Journal of Science Teacher Education
The official journal of the Association for Science Teacher Education

ISSN: 1046-560X (Print) 1573-1847 (Online) Journal homepage: https://www.tandfonline.com/loi/uste20

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To cite this article: Mesut Saçkes & Kathy Cabe Trundle (2014) Preservice Early Childhood Teachers' Learning of Science in a Methods Course: Examining the Predictive Ability of an Intentional Learning Model, Journal of Science Teacher Education, 25:4, 413-444, DOI: 10.1007/s10972-013-9355-y

To link to this article: https://doi.org/10.1007/s10972-013-9355-y

J Sci Teacher Educ (2014) 25:413–444
DOI 10.1007/s10972-013-9355-y

ELEMENTARY SCIENCE TEACHER EDUCATION

Preservice Early Childhood Teachers' Learning of Science in a Methods Course: Examining the Predictive Ability of an Intentional Learning Model

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Published online: 9 July 2013

Abstract This study investigated the predictive ability of an intentional learning model in the change of preservice early childhood teachers' conceptual understanding of lunar phases. Fifty-two preservice early childhood teachers who were enrolled in an early childhood science methods course participated in the study. Results indicated that the use of metacognitive strategies facilitated preservice early childhood teachers' use of deep-level cognitive strategies, which in turn promoted conceptual change. Also, preservice early childhood teachers 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 of intentional learning has a high predictive ability in explaining the change in preservice early childhood teachers' conceptual understandings from the pre to post-interviews. Implications for designing a science methods course for preservice early childhood teachers are provided.

Keywords Preservice early childhood teachers · Early childhood science methods course · Early childhood teacher education · Intentional learning · Conceptual change

Introduction

Early childhood teachers play a crucial role in providing early science learning experiences for young children. However, most early childhood teachers have

This manuscript is based on the first author's doctoral dissertation.

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limited opportunities during their preservice training to develop their science content knowledge and understanding of effective instructional practices for teaching young children science (Akerson 2004; Trundle and Saçkes 2012). Previous studies have identified several factors that prevent early childhood teachers from providing rich and effective science learning experiences. The lack of science content knowledge appears to be one of the major barriers to effective science teaching in the early years, and this lack of content knowledge influences early childhood teachers' decisions to teach less science (Appleton 1992, 1995; Kallery and Psillos 2001; Schoon and Boone 1998; Tobin et al. 1990). Most early childhood teachers do not feel comfortable teaching science and dealing with children's science related questions due to their own limited content knowledge (Garbett 2003; Kallery and Psillos 2001; Pell and Jarvis 2003; Tilgner 1990).

Preservice and inservice early childhood teachers often have limited conceptual understandings of the science content they are expected to teach, including lunar concepts. Previous studies demonstrated that early childhood teachers have various alternative conceptions about lunar concepts including when the moon is observable, the moon's patterns of movement, observable shape changes in the moon, and the cause of the lunar phases (e.g., Bell and Trundle 2008; Saçkes et al. 2011b; Trundle and Bell 2010). Developing a conceptual understanding of lunar concepts is targeted in the *National Science Education Standards* (NRC 1996) (e.g., patterns of observable moon shape changes for grades K-4). Preschoolers and Kindergartners are not expected to understand sophisticated concepts like the cause of the lunar phases (Hobson et al. 2010). However, early childhood teachers who hold alternative conceptions about these concepts may have difficulty introducing basic lunar concepts because they may not be able to recognize misconceptions their children have about lunar concepts, and they may introduce misconceptions or reinforce children's existing misconceptions. Therefore, early childhood teachers should have a sound understanding of the targeted concepts which extends well beyond what they are expected to teach in order to help children develop scientific understanding of natural phenomena (Burgoon et al. 2010; Saçkes et al. 2011b; Trundle et al. 2006; Trundle and Saçkes 2012). In addition to fostering their knowledge of effective instructional strategies for teaching science to young children, science methods courses for preservice early childhood teachers should also promote early childhood teachers' conceptual understanding of the science concepts typically targeted in early childhood classrooms (Saçkes et al. 2011a).

Several studies investigated the effectiveness of various instructional strategies in helping early childhood teachers construct scientific understandings of natural phenomena (Parker and Heywood 1998, 2000; Saçkes et al. 2011b; Trundle et al. 2002, 2007). The results of these studies demonstrated that conceptual change oriented instructional strategies are effective in helping preservice teachers develop a conceptual understanding of several science concepts. However, no previous studies have examined how affective, cognitive, and metacognitive variables influence the preservice teachers' learning of science concepts in early childhood science methods courses (Sinatra and Mason 2008). The methods course in this study involved conceptual change oriented instructional strategies. Thus, this study aimed to examine the predictive ability of a learning model that includes cognitive (use of cognitive strategies), metacognitive (use of metacognitive strategies) and motivational variables (self-efficacy, goal-orientation, and task-value) in explaining the change in preservice early childhood teachers' conceptual understanding of astronomy concepts in a science methods course.

Intentional Learning and Conceptual Change

Many researchers seem to agree that a learning theory must include "skill and will" components to adequately describe and explain how students learn in school (Ausubel 2000; VanderStoep and Pintrich 2003; Vosniadou 1999; Zimmerman 1995; Zusho et al. 2003). While the skill component (i.e., cognitive and metacognitive strategies) provides the necessary tools to process information and construct or restructure conceptual understanding, the will component (i.e., self-efficacy and goal orientation) incites learners to initiate and sustain the use of those mental tools to learn.

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 that promote conceptual change. The intentional learning theory provides a useful theoretical basis for the construction of such a comprehensive learning model (Bereiter and Scardamalia 1989; Margaret 1997). The intentional conceptual change theory, which synthesizes intentional learning and the conceptual change model of learning, suggests that the learners' levels of metacognition and motivation and their use of various cognitive strategies might play an important role in the restructuring of existing conceptual understandings of scientific concepts (Luques 2003; Pintrich 1999; Sinatra and Pintrich 2003; Vosniadou 2003).

