TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 11, Sayı 3, Eylül 2014

Journal of
TURKISH SCIENCE EDUCATION
Volume 11, Issue 3, September 2014

http://www.tused.org

Understanding Pre-service Elementary School Teachers' Mental Models about Seasonal Change

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Received: 23.04.2013 **Revised:** 17.05.2014 **Accepted:** 09.05.2014

The original language of article is English (v.11, n.3, September 2014, pp.3-20, doi: 10.12973/tused.10115a)

ABSTRACT

The objectives of this study are to develop an abductive procedure that students construct their alternative models, and help teacher to construct their scientific models from initial model to them about seasonal change. The data collected from the paper-pencil test and individual interview with students. For this study, 30 pre-service elementary school teachers(1st grade) were participated. The results of this study show that the students had apparent alternative conceptions, and that the 'distance theory' had most important effects on their alternative conceptions. In order to find the origin of structure of their alternative conceptions about seasonal change, we reconstructed the forming process of their alternative concepts according to the inference patterns of abduction. The revision types of main hypothesis as a their alternative models is done through their early age perceptions of typical celestial bodies rather than the acquired specific knowledge, and have the expansion, contraction, and revision of main theory. Implications for pre-service teachers' science education and related research were discussed. For teachers to successfully guide elementary school students in scientific activities, teachers must possess both the appropriate scientific knowledge and the necessary abductive inference skills.

Keywords: Alternative Models; Seasonal Change; Distance Theory; The Inference of Abduction; Pre-Service Teachers' Science Education.

INTRODUCTION

Scientific theories explain regularities in nature by describing their causes. Scientific laws are statements about the relations between observable phenomena, whereas a theory explains the properties of a phenomenon that cannot be observed. When a generalization hypothesis or an explanatory hypothesis is proven, it becomes a law or a theory, respectively. Facts and laws are discovered in nature, whereas concepts and theories are constructed in the abstract. Current scientific theories are, in fact, just explanatory hypotheses (McComas, 2000). Therefore, the key to scientific advancement may lie in developing explanatory hypotheses.

Peirce (1839-1914) was one of the first to claim that abduction is a process that eventually yields explanatory hypotheses (Eames, 1977). He stated that "all of the well-established scientific theories of today are due to abduction" (*PC 5, 172*). In addition,

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© ISSN:1304-6020

researchers who study the hypothesis formation process have claimed that this process is guided by abduction (Magnani, 2001; Walton, 2004) rather than taking place within the inductive or the hypothetico-deductive system (Lawson, 1995)

Normally, the generation of a preliminary explanatory hypothesis is the third stage of abduction. However, scientists and philosophers recognize that it is difficult to accept a hypothesis unless it is evaluated against competing hypotheses based on all available evidence. Philosophers have referred to this stage as “Inference to the best explanation” and consider it as the fourth stage in the process of abduction (Harman, 1973; Thagard, 1988). During the problem-solving process, abductive reasoning can play an important role in scientific discoveries and creative reasoning (Magnani, 2001).

In the field of astronomy, students have reported constructing a few limited mental models. Understanding these explanatory mental models can provide important information about the students’ knowledge structure, based on questions’ responses (Vosniadou, 1994). In other words, if we do not understand students’ mental models, we cannot know the basis from which the students will form theoretical models in the future.

Therefore, the main objective of this study is to explore the types of models developed by pre-service elementary school teachers who are not scientists when they were asked to form their own models about seasonal changes and to develop hypotheses about how they develop. To accomplish this objective, the abduction process was followed in stages to explore the types of alternative conceptions of seasonal changes among pre-service elementary teachers.

Through many surveys (Atwood & Atwood, 1996; Oh & Kim, 2005; Trumper, 2006), many people, especially Pre-service elementary teachers believe that the seasons are the result of the changing distance between the Earth and the Sun.

Mental Models and Concepts

Learning theories that science educators have interest in since 1980c can be divided into concept-learning and problem-solving (Eylon & Linn 1988). They are classified into studies on the contents and structures of knowledge areas of beginners and experts during conceptual changes and studies on kinds of knowledge acquired in process of problem solving. The former is called to be a “Conceptual Change Model” and the latter is called “Model Building Problem Solving.”

