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Enhancing pre-service elementary school teachers' understanding of essential science concepts through a reflective conceptual change model

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Abstract

This study explored the impact of a reflective teaching method on pre-service elementary teachers' conceptual understanding of the lunar phases, reasons for seasons, and simple electric circuits. Data were collected from 40 pre-service elementary teachers about their conceptual understanding of the lunar phases, reasons for seasons and day and night, and simple electric circuits pre and post instruction. Findings show that the instructional approach adopted by a science teacher educator had a significant impact on pre-service elementary school teachers' conceptual understanding of lunar phases, seasonal changes and simple electric circuits. The discussion focuses on pre-service elementary school teachers' misconceptions about the lunar phases, seasonal changes and simple electric circuits as revealed through their answers to the pre-test questions. Further discussion focuses on the implications of the findings for pre-service elementary school science teacher education.

Keywords: *Conceptual Change, Content Knowledge, Pre-service Elementary Teachers.*

Introduction

More than two decades of research on elementary school teachers' knowledge of science reveals that a significant number of them lack sufficient content knowledge and pedagogical wisdom to teach essential scientific ideas in their classrooms (Abell & Smith, 1994; Appleton & Kindt, 1999; Bencze & Hodson, 1999; Kennedy, 1998; Loucks-Horsley et al., 1998; Smith & Neale, 1989). Many of the teachers studied held conceptions about essential scientific ideas that are not congruent with scientifically acceptable ones (Atwood & Atwood, 1997; Aron, Francek, Nelson, & Bisard,

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1994; Galili, Bendall, & Golderg, 1993; Gilbert, Osborne, & Fensham, 1982; Glasson & Teates, 1989; Lane & French, 1994; Trundle, Atwood, & Christopher, 2002). This line of research reveals that students develop misconceptions for several reasons. These reasons are not limited to but include prior exposure to the scientific phenomena in natural settings, exposure to poor teaching of these concepts and lack of access to conceptual resources and experiences (DiSessa, 2002; Mayer, 2002; Vosniadou, 2002; Wandersee, Mintzes, & Novak, 1994). No matter what the source of these misconceptions may be science educators agree that both pre-service and in-service elementary school teachers hold misconceptions about some important concepts that are central to their practice (Asoko, 2002; Heywood, 2007; Schoon & Boone, 1998; Trundle et al., 2007; Webb, 1992). Addressing pre-service elementary teachers' misconceptions about essential science concepts is important for several reasons. First, the teaching of science in the elementary schools often takes place through reading or teacher explanations. Thus, the teacher is often viewed as the sole authority and the dispenser of knowledge that students must rely on for their learning (NRC, 2000). Second, subject matter knowledge is pre-requisite for sophisticated pedagogical content knowledge needed to teach science concepts effectively (Appleton, 2006). Finally, knowledge of subject matter is necessary for the teacher to effectively deal with questions that students may ask during instruction. If the goal of classroom instruction is to improve the quality of students' learning in science in elementary schools, science teacher educators need to pay close attention to pre-service elementary school teachers' conceptual understanding of science concepts that are central to the elementary school science curriculum. Although there is vast amount of research in science education on pre-service elementary teachers' content knowledge, much of research in this domain is descriptive (Trundle, Atwood, & Christopher, 2007). Trundle et al. (2007) call for studies that use interventions to bring about growth in pre-service elementary teachers' content knowledge.

The purpose of this study is to understand the impact of a reflective conceptual change model informed by the principles of situated learning on pre-service elementary school teachers' conceptual understanding of three science concepts: electricity, seasonal changes and lunar phases.

Review of Relevant Literature

A review of recent literature on elementary school teachers' subject matter knowledge and pedagogical preparation reveals that elementary school teachers are not well prepared to teach science. A comprehensive study conducted by Horizon Research, Inc. (2002) revealed only four percent of the 655 elementary school teachers have an undergraduate degree in science, and of the 86%, who graduated with an education degree, 40% have taken four or fewer semesters of science coursework (Fulp, 2002). The same study reports that only fewer than 3 in 10 elementary teachers felt well prepared to teach science.

Elementary school teachers' limited knowledge of science reflects how science is taught in the U.S. schools (Abell & Smith, 1994; Stevens & Wenner, 1996). The Trends in International Mathematics and Science Study (TIMSS) highlights that the percentage of science lessons that were judged to contain challenging science content in the U.S. schools remained at 19 % compared to the 25 % in The Czech Republic. The same study reveals that only 30 % of science lessons taught in the U.S. schools emphasized the learning of content with strong conceptual links compared to 70 % in Japan, 58 % in Australia and 50 % in The Czech Republic. More importantly, researchers found that 66% of science lessons in the U.S. classrooms focused on students' acquisition of facts, memorization of definitions and solving mathematical algorithms compared to 28% for Japan (Roth & Garnier, 2007). These findings highlight how the U.S. science education is behind some developing countries like The Czech Republic and the critical need for well-prepared elementary school teachers in science content and pedagogy.