The intentional conceptual change perspective is a relatively recent model of learning that aims to explain how students restructure their conceptual understanding. 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 and Scardamalia 1989, p. 363), to explain the self-regulated dimension of conceptual change.

The foundation of the intentional conceptual change perspective was established by Pintrich et al. (1993a) in a seminal article where the authors 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. A body of research literature that investigated the relationship between motivation and cognitive and metacognitive strategy use with student learning informed advocates of the intentional conceptual change perspective, and they postulated that conceptual change depends not only on cognitive factors but also on metacognitive, motivational, and affective processes (Sinatra and Pintrich 2003). Arguing that conceptual change requires learners to be aware of their existing conceptual understanding and have an intention to learn and understand new concepts, 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 and Pintrich 2003, p. 6). More specifically, the intentional conceptual change perspective suggests that to engage in successful conceptual change, learners must be aware of the need for change, be able to know what to change, have an intention to change, and be able to control the 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 for conceptual change. In other words, an intentional conceptual change perspective does not focus on how knowledge is represented, constructed, and restructured within learners' mind. Rather, it focuses on individual factors such as motivation and learning strategies that mediate or facilitate the process 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 perspective seems to be more compatible with the intentional conceptual change perspective (Vosniadou 1994). The framework theory provides a powerful explanation for knowledge representation and change mechanism. This theory also acknowledges that intentional learning may facilitate conceptual change because learners monitor their own learning processes and their metaconceptual awareness of beliefs, presuppositions, and understanding of science concepts to be learned (Vosniadou 1999, 2003, 2007).

The conceptual change theory proposed by Vosniadou (1994) and utilized in several studies that investigated the learners' conceptual understanding of astronomical phenomena, the framework theory, appears to be very useful in describing and explaining learners' conceptual change (Trundle et al. 2002, 2007). 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.

Cognitive, Metacognitive, and Motivational Variables

Metacognition and Conceptual Change

A growing body of literature suggests that metacognition plays an important role in students' learning. Metacognition aids learners in selecting and using cognitive strategies required to complete various learning tasks (Romainville 1994), and it facilitates students' use of deep cognitive strategies such as elaboration and organization (Heikkila and Lonka 2006; Wolters 1999). Metacognition promotes problem solving by helping learners to activate, monitor, and regulate necessary cognitive resources (Antonietti et al. 2000; Bielaczyc et al. 1995; Flavell 1979). It supports critical thinking processes by allowing learners to reflect on the knowledge presented, check possible inconsistencies, and monitor their own awareness (Kuhn 1999; Pither and Soden 2000). Metacognition also plays a crucial role in conceptual change by helping learners to recognize the inconsistencies between their alternative ideas and scientific concepts (Kowalski and Taylor 2004; Pintrich et al. 1993a; Thorley 1990; Vosniadou 1994; Vosniadou and Ioannides 1998).

Cognitive Strategies and Conceptual Change

Cognitive strategies can be defined as any cognitive processes that learners employ to carry out an academic task or acquire, retain, and retrieve various types of concepts and knowledge (Pressley et al. 1995). They can also be defined as the procedures students use to select, organize, and integrate novel information and knowledge with their present understanding (Weinstein and Mayer 1986). According to Marton and Saljo (1976a, b), cognitive strategies can be divided into two categories: surface strategies and deep strategies.

Surface strategies include rehearsal, such as reading an entire text or passage repeatedly and memorizing all the new concepts and words through rehearsing (Lyke et al. 2006; Nolen 1988). Deep strategies include elaboration and organization, such as distinguishing information that is key to the conceptual understanding from unimportant one and deciding how new concepts and knowledge fit with the present knowledge structure and understanding (VanderStoep and Pintrich 2003). Deep strategies are more useful in integrating new knowledge with what one already knows. Thus, these strategies seem to be more crucial for conceptual change than surface strategies.

Effective use of cognitive strategies has been reported as a critical variable in successful academic learning. Learners' ability to adaptively select and use cognitive strategies plays an important role in the outcome of learning tasks. Several studies reported that there is a considerable difference between successful and less successful learners regarding their cognitive strategy use (Nolen 1988; Thomas and Rohwer 1986). Successful learners tend to select and employ learning strategies appropriate for the demands of different learning tasks, whereas less successful learners either do not have effective learning strategies in their disposals or fail to select and use them when needed (Nolen 1988). Conceptual change requires learners to monitor and compare their current conceptions with the ones they experience in class. It also requires learners to make connections between what they know and what has been presented to them or what they experience (Sinatra and 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 in several studies to increase the probability of conceptual change (Kang et al. 2005; Kowalski and Taylor 2004; McWhaw and Abrami 2001). For example, Alao and Guthrie (1999) reported that the use of monitoring and elaboration strategies explained 4 % of the variance in fifth grade students' conceptual understandings 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 the students' understanding of physics (Linnenbrink and 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 a science class (Blumenfeld and Meece 1988). Collectively, these studies have shown that the use of cognitive strategies significantly contributes to students' course performance and conceptual understandings.

Self-efficacy and Conceptual Change

The effect of self-efficacy on 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 and Pintrich 2003; Pintrich et al. 1993a). Another way to perceive the relationship between self-efficacy and conceptual change is by 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 the increased persistence and effort, whereas low levels of efficacy are related to decreased persistence and effort (Bandura 1989; Linnenbrink and Pintrich 2003; Pintrich 1999; Pintrich et al. 1993a). 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 beliefs might be an important factor that influences conceptual change. A limited number of studies investigated the relationship between learners' self-efficacy beliefs and their engagement in conceptual change, and the results of those studies were inconclusive. Although the results of some studies supported the expectation that self-efficacy beliefs might promote conceptual change (Olson 1999; Pintrich 1999), other studies did not find the hypothesized positive relationship between the self-efficacy beliefs and conceptual change (Barlia 1999; Kang et al. 2005; Yin 2005). Moreover, in a recent study with high school students, self-efficacy beliefs were found to be an obstacle in changing alternative ideas if students had low metacognitive skills (Anderson and Nashon 2007). These few studies suggest that the role of self-efficacy in conceptual change might not be a simple dichotomy as previously anticipated, and more research is needed to clarify the role of self-efficacy beliefs in conceptual change (Linnenbrink and Pintrich 2003; Pintrich 1999; Pintrich et al. 1993a).