In the research of Conceptual Changes, the unit of learning is concepts, and learning science is defined as changes in the concepts of learners about the nature world. In a conflict situation of concepts, according to status of concepts, conceptual changes occur or existing concepts are maintained. Learners acquire concepts through inquiries with existing conceptions, or form knowledge as conceptual exchange about anomalies (Hewson 1981, Posner, et al., 1982).

In the tradition of Model Building Problem Solving, abilities to solve problems can show that learning was immediately conducted (Stewart & Van Kirk 1990). In this tradition, Learner is compared to a scientist who solves given-problems in a class environment compared to a science laboratory (Peterson & Jungck 1988).

The Conceptual Change Model and Model Building Problem Solving deal with concepts and a mental model as units of learning respectively. Concept and the mental model have something in common in that they play functional roles as means and objects of thinking at the same time. Also, the mental model has private characteristics and is different from a received model prescribed in the society of scientists.

According to Hewson and Hewson (1988), they said that science is shown as a sequent course of conceptual changes. Posner at al (1982) propose that science suggests problems and what things should be decided based on using of paradigms.

These views of science were originated form Kuhn and Lakatos. Accumulations of anomalies are linked with changes of paradigms and progression or degeneration of research programs. In the tradition of Conceptual Change Model, paradigm and core of research program become the foundations for epistemic belief of learners which realize inner consistency and generalization.

On the other hand, in the tradition of Model Building Problem-Solving, science is regarded as activities of problem solving. Science exists as a procedure for theories to be formulated. The tradition of Model Building Problem Solving considers the mental model as conceptual knowledge. As concepts, the mental model is a mental construct on some aspects of the environments (objects) of learners.

The mental model is causal as a unit of problem-solving and can be defined functionally in the meaning that solvers for problem explain, and predict them. In science classrooms or textbooks, the most important approved models among models made by scientists in the past are proposed. Therefore, learners apply to existing concepts and form harmonized models. These may not be profitable to the aims suggested by teachers. The individual and diverse types of model by learners are called the mental model.

Concepts and the mental model have similarity in structural and functional aspects. But, in this research, we use the mental model from accepting the suggestion of Vosniadou (1994) that students infer causally about problem solving with theories and premises of their own, in the process of problems solving, though they are imperfect circumstantially and contextually, especially in the process of knowledge development for astronomical phenomena. And dynamic, physical models are abundant in Earth & Space Science education, at all levels from elementary through college (Kastens & Rivet, 2010).

Abduction and an Inquiry Process

Peirce called this a "reasoning abduction." Charniak and McDermott (1985) characterized abduction as a form of looking back to infer the cause of something and to generate explanations for things we see around us and infer the best explanation. In these views, abduction is inference in which the observed evidence is presented first and the related hypothesis is presented later, as shown in the following general format (Hanson, 1972, p. 86):

The surprising, C. is observed;
But if H [an explanatory hypothesis] were true, C would be a matter of course,
Hence, there is reason to suspect that H is true.

"Abduction can be understood as a mode of inference that seeks explanations for anomalous or surprising phenomena. Here, A might be a general theory (or, using the earlier terminology, it might include both a rule and a case). The conclusion is not A in and of itself but is rather the assertion that there is reason to suspect A is true" (Niiniluoto 1999, p. 439).

Peirce stated the following:

(1) Every inquiry whatsoever takes its rise in the observation…of some surprising phenomenon… (CP, 6.469).

(2) The inquiry begins by pondering these phenomena in all their aspects, in the search for some point of view whence the wonder may be resolved. At length, a conjecture arises that furnishes a possible explanation, by which I mean a syllogism exhibiting the surprising fact as necessarily consequent upon the circumstance of its occurrence together with the truth of the credible conjecture, as Premises (CP, 6.469). "The very phrase '**as a matter of course**' indicates a degree of intuitiveness, a point underscored by the fact that an explanatory conditional conveys a connection of necessity or high probability" (8.231, 7.36). (Kapitan,

1992)
(3) Based on this explanation, the inquirer is led to regard his conjecture, or hypothesis, with favor. As I phrase it, he provisionally holds it to be "plausible" (CP, 6.469).