Improving elementary school teachers' content and pedagogical knowledge has been a great concern for science educators since the launch of Sputnik by The Soviet Union (Heywood, 2007). As part of the solutions, science educators have taken different approaches in their efforts to enhance pre-service elementary school teachers' confidence in content and pedagogy (Alonzo, 2002; Heywood, 2007; Martin, 2006; Trundle, Atwood, & Christopher, 2007). One approach has been requiring pre-service elementary teachers to take a greater number of content courses (Schoon & Boone, 1998). The analysis of the correlation between an increased number of courses and confidence to teach science has revealed mixed results. Schoon and Boone (1998) suggest that content courses helped pre-service elementary teachers to build confidence only if students take courses that are specifically designed for elementary education majors. These courses were effective perhaps because more time was spent on how to teach the scientific concepts than just learning them (Alonzo, 2002; Appleton, 2006; Schoon, 1995; Schoon & Boone, 1998). Moreover, these courses have been proven effective because the instructors adopted pedagogical approaches that focus on fostering students' ownership over their learning rather than those that simply focus on the transmission of expert knowledge to the students (Alonzo, 2002; Appleton, 2006; Abell & Smith, 1994; Trundle, Atwood, & Christopher, 2007). In addition to student-centered pedagogies, science teacher educators must use assessment strategies that will enable students to explain scientific concepts to others, opportunities that will enable them to defend their theories, and learn science with others in a constructive manner (Abell & Smith, 1994; Butts, Kobolla, & Elliott, 1997; Settlage & Southerland, 2007).

This study is an attempt to make contributions to the ongoing discussion about addressing the learning needs of pre-service elementary teachers in science content and pedagogy.

Theoretical Framework: Conceptual Change

The theory of conceptual change guides the design of this study. Conceptual change is a widely respected theory of learning among science educators and cognitive psychologists alike (Driver, Asoko, Leach, Mortimer & Scott, 1994; Posner, Strike, Hewson, & Gertzog, 1982). The work of developmental psychologists such as Piaget (1978) provides the bases for the conceptual change theory (Bransford, Brown, & Cocking, 1999). The fundamental assumption of the conceptual change theory (Posner, Strike, Hewson, & Gertzog, 1982) is that learners' minds are not blank slates, they bring a fund of knowledge about how they think the physical and natural world works to the classroom (Bransford, Brown, & Cocking, 1999; Posner et al., 1982; Vosniadou, 2007). However, students' mental models of the physical and natural world are not often consistent with scientifically acceptable mental models about a particular science concept (Chinn & Brewer, 1993; DiSessa, 2002; Mayer, 2002; Vosniadou, 2007).

Proponents of conceptual change argue that through proper scaffolding and appropriate curriculum, students will be able to develop scientifically acceptable conceptions about the scientific phenomena (Chi, 2005; Mayer, 2002; Nussbaum, & Novick, 1982; Posnanski, 2002; Vosniadou, 2002). Conceptual change theorists (Hewson & Thorley, 1989; Posner et al., 1982) emphasize a set of conditions that are pre-requisite to conceptual change. These conditions include the following: (1) the learner must experience dissatisfaction with an existing conception, (2) the new conception must be intelligible, (3) the new conception must be plausible - the new conception must also be consistent with the learner's personal standards of knowledge, (4) the new conception must be fruitful and/or help the learner to solve problems or predict phenomena. It follows that learning experiences that are designed to bring about conceptual change must be consistent with these principles.

The initial assumptions of conceptual change viewed the process of learning through the assumptions of Piaget (1950) who explained the mechanisms through which the learner constructs and internalizes knowledge. Piaget suggested that individuals construct knowledge from their everyday experiences through the processes of assimilation and accommodation. The growth in learning was perceived to be the result of reorganization of concepts acquired through experience by these researchers (Greeno, Collins & Resnick, 1996). However, current learning theories assume that learning is a social process as much as it is a cognitive process (Vygotsky, 1978) and the growth in knowledge is assumed to result from social negotiation of concepts.

Lave and Wenger (1991) argue that learning should not be viewed as simply the transmission of decontextualized, abstract knowledge from the teacher to the student, but a social process whereby knowledge is co-constructed through negotiation of meaning by all members of a learning community. In this social interaction, the learners are challenged to present, defend, revise and reconstruct knowledge until consensus is reached about the status of knowledge among all members of the community. However, social negotiation of knowledge alone may not be sufficient for long lasting understanding. Learning theorists who are proponents of situated learning theory believe that learning of concepts should take place in contexts relevant to their everyday use (Colins, 1988; Lave & Wenger, 1991). They maintain that learning is a result of the activity situated in the culture and context in which it takes place (Greeno, 1998; Lave & Wenger, 1991), and thus the learning environment should approximate the context in which the knowledge and skills learned will be used (Schell & Black, 1997).