Goal Orientation and Conceptual Change

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 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 of various cognitive strategies for information processing (Ames 1992). Goal orientation and learning strategies have been correlated in several studies. In these 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 et al. 2001). Mastery goals also are related to high self-efficacy. In contrast, performance goals are associated with self-handicapping strategies such as procrastination (Meece et al. 2006). Learners' goal orientations have been associated with their achievement, mediating through their use of cognitive and metacognitive strategy use, and the amount of time they invest in studying (Linnenbrink and Pintrich 2003; Vermetten et al. 2001). Research studies suggest that the adoption of a mastery goal orientation may influence the level of students' cognitive processing and thus facilitate conceptual change (Linnenbrink and Pintrich 2002, 2003; Pintrich 1999; Pintrich et al. 1993a). Nevertheless, studies that investigated the students' goal orientations and their levels of conceptual change have yet to provide strong evidence that the adoption of a mastery goal orientation is a significant predictor of conceptual change. Although, some studies reported a significant relationship between mastery goal orientation and conceptual change (Barlia 1999; Kutza 2000), mastery goal orientation was not a significant predictor of conceptual change in several studies (Alao and Guthrie 1999; Zusho et al. 2003). Some studies reported no relationship between the adoption of a master goal orientation and conceptual change (Kang et al. 2005).

Task-Value and Conceptual Change

Task value is another motivational construct related to academic performance. Although task value does not have a direct effect on academic performance, it is related to students' choices to become cognitively engaged in and inclination to persist at the learning task (Pintrich 1999). Students' task values have been related to their use of cognitive and metacognitive strategies, their willingness to persist at a task, and indirectly, to academic performance (Pintrich et al. 1993a; Pokay and Blumenfeld 1990). Therefore, task value can be perceived as a factor that supports learning by increasing attention, persistence, and use of cognitive strategies. Indeed, some studies have provided evidence that high task value may enhance learning and promote conceptual change (Barlia and Beeth 1999; Olson 1999; Zusho et al. 2003). Conceptual change requires students to maintain their cognitive engagement so that they can efficiently use the cognitive processing necessary to interpret and understand alternative views. Task-value beliefs may facilitate conceptual change by promoting students' cognitive engagement, whereas a lack of value beliefs may constrain conceptual change (Pintrich 1999).

Purpose

The purpose of this study was to examine the predictive ability of the hypothesized model of conceptual change learning model in explaining the change in preservice early childhood teachers' conceptual understanding in a science methods course. It should be noted that examining the instructional effectiveness was not the purpose of this study. More specifically, the aim of this study was to identify the factors that help preservice early childhood teachers benefit most from an empirically tested conceptual change orientated instructional intervention.

Theoretical Model Tested in the Study

Based on the relevant literature, the following six hypotheses were generated and tested in the present study.

Hypothesis 1: *Motivational beliefs have a direct influence on the use of metacognitive strategies*. Motivational beliefs, such as self-efficacy, mastery goal orientation, and task value, promote learners' uses of various metacognitive strategies. Previous studies reported that students with high motivational beliefs are more likely to control and regulate their cognitive processing through the use of metacognitive strategies (Linnenbrink and Pintrich 2002, 2003; Pokay and Blumenfeld 1990; Zusho et al. 2003). Therefore, the hypothesized model includes a direct influence of motivational beliefs on metacognitive strategies.

Hypothesis 2: *Motivational beliefs have a direct influence on the use of deep-level cognitive strategies*. Motivational beliefs influence the amount of cognitive effort learners commit to completing a learning task. The results of previous studies indicated that students with high motivational beliefs tend to use deep-level cognitive strategies such as elaboration and organization, which promote conceptual understandings of scientific concepts (Ames 1992; Pintrich et al. 1993a; Vermetten et al. 2001). Therefore, the hypothesized model includes a direct influence of motivational beliefs on deep-level cognitive strategies.

Hypothesis 3: *The use of metacognitive strategies has a direct influence on the use of deep-level cognitive strategies*. The results of a growing body of literature suggest 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 in order to solve problems (Antonietti et al. 2000; Bielaczyc et al. 1995; Flavell 1979). Metacognition also facilitates students' use of deep-level cognitive strategies such as elaboration and organization (Heikkila and Lonka 2006; Wolters 1999). Therefore, the hypothesized model includes a direct influence of metacognitive strategies on deep-level cognitive strategies.

Hypothesis 4: *The use of metacognitive strategies has a direct influence on conceptual change*. The results of 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; Yuruk2007). 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 or new content. Consequently, the hypothesized model includes a direct influence of metacognitive strategies on conceptual change.

Hypothesis 5: *The use of deep-level cognitive strategies has a direct influence on 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; Linnenbrink and Pintrich 2002; McWhaw and Abrami 2001). The results of 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 promoting conceptual understandings of scientific concepts. Therefore, the hypothesized model includes a direct influence of deep-level cognitive strategies on conceptual change.

Hypothesis 6: *Motivational beliefs have an indirect effect on conceptual change through the influence on metacognitive strategies and deep-level cognitive strategies*. The results of previous research studies suggest that motivational beliefs do not directly influence learners' academic performance, but motivational beliefs are associated with students' learning, influencing their use of cognitive and metacognitive strategies and the amount of time they invest in studying (Linnenbrink and Pintrich 2003; Vermetten et al. 2001). Previous research suggests 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 and Pintrich 2002, 2003; Pintrich 1999; Pintrich et al. 1993a). Therefore, the hypothesized model includes an indirect effect of motivational beliefs on conceptual change through cognitive and metacognitive strategies. Figure 1 illustrates the hypothesized model tested in the study.