Thus, we propose that premise one (1) in [PA] corresponds to the "**surprising observations.**" Premise two (2) in [PA] corresponds to the "**conjecture and invention of hypotheses**" and the conclusion (3) in [PA] corresponds to the "**selection of hypotheses**."(Oh, 2012; Oh, 2013)

1**. Generation of Hypotheses Phase:** According to Peirce, we study science for the purpose of understanding reality, and the first phase of reasoning that needs to be performed for this purpose is abduction. In turn, abduction is classified as the observation of unusual phenomena and the speculation about what was observed. Observation of an unusual phenomenon makes us seek a hypothesis to explain that phenomenon. Following Hanson's suggestions, the reasoning process was specifically adjusted as follows. Although Hanson himself did not develop these ideas in this exact manner, these points can be viewed as strategic principles (Paavola, 2004).

Oh (2012, 2013)'s suggestions was referred to individually as "**Surprising Observation (1)", "Conjecture and Invention of Hypothesis (2)**", and "**Selection of the Hypothesis (3)**."

"Surprising Observation" refers to a rather unexpected phenomenon. In other words, it refers to a phenomenon that cannot readily be explained by ordinary experience or existing knowledge because it is a phenomenon that does not normally occur. When new knowledge is required to solve a difficult problem, beginning with unusual or little facts and attempting to discover a solution or hypothesis is a good strategy (Niinluoto, 1996b).

"Conjecture and Invention of Hypothesis" refers to developing hypotheses in our minds. At first, we begin our conjecture from inconclusive and varying data, but eventually, we can make reliable inferences from well-organized evidence. The transition from poorly understood data collected by a person making an inference to rich and well-documented evidence based on well-developed theories is continuous. These endpoints differ only in degree, not in logical pattern. Initially, of course, good evidence is lacking (Hanson, 1965).

"Selection of Hypothesis" refers to expressing and adhering to preferences for one hypothesis out of several possible hypotheses. An abduction is completed with the selection of a hypothesis. The reasoning process involves analogical reasoning and eliminative induction (Laudan, 1987).

A characteristic of the abduction process is that the initial process of developing explanatorily useful hypotheses and the subsequent choice of one hypothesis takes place during the process of critically evaluating the best explanation (Josephson & Josephson, 1996). Therefore, this study considers not only the hypothesis-generation phase but also the process of evaluating the selected hypothesis as follows.

Testing of Hypotheses Phase

Preliminary testing of Hypotheses: When considering a new, inconsistent event as part of the preliminary evaluation of a hypothesis, it may be necessary to determine the explanatory consistency of the hypothesis. Let us resume the kinds of change considered in the original **belief revision framework** (see Figure 1) (Magnani, 2001, p.31-32). The ***expansion*** of a set of beliefs ***K*** taken from some underlying language (considered to be the closure of some finite set of premise ***KB***. The addition happens "regardless" of whether the larger set is *consistent*.

The case of ***revision*** happens when the new ***A*** is inconsistent with ***K*** and we want to maintained consistency: some beliefs in ***K*** must be withdrawn before A can be accommodated

(Gärdenfors, 1988). Hence, *inconsistent resolution* in belief revision framework is captured by the concept of revision.

Another way of belief change is the process of ***contraction***. When a belief set ***K*** is contracted by ***A***, the resulting belief set K + A is such that A is no longer held, without adding any new fact. Aliseda (2000) makes use of the belief revision framework to construct a theory of the epistemic transmission between the states of doubt and belief revision dynamics in data bases and abduction.