The teaching methods informed by the principles of these current understandings of learning are assumed to engage students in meaningful and cognitively complex learning tasks, the end result of which may be conceptual change. We explain how we used the principles of these learning theories in the intervention section of this study to promote conceptual change among the participants of this study.

Methodology

Two sets of data served as the bases for our analysis: (1) participants' pre and post test scores, and (2) participants' drawings of the lunar phases, seasonal changes and simple electric circuits. We report the percentages of participants who provided correct answers to the questions that measured their understanding of the three concepts; the lunar phases, seasonal changes and simple electric circuits both before and after the intervention. Further analysis includes qualitative analysis of participants' drawings of lunar phases, seasonal changes and simple electric circuits (see Appendix B). The qualitative analysis helped us identify common misconceptions in participants' responses.

Participants and Data Collection

Participants for this study were 40 pre-service elementary school teachers enrolled in an Elementary Science Methods Course. The majority of participants enrolled in the course were students who majored in psychology and minored in education. All of the participants indicated that they learned about the lunar phases, reasons for seasons, and simple electric circuits at one point in their schooling experiences through a short survey. The age of participants ranged from 22 to 34. Only two of the participants were male.

We administered a pre-test (see Appendix A) to elicit participants' prior knowledge related to the lunar phases, seasonal changes and simple electric circuits. After participants took the pre-test, we provided them with three learning opportunities (see intervention) using multiple methods to bring about conceptual change in their understanding of the lunar phases, seasonal change and electricity. Participants took a post-test (the same as pre-test) that measured their conceptual understanding of the lunar phases, seasonal changes and simple electric circuits at the end of the course. The pre-test and post-test were graded for comparison.

Intervention

The intervention consisted of three sequenced learning activities. The learning activities were designed according to the principles of social constructivism and situated learning in particular. A learning environment that is consistent with the principles of social constructivism creates conditions for conceptual change. Social constructivism assumes that learning takes place through a social and communicative process, whereby knowledge is shared and understandings are constructed (Aldridge, Fraser, & Taylor, 2000; Mercer, Jordan, & Miller, 1994; Tobin, Tippins, & Gallard, 1994; Vygotsky, 1978). Social constructivists maintain that individuals come to develop understanding through social interaction with others and by the use of cultural tools that the context of their learning makes available to them (Driver, 1995; Solomon, 1994; Tobin, Tippins & Gallard, 1996; White & Frederiksen, 2000). Situated learning theory states that individuals will construct knowledge when the learners are able to actively participate in learning in a meaningful context (Greeno, 1998; Lave & Wenger, 1991). Research also points out that learners' prior conceptions are rooted in their personal experiences, therefore, for conceptual change to take place, students must re-experience the phenomena (Gorsky & Finegold, 1992).

We started the intervention by problematizing participants' prior knowledge through two videos. The teaching of the lunar phases and seasonal changes was problematized through the private universe video (Schneps, 1988) and participants' prior knowledge of the concept of electricity was problematized through a series of VISTA videos (Pearson, Inc, 2008). These two videos emphasize common misconceptions held by students about the concepts of interest. After the participants watched the videos, they were prompted to compare their previously–held understanding of the concepts of interest to what they had just watched. Participants were then asked to discuss their learning experiences pertinent to these concepts in pairs. After the group discussions, we engaged the participants in hands-on and minds-on learning experiences, in an effort to help them develop scientifically accurate understanding about the concepts of interest. For instance, students built simple circuits, series and parallel circuits. A discussion about how to teach the concepts of interest followed after the participants' completion of the hands-on activities. The hands-on learning activities on electricity engaged participants in building simple, series and parallel circuits using the Electric KitBook (Edamar, 2008). The hands-on learning activity on the phases of moon involved the following. Participants used a Styrofoam ball to represent the Moon, their bodies to represent the earth and a light source to represent the Sun. The Styrofoam ball was lit by a light source (overhead projector). This enabled the participants to observe how different portions of the ball are illuminated as they rotated on their axis counter clockwise. Then, participants created a complete series of phases matching the appearance of the Moon and related the moon phases to the positions of Earth and the Sun. Participants learned about the seasons by a simulation activity that enabled them to see how the sun rays (flashlight) hit the surfaces of a Globe model at different angles. They were then asked to represent their understanding of different seasons through drawing models. In addition, participants were asked to compare their models with one another and engage in discussions.

After participants completed the hands-on learning activities, we asked them to take a critical look at how the students they watched in the videos might have developed misconceptions about the scientific phenomena of interest. Finally, participants engaged in a collective discussion that focused on their pre-conceptions and those of the students shown in the videos.

Findings

We present the pre and post test data in percentages for each of the science concepts tested in Table 1. Figure A visually documents the growth in participants' conceptual understanding of lunar phases, seasonal changes and simple electric circuits.