Methodology

Design of the Study

This study utilized an observational, non-experimental, research design (Cook and Campbell 1979). A theoretical model that depicts the hypothesized relationships among the dependent and the independent variables of the study were generated and tested using a partial least square path analysis technique. Aligned with the study design, none of the independent variables were manipulated during the instructional intervention. Only the relationships between preservice early childhood teachers' self-reported strategy use and motivational beliefs and the change in their conceptual understandings were examined.

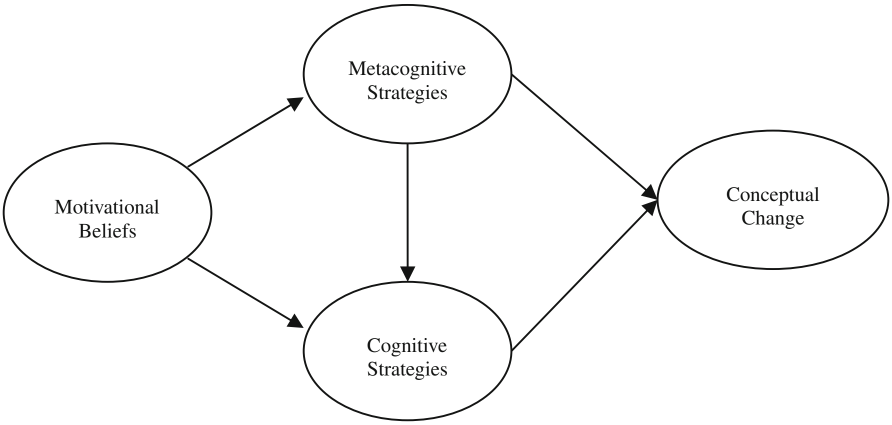

Fig. 1 Hypothesized model of intentional conceptual change

Participants and Setting

A convenience sampling technique was utilized in selecting the participants of the study (Johnson and Christensen 2004). Fifty-two preservice early childhood teachers participated in the study. Participants were enrolled in an early childhood science methods course, which was part of the early childhood education program. Most participants were female (98 %), and only one male (2 %) participated 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 participants completed before joining the study ranged from 9 to 35 quarter hours, with a mean of 15 h. Nineteen participants previously completed one astronomy course and four participants completed two astronomy courses before enrolling in the methods course.

Instruction

The instruction on lunar concepts integrated the *Starry Night Backyard* software with instruction on moon phases from *Physics by Inquiry* by McDermott (1996). This inquiry-based instructional intervention was identical to that of previous investigations by Trundle et al. (2002, 2006, 2007) 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 one computer for the entire class (Bell and Trundle 2008; Trundle and Bell 2010). Interpretive, sense-making discussions were essential components of the instruction. The instructional intervention motivated preservice teachers to be intentional in their learning and become more metacognitively aware about the content of their existing conceptual understandings of lunar concepts. The instruction also encouraged learners to evaluate inconsistencies between their own understandings of lunar phases and a scientific explanation (Trundle and Bell 2010). The second author was the instructor of the science methods course and the first author was a doctoral student researcher and participant observer in the class.

Participants received instruction while enrolled in a science methods course designed for preservice early childhood teachers. A total of 6 h of class time was devoted to instruction on lunar concepts, and the instruction consisted of three parts: (a) gathering, recording, and sharing moon data, (b) analyzing moon data by looking for patterns in the data, and (c) modeling the cause of moon phases (Bell and Trundle 2008). Participants recorded daily moon observations from the *Starry Night Backyard* software during class time. First, the preservice teachers were taught how to use the *Starry Night Backyard* software program, which involved teaching the participants the basic controls of the software including setting the time, date, and viewing location and orienting the observation to the cardinal directions (i.e., north, south, east, west). This portion of the instruction utilized a single computer and projector, and the Starry Night image was projected onto a large projection screen. The instructor modeled and explained how to use the software and then guided the 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 the moon and sun, the direction the moon was observed in the sky, 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. After the inital class demonstration of the software, the participants collected 9 weeks of data during portions of two class sessions. As previously noted, all moon data were collected from images projected onto a screen using a projector and one computer for the entire class. For more information on the use and features of the *Starry Night Backyard* software, please see a full description by Trundle and Bell (2003).

Following data gathering, volunteers shared their data by replicating their sketches on posters hung on the chalkboard and recording the dates, times, angular separation, and directions for the observation during class sessions. Then the participants looked for and discussed any anomalies in the shared data.

After the 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: (a) identifying observable shapes and patterns of moon phases, (b) determining the length of the lunar cycle, (c) sequencing the moon phases, (d) applying new concepts and scientific labels, and (e) modeling the cause of moon phases through a psychomotor modeling activity (an exposed light bulb was placed at eye level in a darkened room to represent the sun. Participants used Styrofoam balls as a model for the moon to reproduce all the phases in the order they were observed, and they wrote and orally explained their understandings of the causes of moon phases). The analysis of moon data and modeling of moon phases took place during two additional class sessions, for a total of four sessions of instruction on this topic and six total hours of instruction as previously noted.

Data Collection

Pre- and Post-interviews: Conceptual Understanding of the Cause of Lunar Phases

To reveal the participants' understandings of moon phases, semi-structured interviews were conducted before and after instruction using a set of interview questions. This protocol was developed and used by Trundle et al. (2002, 2007) in various conceptual change studies with participants who had similar characteristics (i.e., preservice and inservice early childhood and elementary teachers who typically have limited science content knowledge) to the participants in the current study.