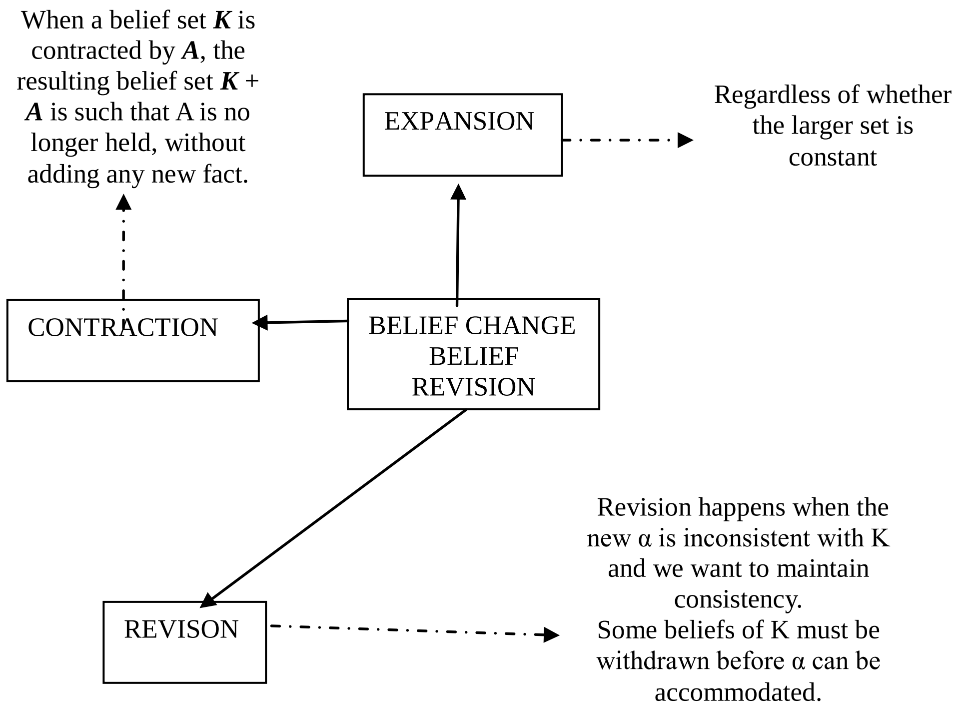

Figure 1. *Belief Change (Aliseda, 2000)*

In this study, to understand the development of students' theories, it is necessary to examine the changes in the patterns of the students' **existing main concepts (K)** when an **inconsistent event (A)** is presented. This approach assumes that such changes are analogous to the changes in scientific theories in response to anomalies for the generation and development of scientific theories that emphasize existing background knowledge (see Figure1).

Explanatory Coherence/Consistency: The degree of explanatory coherence, or the explanatory power, of a model must be relatively high (Thagard, 1992).This standard was used to evaluate the structures and types of the students' explanatory model sand their explanatory consistency.

First, many students have a theoretical basis (an underlying rationale) for their explanation. The students' explanations differ from the scientific viewpoints, but from the perspectives of the students themselves, they appear consistent. In our study, we refer to the students' explanations as the **main theory (K)** (Watson et al., 1997).

Second, the degree of explanatory coherence is said to be high as the number of primary theories among the students' explanations is low, as is the number of auxiliary (ad-hoc) hypotheses (number of ad hoc) based on one primary theory. The number of auxiliary hypotheses related to the main theory is found during the process of forming a scientific theory. Strictly speaking, the one of the auxiliary hypotheses are ad-hoc hypotheses, which have the sole purpose of avoiding refutation. For the main theories, when an anomaly is presented, the initial theory is considered to be on hold temporarily, even if it is modified, and the initial and modified theories are provisionally considered to coexist.

This process of establishing and evaluating the hypothesis can be summarized as follows. Surprising observations, conjecture and invention of hypotheses and the selection of hypotheses together constitute abduction. Preliminary testing of a hypothesis involves "inference to the best explanation", and abduction ends when the individual is mentally satisfied. However, the hypothesis test provides a more accurate evaluation in the form of a "hypothetico-deductive" process.

"**Hypothetico-Deductive Method**": The hypothetico-deductive method, HD, is a process that starts with established hypotheses and initial conditions and proceeds to form testable statements. In summary, plausible hypotheses are generated through abduction, and generated hypotheses are tested through HD. Preliminary hypothesis testing is the first stage. After the predictions are deduced from the hypothesis, an experiment is performed to obtain evidence to support the hypothesis. The inquiry begins with observation and ends with experiments. (See Figure 2)