Table 1. *Pre and Post Test Percentages of Correct Responses*

Concept	Pre-Test Percent Correct	Post Test Percent Correct	Difference
Lunar Phases	27.50	95.00	68.50
Seasonal Changes	43.50	98.00	54.50
Simple Circuit: One Battery	37.50	100.00	63.50
Simple Circuit: Two Batteries	10.00	98.25	88.25

Analyses of the pre-test scores revealed that participants' conceptions of lunar phases, seasonal changes and simple electric circuits were not consistent with the scientifically correct ones as shown in Table 1. While only 27.5 % of the participants (n = 11) accurately answered the question about the lunar phases, 43.5 % of them (n = 17) answered the question about the seasonal changes correctly. Participants scored relatively low on the pre-test questions that measured their conceptual understanding of simple electric circuits. More importantly, there was a difference in percentages of participants who correctly answered the simple circuit question with one battery only (37.50% or n = 15) and the simple circuit question with two batteries (10.00% or n = 4). Next, we provide in-depth analyses of participants' responses by highlighting their misconceptions.

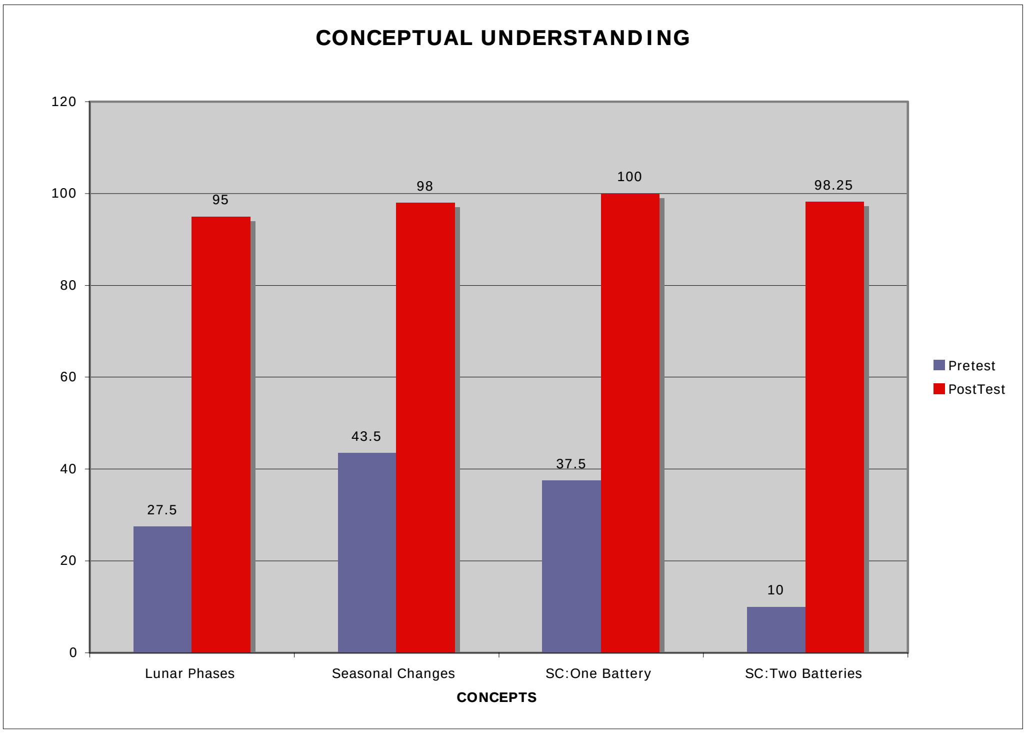

Figure A. Pre and Post Change

Misconceptions about Lunar Phases

Two common misconceptions about lunar phases surfaced when participants' answers to the pre-test were analyzed. First, 27% of the participants (n = 11) failed to accurately locate the Sun, the Moon and the Earth relative to one another. For instance, some participants placed the Sun is in the centre of their models, and the earth and the moon simultaneously rotating around the Sun. The second dealt with how participants conceptualized the ways in which the sun's rays reached the surface of the moon. Although the participants were able to show that there are eight different phases of the moon, they failed to accurately show how the sun reached the surface of the moon in each phase. For instance, the analysis of students' drawing of the lunar phases shows that they failed to differentiate between the way in which the sun' rays hit the surface of the moon during waxing crescent and waning crescent. It follows that in order for pre-service elementary teachers to develop conceptual understanding; they should be explicitly shown that the reasons why we see the moon in different shapes at different days of the month are because of the sun's reflection on the moon and the revolution of the moon around the Earth. Moreover, they should be challenged through reflective learning experiences to develop an understanding about how the sun's rays reach the surface of the moon in each phase.