The interview protocol included two tasks (verbal explanation and model manipulation) that aimed to reveal the participants' understandings of the cause of the moon phases. In the pre and post-interviews participants were initially asked to verbally explain what they thought caused the moon phases. Then, the three-dimensional models of the moon, earth, and the sun were provided to the participants to support their verbal explanations about the cause of the moon phases. During the interview, the researcher first repeated what preservice early childhood teachers exactly said instead of paraphrasing their ideas to ensure that what the researcher recorded accurately reflected the participants' 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 conceptual understanding of the participants rather than accepting participants' initial responses (Trundle et al. 2002, 2007).

All participants were individually interviewed in a quiet interview room. Pre-interviews lasted about 30 min and post-interviews lasted about 20 min each. Interviews were video-taped and notes were taken immediately after each interview.

A Self-Report Instrument: Cognitive, Metacognitive, and Motivational Variables

The *Motivated Strategies for Learning Questionnaire* (MSLQ), which was 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 et al. 1993b). The MSLQ is a self-report instrument consisting of six motivation subscales (31 items), and nine learning strategies scales (50 items), for a total of 81-items. The following motivational beliefs subscales of MSLQ were used in this study: intrinsic (mastery) goal orientation, task value, and self-efficacy. To assess the participants' use of cognitive strategies, the elaboration and organization subscales were used. To assess the participants' metacognition, the metacognitive self-regulation subscale was used. Sample items from each subscale are provided on "Appendix 1".

Subscales of the MSLQ produced scores with reliability coefficients ranging from 0.52 to 0.93 with a sound factor structure (Duncan and McKeachie 2005; Pintrich et al. 1993b). The reliabilities of measures in this study, ranging from 0.58 to 0.90, were very similar to the reliability coefficients reported in the literature. The

MSLQ was administered during the science method course with the permission of the instructor. Participants took approximately 15 min to complete the instrument.

Data Analysis

Qualitative Analysis (Analysis of Pre- and Post-interviews)

The framework of codes developed in previous lunar concepts studies and constant comparative analysis were used to code and analyze the participants' pre and post conceptual understandings of the cause of the lunar phases in the study (Glaser and Strauss 1967; Trundle et al. 2002, 2007). The framework served as a partial framework of codes that helped researchers to identify and describe a scientific mental model and possible alternative mental models participants might have. A partial framework of codes was an open coding system that permitted any additional codes that emerged during the analysis to be included in the framework. For example, during the analysis of the interview data a new code (AltSeason) emerged and was included in the framework to code a novel alternative mental model identified in this study to explain the cause of moon phases, the season model (See "Appendix 2" for the examples of codes). A coding sheet, which was designed based on the partial framework, was used to organize and standardize the analysis of data collected through semi-structured interviews.

To demonstrate the dependability of the coding of the qualitative data, inter-rater reliability was calculated using Cohen (1968) weighted kappa statistics. Thirty-three percent of the pre and 23 % of the post interviews were independently analyzed by two researchers. Cohen's weighted kappa was 0.83 for the pre interview codings and 0.93 for the post interview codings, indicating high inter-rater reliability between the two coders.

Quantitative Analysis (Quantification of the Qualitative Data)

To make statistical analysis possible, participants' pre-, and post conceptual understandings were scored with a rubric, which was designed for this study (See "Appendix 3"). Chi (1997) suggested that mental models can be quantifiable for statistical analysis based on their level of sophistication and coherency. In this study participants were given scores ranging from 0 to 10 based on the number of scientific elements and alternative mental models included in their conceptual understanding. These scores were used in the statistical analysis performed in the study.

Partial Least Squares Path Modeling

Partial least squares path modeling (PLS-PM) was used to investigate whether the hypothesized model of intentional conceptual change has a predictive power on the change in participants' conceptual understandings. 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 and 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) (Joreskog and Sorbom 1993) and “Analysis of Moment Structures” (AMOS) (Arbuckle 1994), PLS-PM employs the partial least square method of estimation to analyze the variance matrix, and it utilizes principal component analysis rather than common factor analysis in estimating latent variable scores (Falk and Miller 1992; Lohmoller 1989).

According to Joreskog and Wold (1982), the maximum likelihood and the 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 and the small sample size, the PLS-PM technique was employed as the main statistical analysis tool for the study. A PLS-PM analysis was performed using the SmartPLS software (Ringle et al. 2005).

Results

Conceptual Profiles of Participants

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 (See “Appendix 3” for the description). Only 6 participants (12 %) demonstrated a scientific conceptual understanding of the cause of moon phases in the pre-interview assessment. The number of participants who demonstrated a scientific understanding increased to twenty-five (48 %) after instruction.

Participants’ conceptual understanding of the cause of the moon phases was identified as scientific fragments if it included some but not all four of the scientific elements and included no alternative ideas. Only two participants (4 %) held scientific fragments as their type of understanding in the pre-interviews. In the post-interviews thirteen participants’ (25 %) conceptual understandings were categorized as scientific fragments.

Participants’ conceptual understandings were categorized as scientific with an alternative fragment if they included all four elements of scientific understanding along with an alternative fragment. None of the participant’s conceptual understanding was categorized as scientific with an alternative fragment in pre-interviews and only one participant (2 %) held this type of conceptual understanding in the post-interview.

A conceptual understanding that included some but not all four elements of scientific understanding along with an alternative mental model was categorized as alternative with scientific fragments. Eight participants' (15 %) conceptual understandings in the pre- and 10 participants' (19 %) conceptual understandings in the post-interviews were categorized as alternative with scientific fragments.

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 understandings in the pre-interviews and only one participant held (2 %) an alternative conceptual understanding in the post-interview. The eclipse model was the most common alternative mental model participants held in the pre-interview (27 %). The earth's rotation model (13 %), the heliocentric model (10 %), and the geocentric model (2 %) were among the other alternative mental models that participants held.

Participants' conceptual understandings that included fragments of more than one alternative mental model were categorized as alternative fragments. Nine participants' (17 %) conceptual understandings were categorized as alternative fragments in the pre-interviews. Only two participants held alternative fragments as their type of conceptual understanding (4 %) in the post-interviews. Table 1 summarizes the results of the qualitative analysis of the pre- and post-interviews.