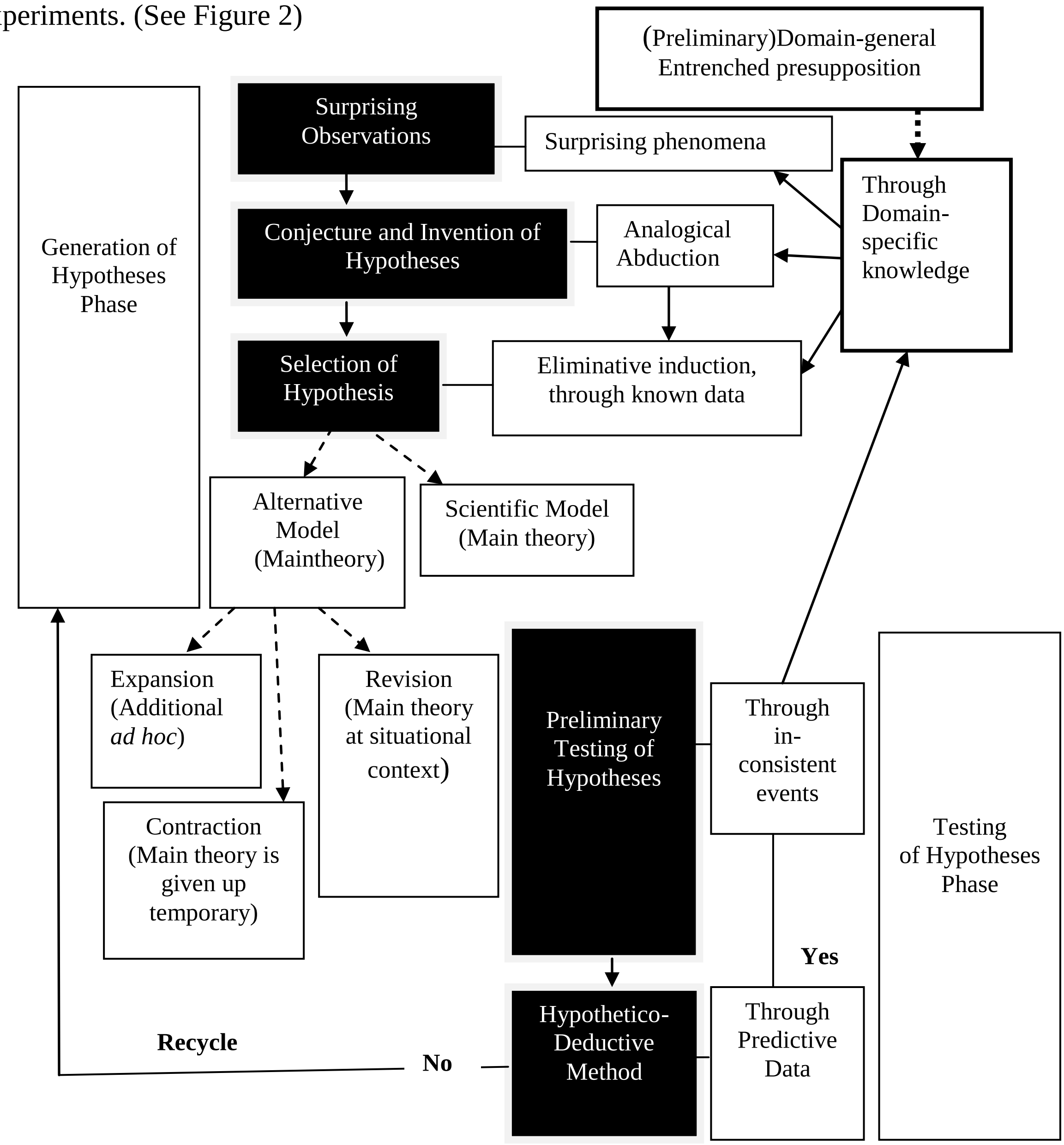

Figure 2. *Abductive Process Involving Testing Process of Hypotheses*

METHODOLOGY

a) Participants

30 first-year students of J. National University of Education (South Korea) participated in this research. First-year students were selected because we determined that scientific knowledge acquired from high school classes would be utilized the most for generating explanatory hypotheses that explain astronomical phenomena. All students had completed physics and earth science courses during high school and consented to participate in the study.

b) Testing Instruments and Interview

Understanding the growth of scientific knowledge has been one of the main goals of the philosophy of science for the past 30 years (for example, see Kuhn, 1970; Toulmin, 1972; Lakatos, 1970; Laudan, 1977). Another new approach is to view science as a problem-solving method. Domain-general and domain-specific knowledge are used as background to solve novel problems (Nickles, 1987; Thagard, 1988).Therefore, students' domain-general and domain-specific knowledge was considered to be a source of possible hypotheses. In this study, interviews were conducted by utilizing the following testing tools to find out how pre-service elementary school teachers use their existing background knowledge to explain the astronomical phenomenon of seasonal changes.