Misconceptions about Simple Electrical Circuits

The questions about simple electric circuits asked the participants to show the direction of flow in the simple circuit built with one battery, enough wiring and a light bulb and in the simple circuit built with two batteries, enough wiring and a light bulb (see Appendix A). Four essential misconceptions emerged from the analysis of participants' circuit drawings. These misconceptions include: (1) the direction of flow is not of significant importance in the design of simple electrical circuits, (2) a battery holds a certain amount of stored energy that starts to flow once connected to a wire; so, it does not matter which end of the battery is connected to the wire, (3) electricity flows from the battery to the bulb and is consumed there, and (4) the flow of electricity is bidirectional when the two batteries are used to build a simple electric circuit. Tables 2 and 3 provide a description of participants' misconceptions in both cases.

Table 2. *Pre-service Elementary Teachers' Conceptions of a Simple Circuit: 1 Battery*

Misconceptions	Description	#Of responses
Case 1	No direction of flow Wire is attached to the positive end One directional	15
Case 2	No direction of flow Wire is attached to the negative end	1
Case 3	No direction of flow Wire is attached to the positive end and to the glass part of the bulb	1
Case 4	Positive or negative not indicated No direction of flow One directional	7
	Positive and negative end connected but flow is from the positive end Two wires go from the positive end to the battery	1
Correct case	Scientifically correct drawings (i.e. applies the principles of closed circuits).	15

As the data indicate, the majority of the participants (n=26) failed to accurately design a simple electrical circuit with one battery, one bulb and enough wiring.

Table 3. *Pre-service Elementary Teachers' Conceptions of a Simple Circuit: 2 Batteries*

Misconceptions	Description	#Of responses
Case 1	Bulb in the middle electricity flowing to the bulb from the positive end of both batteries but after the electricity reaches the bulb it travels back using the same bath it used to reach the bulb.	2
Case 2	Closed circuit but electricity is flowing from the positive end and completing the entire circuit.	2
Case 3	Bulb in the middle electricity flowing to the bulb from the positive end of both batteries but the electricity travels back and forth and the two negative ends of batteries are connected with an external wire.	1
Case 4	Bulb in the middle but electricity is flowing to the bulb from both the negative and the positive end of both batteries to the bulb from the opposite directions.	1
Case 5	Two Batteries are externally attached to the bulb from the same side, the triangle wires connect each battery to the bulb, the flow is one directional in both batteries.	2
Case 6	Bulb in the middle each battery is on the opposite side of the bulb the flow is from the negative end of battery one, pass through the bulb and reaches the positive end of battery 2. The other one is from positive end of batter 1 to the positive end of battery 2.	2
Case 7	Bulb in the middle but electricity is flowing to the bulb from both the positive end of each battery and they reach the bulb and end there. In two cases positive end of the batteries connect first	11
Case 8	Closed circuit with two batteries connected to on another. The flow is from the positive end of the second battery and the flow stops after it reaches the bulb.	1

Misconceptions	Description	#Of responses
Case 9	Closed circuit with two batteries connected to on another. The flow is from the positive end of the second battery and the flow continues.	1
Case 10	Closed circuit with two batteries connected to one another. The flow is from the negative end of battery one to the positive end of battery. Then the flow is from negative end of battery 2 through the bulb and reaches the positive end of battery 1.	1
Case 11	Two batteries are connected positive end of battery 2 and the negative end of battery one connects. After they connect the electricity reaches the bulb the flow is one directional.	1
Case 12	Two batteries are connected positive end of battery 2 and the negative end of battery 1 connects and the other end reaches the bulb the flow is one directional.	3
	Bulb in the middle but electricity is flowing from the bulb to the positive end of batteries on the opposite side.	5
Case 13	Two batteries are independent not connected to one another but to the bulb at the same time. The electricity flows from positive end of battery 1 to the negative end of battery 2.	2
Case 14	Two batteries are independent not connected to one another but to the bulb at the same time. The electricity flows from negative end of battery 1, through the bulb and to the negative end of battery 2.	1
Case 15	Closed circuit flow is from the positive end of battery 1 to the negative end of battery 2.	
Correct Case	Correct answer (i.e. applies the principles of a closed circuit)	4

The analysis of participants' responses illustrated in drawings (see Appendix B) suggests that participants did not know how the current is produced, or the fundamental scientific principles that cause the electricity to flow from the battery to the bulb. Six different patterns emerged from participants' incorrect responses to the first electricity question that asked them to build a simple circuit using only one battery and one bulb.

Fifteen patterns were identified in students' incorrect responses to the question that asked them to build a simple electric circuit using two batteries and one bulb. The analysis of data from the drawings of a simple circuit with two batteries indicates that the participants did not understand the scientific principle that guides the movement of electrons in a simple circuit. More than half of them failed to correctly draw a simple circuit when challenged to draw a simple circuit by using one battery, enough wiring and one bulb. In addition, 74% of those who correctly drew a simple circuit with one battery failed to draw a simple circuit with two batteries.