Qualitative Evidence of the Change in Conceptual Understandings: Excerpts from the Interviews

The following excerpts provide an example of the change in one participant's conceptual understandings of the cause of the moon phases from pre- to post-interviews. This first excerpt is from the interview that occurred before instruction:

> **Researcher**: Okay. This is a new moon. Can you arrange your model to a new moon position? (A drawing representing a new moon phase provided)

Table 1 Profiles of participants' conceptual understanding

Type of conceptual understanding	Participants expressing this conceptual understanding	
	Pre-interview (n = 52)	Post-interview (n = 52)
Scientific	6 (12 %)	25 (48 %)
Scientific fragments	2 (4 %)	13 (25 %)
Scientific with alternative fragment	0 (0 %)	1 (2 %)
Alternative with scientific fragments	8 (15 %)	10 (19 %)
Alternative	27 (52 %)	1 (2 %)
Alternative fragments	9 (17 %)	2 (4 %)

Participant: It would go on this side [*Participant moved the moon component to a full moon position*]. **So it would be like aligned on the opposite side hidden behind the earth (AltEcl)** [*Pointing the moon component*].
Researcher: Why would the moon appear like this drawing?
Participant: Because **the sun cannot get to. the light cannot get the moon**… **(AltEcl)**.
Researcher: Because?
Participant: Because **the earth is blocking the light (AltEcl)** [*Pointing the earth component*].

This participant's pre-conceptual understanding included a single alternative mental model, an eclipse model, and she consistently used this alternative model to explain the cause moon phases throughout the interview. The participant believed that the earth blocks sunlight from reaching the moon, thus, producing different phases of the moon. According to her explanation, the portion of the moon that is observable from the earth is the part that is not covered by the earth's shadow. Therefore, participant's pre-interview response was categorized as an alternative model.

The following excerpt, which comes from the same participant's responses during the post-instruction assessment, demonstrates the change in her conceptual understandings.

Researcher: What do you think causes the phases of the moon?
Participant: **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 is facing the sun. And then, **as it moves around us (SciOrb) whatever angle umm earth is at with the moon and the sun (SciEMS)., that determines the portion that we see (SciSee)**
Researcher: 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?
Participant: 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 so that her body, her fist and the camera make a 90 degree angle*]. 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, her sun model*] but since we are here [*Pointing to her head that faces to the her left fist*], earth, **we only see like that part (SciSee)** [*Pointing to the side of her left fist that towards to the left side of her head*].
Researcher: I want you to use these models to explain to me, and show me while you are explaining what you think causes the phases of the moon.
Participant: Okay, so it takes the moon about 29.5 days I think we learned, **29.5 days to move around (SciOrb)** [*Moving the moon component around the earth in counterclockwise direction*]. So that's the complete phases. And right here this going to be your new moon [*Positioning the moon component between the sun and the earth component in a new moon position*]. So **this side of the moon is lit by the sun but we don't see it (SciSee)** [*Pointing the side of the*

moon component that faces the sun], we can't see it up in the sky. And then as the **moon moves around this way (SciOrb)** [*Moving the moon component in counterclockwise direction around the earth component away from the sun*], **this is still the only half that is lit by the sun (SciHaf)** [*Pointing the side of the moon component that faces to the sun*], so **we can start to see more of the lighted part (SciSee)** [*Pointing to the part of the moon that faces the earth component*].

As the excerpt illustrates, the participant's verbal explanation and use of the model components throughout the post-instruction interview process consistently included all the elements of a scientific mental model. Because her responses consistently included all the elements of scientific mental model and included no sign of an alternative mental model or alternative fragments, her conceptual understanding was categorized as scientific. The above excerpts from the pre- and post- instruction interviews of the same participant demonstrate the change in the participant's conceptual understanding of the cause of the moon phases.

Quantitative Evidence of the Change in Conceptual Understandings: Pre- and Post-conceptual Scores

As previously mentioned, participants' conceptual understandings were quantified using a rubric designed for this study. These scores were used in the statistical analysis. There was a substantial increase in participants' conceptual understanding scores from pre-interview ($M = 3.15$, $SD = 2.8$) to post-interview ($M = 7.81$, $SD = 2.92$). The results of the paired sample *t* test analysis indicated that participants' post-conceptual understanding score was significantly higher than their pre-conceptual understanding scores [$t_{(51)} = 10.49$, $p < 0.001$]. The effect size was quite large, $d = 1.45$, suggesting that the instructional intervention had a high impact on the participants' conceptual understanding of the cause of the moon phases.

Descriptive Statistics for MSLQ Subscales

Participants' scores from the subscales of the MSLQ were calculated to determine variations in the preservice teachers' self-reported level of metacognition, motivation, and use of cognitive strategies. Participants tended to report relatively higher use of deep level strategies (elaboration and organization) and metacognitive strategies. Participants reported relatively high levels of self-efficacy and task value, and they tended to adopt a mastery goal orientation. Table 2 presents the mean scores and standard deviations for each subscale of the MSLQ (the total scores were divided by the number of items to put the scores on the same scale and to aid readers in interpreting the data. For each subscale scores ranged from 1 to 7).

Partial Least Square Path Analysis: Testing of Hypothesized Model

Partial least square path analysis (PLS-PM) was used in the current study to examine the predictive power of the hypothesized model. The goodness of fit (GOF) index is considered as a global index for evaluating model quality in the PLS-PM

Table 2 Descriptive statistics of the subscales of MSLQ

Subscales of MSLQ	N	Mean	SD
Metacognition	52	4.28	0.92
Elaboration	52	4.60	1.07
Organization	52	3.71	1.31
Self-efficacy	52	5.99	0.68
Intrinsic (mastery) goal	52	5.36	0.81
Task value	52	5.73	0.90

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 within this range 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 was 0.61 and the relative GOF index was 0.94, indicating that the hypothesized model was able to take into account 94 % of its achievable maximum. Both the absolute and relative GOF indices suggest that the model has a high predictive ability. Moreover, the composite reliability of motivational beliefs and the deep-level cognitive strategies were 0.90 and 0.87 indicating high internal consistency. The loadings of the indicators of the latent variables ranged from 0.82 to 0.91 and none of the observed variables loaded higher with other latent variables than the one they were intended to measure, providing strong evidence for the convergent and discriminant validity of the model. Also, the Average Variance Extracted (AVE) value was 0.76 for the motivational beliefs and 0.78 for the deep-level cognitive strategies, which provided further evidence for the convergent validity of the measurement model (Chin and Newsted 1999). Figure 2 illustrates the model tested in the study.