1) Domain-general entrenched presupposition background knowledge: Questions (Questions 1, 2) developed by Feigenberg et al. (2002) were used and expanded upon throughout the interviews.

2) Domain-specific background knowledge of specific astronomical phenomena: The questionnaire (Questions 3, 4) developed by Kikas (1998a,b) was used, and the interview was conducted to elicit more detail about the students' thoughts.

3) Interview Stages

Preliminary Stage (Domain-general background knowledge, entrenched presupposition): Draw a diagram in the survey to illustrate your thoughts.

First Stage (Unexplained phenomena, Surprising phenomena): Seasonal temperature changes occur in Korea, which lies at a middle latitude. Describe the phenomena accompanying seasonal temperature change.

Second Stage (Domain-specific background knowledge, Conjecture and invention of hypotheses):List the possible explanations for the phenomena you identified. Use as much of your existing knowledge as possible.

Third Stage (Domain-specific background knowledge, the selection of hypotheses): Check to see if the explanations of the observed phenomena proposed are adequate. What is the most plausible explanation?

Fourth Stage (suggesting anomalies):How is your explanation affected by the fact that the distance between the Sun and the Earth is slightly greater during summer than in the winter?

Fifth Stage (Hypothetico-deductive Method, justification of selected hypothesis) If your hypothesis is correct, then what happen?

c) Classification of the Pre-service Elementary School Teachers' Alternative Models through Belief Revision based on Abductive Process

Construction of the Explanatory Alternative Models

Preliminary Stage *(Domain-general entrenched presupposition background knowledge)*

After exploring students' knowledge related to astronomical phenomena based on their responses to the questions developed by Feigenberg et al. (2002), we interviewed students about the concept of celestial bodies that are far from Earth. We investigated whether they understood sunlight as rays emitted from a nearby heat source (the "lamp theory") or as a nearly parallel ray from a distant celestial body. We selected six people who proposed the lamp theory and conducted the interviews according to an abduction strategy. We assumed that all six students generated this theory on their own.

The question about the shadow of a tree in the appendix (Appendix1, Question 2) was used only as a reference. This is because the lamp theory is rarely proposed when considering a narrow range and is more often shown when the range is large, as in (Appendix1, Question 1) As shown in Figure 3 below, the responses for the two cases were tied in to the "lamp concept". Similarly, in Figure 4 (b), the light of the lamp is in close proximity to the ground, so it spreads everywhere and illuminates everything nearby.

