were in this arrangement? Draw what you would see on this sheet. Why would the moon appear like your drawing?**
11. **I want you to put these 8 drawing in the order you predict to see them.**

Appendix B: Interview Protocol B

Interview Protocol B

(Metacognitive Awareness)

1. Do you remember what your ideas/responses were about the cause of the moon phases in the first interview? What did you think was the cause of the moon phases?

2. What happened when you first realized that your understanding was different from what the instructor taught in the class?

3. How did you realize that what you think was not scientifically acceptable response for the cause of the moon phases?

4. How did your ideas change over the course of the instruction?

5. What did you do to change your understanding of the cause of the moon phases? How did you study? What did you pay attention to during instruction? Was there a moment when you realized and suddenly understood the cause of the moon phases? Can you describe it?

6. What steps did you follow to change your understanding?

Appendix C: Coding Sheet for Interview Protocol A

Participant #____________ Type of Conceptual Understanding__________

Researcher: **S** **T** Interview Pre Post Delayed-post

1 and 2. **What do you think causes the phases of the moon**? Probe to get the student to **explain.**

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

3. **Use these models to explain to me, and show me while you are explaining what you think causes the phases of the moon**.

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

4. (Drawing provided to **show a representation of the full moon phase**. Orange areas represent what we see of the moon from.) Take these models and **arrange them so that we would see a full moon**. **Why** would the moon appear like this drawing?

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

5. (Drawing provided to **show a representation of the new moon phase.**) Now **arrange them so that we would have a new moon**. **Why** would the moon appear like this drawing?

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

6. (Drawing provided to **show a representation of the crescent moon**. Show the drawing) **Could we see a moon that looks like this?** If so, arrange the models so that we would be able to see a moon that looks like this drawing. Why would the moon appear like this drawing? If not, why not? **YES** **NO**

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

7. (Drawing provided to **show a representation of the gibbous phase.**) **Could we see a moon that looks like this?** If so, arrange the models so that we would be able to see a moon that looks like this drawing. Why would the moon appear like this drawing? If not, why not? **YES** **NO**

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

8. (Drawing provided to **show a representation of the "false gibbous" phase.**) **Could we see a moon that looks like this?** If so, arrange the models so that we would be able to see a moon that looks like this drawing. Why would the moon appear like this drawing? If not, why not? **YES** **NO**

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

9. **Use the models to show me what happens as the moon goes through one complete cycle of phases.**

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

10. (**Place the models** so that the phase of the moon is approximately at the **first quarter phase**). Look how the models are arranged now. **Could the sun, earth and moon be arranged like this?** If not, why not? If yes, suppose that this straight pin is located to indicate where you are. With a very clear sky, **what would you see** when you looked at the moon if the sun, earth, and moon were in this arrangement? **Draw what you would see on this sheet**. **Why** would the moon appear like your drawing?

YES **NO**

SciOrb	SciHaf	SciSee	SciEMS	AltEcl	AltRot	AltHel	AltGeo	AltClo	AltPla	AltDis	AltT	Alt Oth

11. **I want you to put these 8 drawing in the order you predict to see them**

Scientific Sequence **Alternative Sequence**

Appendix D: Scoring Rubric for Interview Protocol A

Scoring Rubric for Interview Protocol A (Conceptual Understanding)		
Scientific:	Participant's conceptual understanding exhibits all element of scientific understanding without exhibiting alternative conception.	
	10 Points	Includes all elements of scientific understanding.
Scientific fragment:	Participant's conceptual understanding does not exhibit an alternative mental model, but fails to include all elements of scientific understanding.	
	9 Points	Missing one element of scientific understanding.
	8 Points	Missing two elements of scientific understanding.
	7 Points	Missing three elements of scientific understanding.
Scientific with alternative Fragment:	Participant exhibit all <u>four</u> elements of scientific understanding along with an alternative mental model.	
	6 Points	Includes all elements of scientific understanding with an alternative mental model.
Alternative with Scientific fragments:	Participant's conceptual understanding exhibits an alternative mental model, but also includes some elements of scientific understanding.	
	5 Points	Includes an alternative mental model, but also contains three elements of scientific understanding.
	4 Points	Includes an alternative mental model, but also contains two elements of scientific understanding.
	3 Points	Includes an alternative mental model, but also contains one element of scientific understanding.
Alternative:	Participant' conceptual understanding exhibits no elements of scientific understanding and includes a single mental model.	
	2 Points	Includes a single alternative mental model without any elements of scientific understanding.
Alternative fragments:	Participant' conceptual understanding exhibits two or more alternative mental models. Conceptual understanding may or may not exhibit some elements of scientific understanding.	
	1 Points	Includes two or more alternative mental models.
No conceptual Understanding:	Participant exhibits no conceptual understanding.	
	0 Points	Participant exhibits no conceptual understanding.