Misconceptions about Seasonal Changes

Pre-service elementary school teachers' misconceptions about seasonal changes were identified through a qualitative analysis of students' drawings. Although most participants (n = 34) had a general understanding that the seasons were caused by the tilt of the earth, a small number (n = 6) failed to acknowledge the tilt of the earth as a factor for the seasons. Those who were able to provide a correct answer acknowledged that solstices and equinoxes mark the points at which the poles are tilted at their maximum toward or away from the sun (see Appendix). However, the majority of the participants (n = 32) failed to acknowledge that the sun's glancing rays are spread over a greater surface area and must travel through more of the atmosphere before reaching the earth in their drawings or explanations. Although participants acknowledged that the sun is the source of light, energy and heat, they failed to acknowledge that the changing intensity and concentration of its rays gave rise to the seasons of winter, spring, summer and the fall. Instead, they mentioned that seasons took place because of the earth's tilt in simple terms. Such naïve understanding of content may not be sufficient for pre-service teachers to design effective science instruction in their classrooms.

Discussion

The findings highlight that the majority of pre-service elementary school teachers in this study came to the science methods course with scientifically inaccurate conceptions about lunar phases, seasonal changes and simple electrical circuits. As shown in this study, although the majority of the participants were able to show eight different phases of the moon in their drawings, they failed to understand the causes of the changes in the shape of the moon. Two things can account for this finding. Either these concepts were not covered in these teachers' science content courses or it may be that the participants failed to develop conceptual understanding because of learning science through an authoritarian rather than a constructivist learning environment. For instance, instead of challenging students to construct understanding about a particular scientific phenomenon, students are often asked to accept the knowledge presented by the teacher as truth

(Tobin et al., 1994). Such learning experiences limit students' ability to explain the scientific phenomena. If the students are not given the opportunity to construct knowledge on their own through the support and challenge provided by the members of the learning community in which they are a part, their conceptual understanding of scientific concepts may be limited.

As the growth of participants' conceptual understanding between pre and post tests indicates, when learning activities are informed by a social constructivist epistemology and learning experiences are situated in a context that best approximates he context in which such knowledge will be used, students have better chances of developing conceptual understanding of key scientific ideas. This finding is consistent with previous studies that indicate that the science courses specifically designed for pre-service elementary teachers have a greater impact on their learning than the traditional science courses taught in the college of arts and sciences do (Schoon & Boone, 1998). Learning activities informed by social constructivism provides a context for the discrepancies in students' understanding to come to fore as it challenges the learner to make his/her understanding visible (Rogoff, 1990). By the same token, the challenge and further understanding provided by the other members of a learning community (i.e. peers and the instructor) can help students to solve the discrepancies in their understanding and thus achieve conceptual understanding. Both the challenge and support provided by the other members of the community stimulates the process of knowledge reconstruction (Rogoff, 1990; Roschelle, 1992; Vosniadou, 2007).

In addition to the structure of the learning activities, the context in which the learning took place may have accounted for some of the reported improvements in participants' conceptual understanding. Consistent with the assumptions of situated learning, the participations learned the science content in a context that allowed them to become familiar with the challenges that elementary school students have in their learning of science content and discuss ways to help the students to overcome those challenges. This situated perspective on learning might have facilitated the process of conceptual change among the participants. These findings are also consistent with socio-cultural views of conceptual change literature (Hatano, & Inagaki, 2003). The participants discussed the misconceptions that they had, the ways in which they learned concepts themselves and elaborated on ways to teach them.

Implications

This study has significant implications for pre-service elementary teacher education. First, it highlights the prevalence of misconceptions pre-service elementary teachers hold about fundamental science concepts that are central to their practice. These misconceptions must be explored and addressed in their science methods courses. Exploring and addressing such misconceptions among pre-service elementary school teachers is significant in that they impact their students' learning (Stahly, Krockover, & Shepardson, 1999; Trundle et al, 2007). Second, it demonstrates that assessment methods that require students to explain their understanding are more powerful for exploring students' misconceptions than the traditional assessments that simply ask students to simply choose an answer among several choices. Finally, it suggests that reflective learning activities informed by the epistemologies of social constructivism and the situated learning model are promising in helping pre-service elementary teachers to experience conceptual change and thus develop scientifically accurate conceptions about simple electric circuits and lunar phases. These types of reflective learning opportunities must become essential component of pre-service elementary science instruction.

Understanding the types and nature of pre-service elementary teachers' misconceptions related to fundamental science concepts is critical. Such understanding will enable science teacher educators to design responsive instruction and thus address the learning needs of pre-service elementary teachers related to science. Making pre-service elementary teachers' misconceptions visible and changing them through effective instruction has significant implications for how they may teach these science concepts once they become classroom teachers. The link between elementary teachers' enhanced content knowledge and their students' conceptual understanding of essential science concepts needs to be substantiated through empirical studies. Establishing such link is important simply because pre-service elementary teachers' conceptual understanding of essential science concepts gained in a science methods course may not be durable. Further studies should explore the durability of conceptual understanding gained through reflective conceptual change strategies such as the one modelled in this study.