Assessment of Path Coefficients

The SmartPLS software computes path coefficients for the hypothesized relationships among the variables in the model. Because PLS-PM analysis makes no distributional assumption, 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 1,000 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 ($\alpha = 0.05$). The statistical significance of indirect effects is assessed using a Sobel test (Hoyle and Kenny 1999; Preacher and Hayes 2008). Chin and Newsted (1999) suggest 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 considerations.

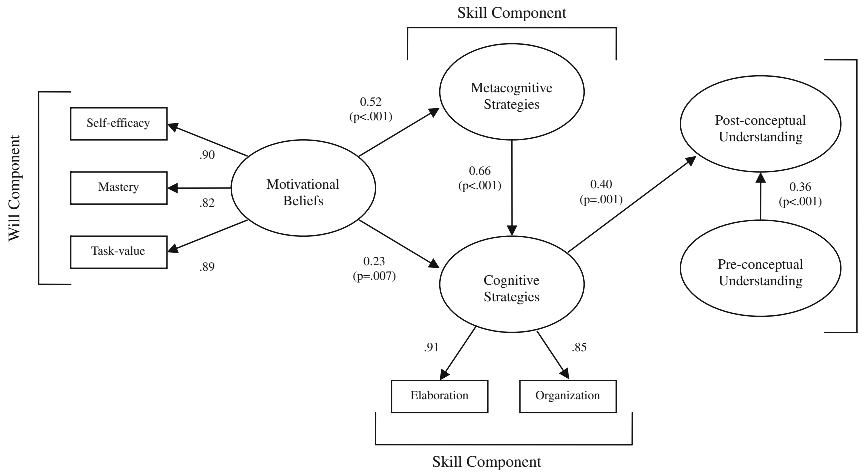

Fig. 2 Results for the model tested in the study

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: *Motivational beliefs have a direct influence on the 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: *Motivational beliefs have a direct influence on the 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: *The use of metacognitive strategies has a direct influence on the 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: *The use of metacognitive strategies has a direct influence on 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: *The use of deep-level cognitive strategies has a direct influence on 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. Therefore, based on empirical and theoretical reasons, while the path between the metacognitive strategies and conceptual change was removed, 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: *Motivational beliefs have an indirect effect on conceptual change through the influence on metacognitive strategies and deep-level cognitive strategies*. The indirect effect of motivational beliefs 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 was rejected. Table 3 presents the direct, indirect, and total effect statistics for the variables in the model.

Amount of Variance Explained and Effect Size Estimates

The amount of variance accounted for in metacognitive strategies by motivational beliefs was 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.

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. The effect size estimate for the

Table 3 Direct, indirect, and total effects

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

deep-level cognitive strategies variable in predicting post conceptual understanding was $f^2 = 0.23$. The effect size estimate for the motivational beliefs 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.

Discussion

Previous research studies suggest that metacognitive strategy use has a direct influence on conceptual understandings (Kowalski and Taylor 2004; Pintrich et al. 1993a, b; Vosniadou 1994; Vosniadou and Ioannides 1998). However, when cognitive strategy use was controlled, 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 and Lonka 2006; Pintrich 1999; Romainville 1994; Wolters 1999). Results suggest that use of metacognitive strategies facilitated preservice teachers' use of deep-level cognitive strategies, which in turn promoted their scientific conceptual understandings of the cause of the moon phases. Metacognitive strategies alone seem to not be sufficient to ensure the construction of scientific conceptual understanding. Learners should have effective cognitive strategies at their disposable to process scientific concepts and the use of these cognitive strategies appears to be guided by metacognitive strategies.

Use of deep-level cognitive strategies predicted 17 % of the variance in post-conceptual understandings scores. Preservice early childhood teachers 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 and Taylor 2004; Linnenbrink and Pintrich 2002; McWhaw and 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 preservice teachers' 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 as reported in other research studies (Kutza 2000; Olson 1999; Pintrich 1999; Zusho et al. 2003). Overall, results provided evidence for the predictive ability of the hypothesized model of intentional conceptual change in explaining the change in conceptual understandings of the cause of the moon phases.

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

In the present study preservice teachers who frequently use metacognitive strategies were more likely to use cognitive strategies that facilitate the development of scientific conceptual understanding. These results suggest that preservice teachers' metacognitive strategy use 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 1998; Hewson et al. 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 preservice teachers engaging in conceptual change.

Motivational beliefs were significant predictors of preservice early childhood teachers' level of cognitive and metacognitive strategy uses. Preservice teachers 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 preservice teachers put in understanding the cause of lunar phases. Therefore, instructional strategies designed to facilitate conceptual change should also incorporate strategies to promote preservice teachers' motivational beliefs in early childhood science methods courses.