Appendix E: Coding and Scoring Sheet for Interview Protocol B

Coding and Scoring Sheet for Interview Protocol B

1. Do you remember what your ideas/responses were about the cause of the moon phases in the first interview? What did you think was the cause of the moon phases?

MA of Contradiction									MA of Change in Und.						MA of Str. and Exp.												MA Other	
MAC Init.			MAC UnSci.			Oth.			MAU Chn.			Oth.			MAS Act			MAS Exp			MAS Step			Oth				
0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2		

2. What happened when you first realized that your understanding was different from what the instructor taught in the class?

MA of Contradiction									MA of Change in Und.						MA of Str. and Exp.												MA Other	
MAC Init.			MAC UnSci.			Oth.			MAU Chn.			Oth.			MAS Act			MAS Exp			MAS Step			Oth				
0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2		

3. How did you realize that what you think was not scientifically acceptable response for the cause of the moon phases?

MA of Contradiction									MA of Change in Und.						MA of Str. and Exp.												MA Other	
MAC Init.			MAC UnS.			Oth.			MAU Chn.			Oth.			MAS Act			MAS Exp			MAS Step			Oth				
0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2		

4. How did your ideas change over the course of the instruction?

MA of Contradiction									MA of Change in Und.						MA of Str. and Exp.												MA Other	
MAC Init.			MAC UnS.			Oth.			MAU Chn.			Oth.			MAS Act			MAS Exp			MAS Step			Oth				
0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2		

5. What did you do to change your understanding of the cause of the moon phases? How did you study? What did you pay attention to during instruction? Was there a moment when you realized and suddenly understood the cause of the moon phases? Can you describe it?

MA of Contradiction									MA of Change in Und.						MA of Str. and Exp.												MA Other	
MAC Init.			MAC UnS.			Oth.			MAU Chn.			Oth.			MAS Act			MAS Exp			MAS Step			Oth				
0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2		

6. What steps did you follow to change your understanding?

MA of Contradiction									MA of Change in Und.						MA of Str. and Exp.												MA Other	
MAC Init.			MAC UnS.			Oth.			MAU Chn.			Oth.			MAS Act			MAS Exp			MAS Step			Oth				
0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2		

Indicators	Thoroughly (2 points)	Somewhat (1 point)	Fails (0 point)
Metacognitive Awareness of Contradiction			
Participant states her/his initial ideas about the cause of the moon phases.			
Participant explains how she/he realized that her initial ideas were not scientific.			
Metacognitive Awareness of Change in Understanding			
Participant explains how her/his initial ideas changed over the course of the instruction.			
Metacognitive Awareness of Strategies and Experience			
Participant explains the specific action she/he took to change her/his initial ideas and gives specific examples about her/his experience in learning lunar concepts.			
Participant explains the specific steps she/he took to change her/his initial ideas.			

Participant's Code:_________________

Participant's Score:_____________

Assigned category:

Participant's score > 5 points:_________High metacognitive awareness

Participant's score = 5 points:_________Moderate metacognitive awareness

Participant's score < 5 points:_________Low metacognitive awareness

Appendix F: Residual Change Scores and Raw Change Scores of Participants

Residual Change Scores and Raw Change Scores of Participants

Participant #	Residual Change Scores	Raw Gain Scores	Participant #	Residual Change Scores	Raw Gain Scores
1	2.64	8	27	0.25	5
2	3.03	9	28	-0.48	0
3	2.64	8	29	0.64	6
4	2.64	8	30	-0.35	5
5	-3.96	2	31	2.25	7
6	2.64	8	32	0.64	6
7	-5.96	0	33	1.64	7
8	2.64	8	34	0.64	6
9	-5.35	0	35	2.64	8
10	-0.30	2	36	1.47	5
11	-2.74	2	37	2.25	7
12	-1.70	0	38	-1.35	4
13	2.64	8	39	-0.48	0
14	-0.48	0	40	2.25	7
15	1.64	7	41	1.64	7
16	-3.96	2	42	-1.96	4
17	-5.96	0	43	-0.48	0
18	0.64	6	44	-3.35	2
19	3.03	9	45	2.25	7
20	2.64	8	46	-0.48	0
21	-4.35	1	47	2.64	8
22	-2.96	3	48	1.64	7
23	-0.48	0	49	-4.35	1
24	2.64	8	50	-3.96	2
25	-3.35	2	51	1.25	6
26	2.64	8	52	2.64	8

Regression equation for the calculation of residual change scores

Predicted Post-Conceptual Scores = 6.576 + (0.391) Pre-Conceptual Scores

Residual Change Scores = Post-Conceptual Scores- Predicted Post Conceptual Scores