Limitations

Although this study brings an important aspect of elementary school teachers' knowledge base for teaching science to science educators' attention, it has certain limitations as well. The main limitation of this study is that we did not record the conversations that took place between the pre-service elementary teachers when they engaged in lengthy discussions about the source of their misconceptions and ways of teaching science for the purpose of triggering conceptual change. Such data would have been invaluable for understanding the source of students' misconceptions and the misconceptions that they may hold about teaching science to young children.

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APPENDIX A

PART A. Phases of The Moon:

1. Draw the phases of the moon in relation to the Sun and the Earth.
   The following directions were verbally provided.
   a. In your drawing, indicate the relative location of the earth, moon and the sun.
   b. In your drawing, indicate the direction in which the moon rotates.
   c. In your drawing, indicate the part of the moon that is lit and the part that is dark.

PART B. Electricity

1. Simple Circuit

   a. Draw a simple electrical circuit using a battery, a wire and a light bulb. In your drawings show the source and direction of the flow of electricity. *Verbal directions*: Label parts of the circuit with appropriate names.

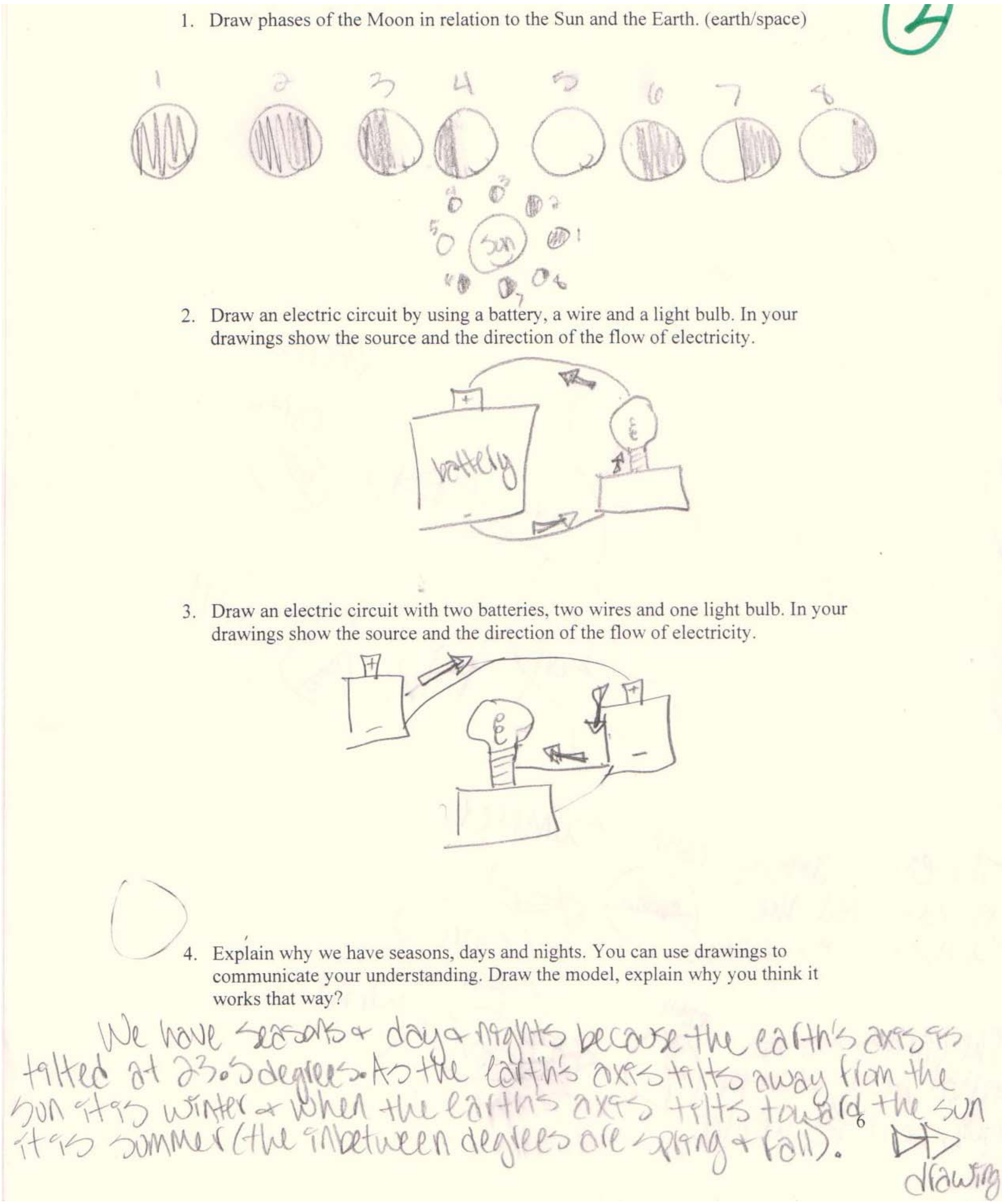
2. Simple Circuit:

   a. Draw a simple electrical circuit with two Batteries, two wires and one light bulb. *Verbal directions*: Label parts of the circuit with appropriate names.