More specifically, instructors can model the use of deep-level cognitive strategies and make cognitive strategy use a part of the instructional design. For example, instructors can relate concepts to what preservice teachers already know and introduce ways to organize and understand concepts such as concept mapping and model building and manipulation before or during instruction to help preservice teachers recognize the ways to process course content with ease (Schraw et al. 2006). Previous studies suggest that many students can benefit from the explicit introduction of cognitive strategies in classrooms (Butler 2002; Hofer and Yu 2003). Metacognitive strategies also can be explicitly taught or embedded within the instructional design. Examples include asking questions that invite preservice teachers to reflect on their conceptual understandings before the instruction, providing opportunities for them to test their ideas with the use of physical or computer generated models, and discussing the similarities and differences between their ideas in small groups can promote their regulation and monitoring of cognitive processing (Beeth 1998; Greene and Azevedo 2009; Schraw et al. 2006; Vosniadou et al. 2001). Modeling and discussion of the types of cognitive strategies that are relevant and have potential to facilitate learning can also promote preservice teachers' regulation of their cognitive strategy use (Hofer and Yu 2003). Preservice teachers' motivational beliefs can also be promoted with various instructional strategies. Helping preservice teachers recognize how their learning of new science concepts builds on what they already know. We can organize small groups that pair more knowledgeable preservice teachers with those who have emerging skills and knowledge, and we can provide immediate feedback on their learning of specific science concepts, which can make preservice teachers feel more efficacious about learning science (Greene et al. 2004; Pajares and Miller 1994; Tuckman 2003; Tuckman and Sexton 1992). When we value understanding over performance and organize instruction in a challenging but manageable fashion, we enhance preservice teachers' mastery beliefs (Covington 2000; Eccle and Wigfield 2002; Horvath et al. 2006). Raising preservice teachers' interest in learning science concepts and helping them see the utility of the science concepts can promote their task-value beliefs (Chambers and Andre 1995; Horvath et al. 2006). Motivational beliefs, in turn, facilitate preservice teachers' cognitive and metacognitive engagement with the learning of science concepts (Schraw et al. 2006; Wolters 1999; Wolters and Rosenthal 2000).

The present study focused on the instruction induced change in conceptual understanding rather than the kind of conceptual change that spontaneously occurs throughout the course of cognitive development (Inagaki and Hatano 2008; Vosniadou et al. 2008). This study focused on the change that happens at the specific theory level, which includes interrelated propositions about natural phenomena and supports the generation of mental models, rather than the change at the framework theory level, which includes entrenched presuppositions about natural phenomena acquired early in life and difficult to change (Although this might have happened for some participants). Vosniadou (1994) refers to the type of change that happens at the specific theory level as weak revision. The findings of the current study suggest that motivational beliefs encouraged preservice early childhood teachers to initiate and sustain the use of cognitive and metacognitive strategies. Cognitive engagement in turn facilitated preservice teachers' monitoring of their learning process, promoted their awareness of the content of the specific theories they held about the lunar concepts, and helped them to revise and restructure their mental models of the cause of the lunar phases (Vosniadou 1999, 2003, 2007).

The current study utilized a semi-structured interview method, developed by authors (2002, 2007) and used in various conceptual change studies to assess participants' conceptual understanding. Moreover, participants of the current study received instruction that was highly effective in promoting conceptual change (Trundle et al. 2002, 2007). Therefore, the present study, unlike previous studies, was in a better position to assess participants' conceptual change and examine how motivational, cognitive, and metacognitive factors helped participants benefit from the instruction that was designed to promote conceptual change.

There are, however, several limitations of this study. 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. 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.

Appendix 1

Example items from The Motivated Strategies for Learning Questionnaire

	Sample items from the subscales of the MSLQ[a]
Cognitive strategies	
Elaboration strategies	
	When I study for this course, I write brief summaries of the main ideas from the readings and my class notes
	I try to understand the material in this class by making connections between the readings and the concepts from the lectures
Organization strategies	
	When I study the readings for this course, I outline the material to help me organize my thoughts
	When I study for this course, I go over my class notes and make an outline of important concepts
Metacognitive strategies	
Metacognitive control strategies	
	When studying for this course I try to determine which concepts I don't understand well
	I ask myself questions to make sure I understand the material I have been studying in this class
Motivational beliefs	
Self-efficacy	
	I'm confident I can learn the basic concepts taught in this course
	I'm confident I can understand the most complex material presented by the instructor in this course
Mastery goal orientation	
	In a class like this, I prefer course material that really challenges me so I can learn new things
	The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible
Task-value	
	It is important for me to learn the course material in this class
	I am very interested in the content area of this course

[a] Pintrich et al. (1991). *A manual for the use of the motivated strategies for learning questionnaire (MSLQ)*. (ERIC Document Reproduction Service No. ED 338 122)

Appendix 2

Conceptual understanding categories and codings

Categories	Codes
Scientific	All four criteria for scientific included:
	Half the moon is illuminated by sun [SciHalf]
	Moon orbits earth [SciOrb]
	Varying portions of the illuminated half are seen from earth as moon phases [SciSee]
	Relative positions of sun, earth, and moon determine how much of the illuminated half is seen from earth [SciEMS]
	See Qualitative Evidence of the Change in Conceptual Understandings section for the example
Scientific fragment	Included a subset, but not all, of the four scientific criteria [SciFrag]
Scientific with alternative fragment	Met all four scientific criteria but also included one of the alternative fragments below [Sci_AltFrag]
Alternative with scientific fragments	Alternative, nonscientific explanation with some scientific criteria included [Alt_SciFrag]
Alternative	Alternative, nonscientific explanation
	Earth's shadow causes moon phases [AltEclipse]
	Earth's rotation on axis causes moon phases [AltRot]
	Moon independently orbits sun but not earth. When the sun gets between earth and moon, the moon is in a new moon phase [AltHeliocentric]
	Sun and moon orbit earth [AltGeocentric]
	Clouds cover the moon and cause moon phases [AltClouds]
	Seasonal changes cause moon phases [AltSeason]
	See Qualitative Evidence of the Change in Conceptual Understandings section for the example
Alternative fragments	Included a subset or subsets of alternative understandings [AltFrag]

Appendix 3

Scoring rubric for semi-structured interviews

	Scoring rubric for interview protocol
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

Appendix 3 continued

	Scoring rubric for interview protocol
Scientific with alternative fragment	Participant exhibit all four 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

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