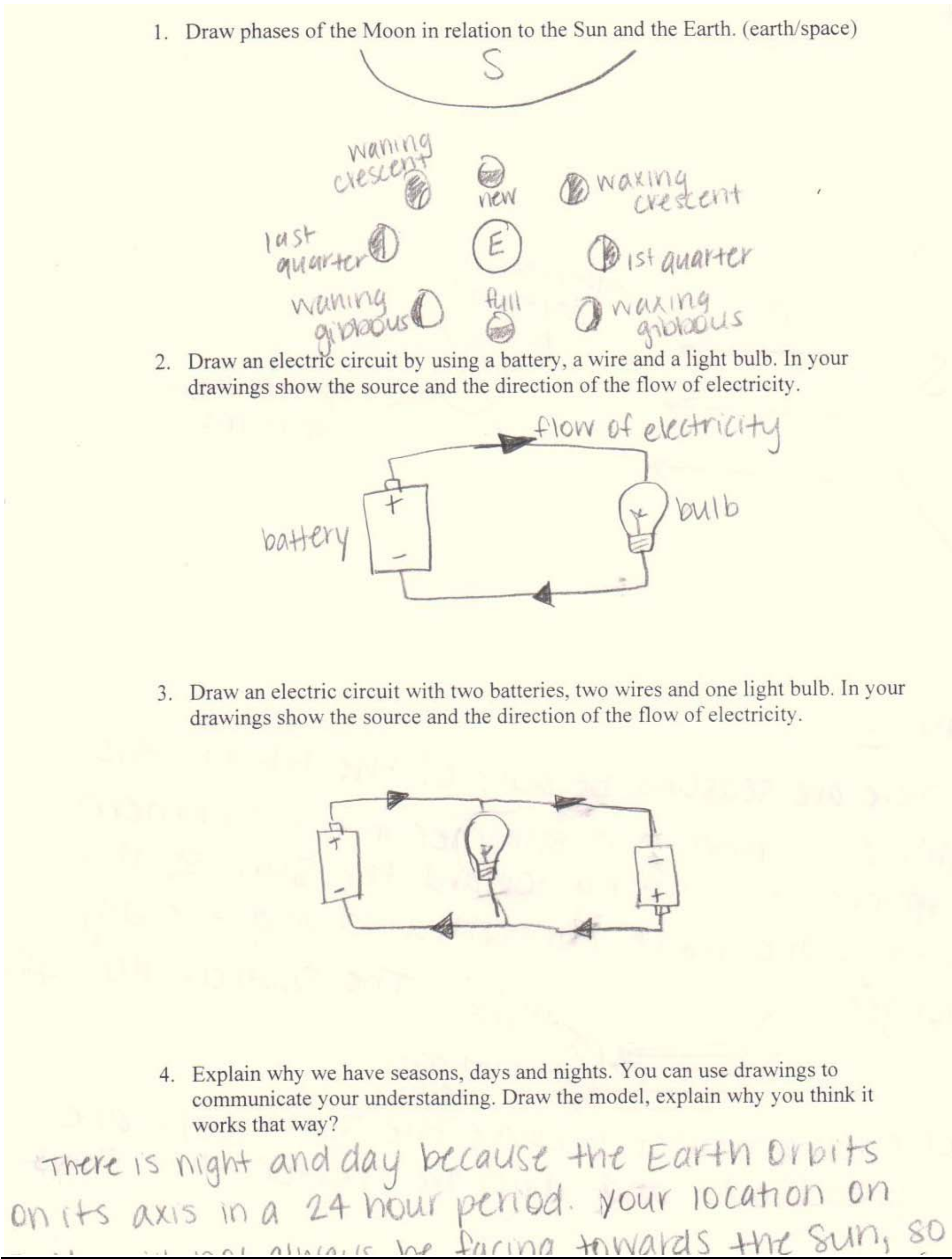
PART C. Seasons

1. Explain why we have seasons, days and nights. You can use drawings to communicate your understanding. Draw the model and explain why you think it works that way.

Appendix B. Students' Drawings



Appendix B. Students' Drawings


1. Draw phases of the Moon in relation to the Sun and the Earth. (earth/space)

2. Draw an electric circuit by using a battery, a wire and a light bulb. In your drawings show the source and the direction of the flow of electricity.

3. Draw an electric circuit with two batteries, two wires and one light bulb. In your drawings show the source and the direction of the flow of electricity.

4. Explain why we have seasons, days and nights. You can use drawings to communicate your understanding. Draw the model, explain why you think it works that way?

There is night and day because the Earth orbits on its axis in a 24 hour period. your location on