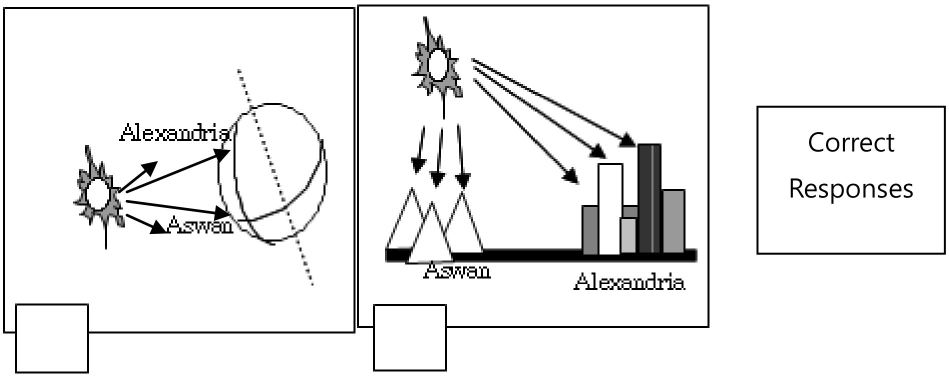

Figure 3. *Students' Explanations About Sun's Position At Noon*

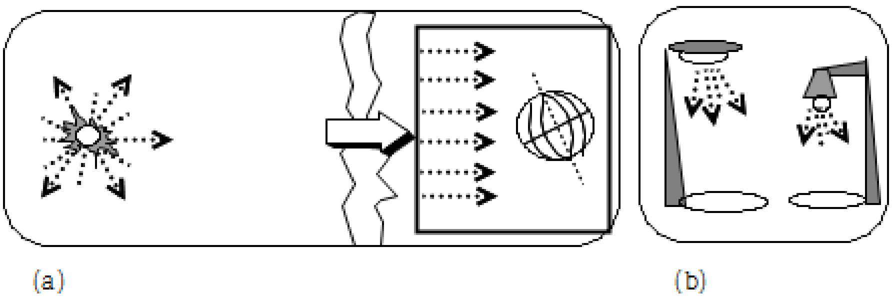

Figure 4. a) Correct understanding b) every day experiences

For this preliminary interview stage, we used the diagrams by Feigenberg et al. (2002).They show that light radiates in all directions when close to the Sun, as in Figure 4 (a), but once the light reaches the Earth, it is approximately parallel because the distance between the Sun and the Earth is very great. Therefore, it is not externally apparent but is deeply latent.

Surprising Phenomena (domain-specific background knowledge):

Students were given the following prompt: *Seasonal temperature changes occur in Korea, which lies at a middle latitude. Describe the phenomena accompanying seasonal temperature change.* The main strategy in this stage is to emphasize that the phenomenon occurs only in the middle latitudes, as in Korea.

Conjecture and Invention of Hypotheses:

This step involves identifying the key explanatory hypothesis for explaining a certain astronomical phenomenon. First, the students' main thoughts were investigated using the questionnaire (Appendix 3, 4) developed by Kikas (1998a, 1998b). The interviews were based on this questionnaire to understand their thoughts more clearly. The interviews were tape recorded. The interviews began with the following instructions: *List all possible explanations and how they explain the phenomena observed around us.*

Development of possible hypotheses determines which background knowledge will be used. In other words, we first consider whether the background knowledge being used is based on life experience, existing scientific knowledge, or both. Thus, the hypotheses generated can be grouped according to their source.

Selection of Hypotheses:

This phase involves selecting the most plausible explanation out of the possible explanatory hypotheses generated. The students were given the following instructions:

Of the explanations you have proposed, determine if there is any explanation that is not adequate for explaining the observed phenomena based on your background knowledge. Additionally, identify the most plausible explanation.

In abductive reasoning, eliminating the explanations that contradict background knowledge or the observed phenomena is an important strategy. At least one hypothesis with a relatively high probability of survival should be selected.

Preliminary Testing: In this phase, students evaluate the selected hypothesis in terms of consistency with the presentation of an inconsistent event. The anomaly that was presented varied according to each student's thought process.

Preliminary hypothesis testing is usually defined as the selection of the hypothesis, but the two phases can be distinguished from each other. If a hypothesis is selected based on what is believed to be plausible, preliminary hypothesis testing is an evaluation of the probability and truth of the hypothesis itself.

In epistemology, hypotheses that become laws are called generalization hypotheses, and hypotheses that become theories are called explanatory hypotheses (McComas, 2000). Theories are developed based on the laws of nature, and they explain the laws by presenting their causes. Furthermore, a law is a statement about the relationship between observable phenomena, whereas a theory is a system explaining the properties that cannot be observed (McComas, 2000).

Consistency, an important element of coherence, is a form of epistemological commitment that shows the reasoning between the concepts. Students organize existing concepts, and in the process of validating them, they display a pattern of explanatory consistency. Here, explanatory consistency does not refer to reasoning about scientific concepts but rather to the students' individual consistency. In conflicting situations, explanatory consistency is important for the maintenance and protection of the existing concepts or for developing temporary hypotheses (Watson et al., 1997, p.426).

In this study, the explanatory hypotheses were considered to be incomplete as they explain only some phenomena, despite being developed for use as theories. In the preliminary evaluation stage, we examined how the students' explanatory hypotheses changed based on their explanatory consistency.

■ **Revision**: Participants with an in-depth **(entrenched presupposition)** lamp conception were selected, and their process of explaining the seasonal changes was reconstructed through interviews as follows. The following is an excerpt from the interviews with pre-service teachers who hypothesized a visibly elliptical orbit and placed summer at the perihelion.

Researcher: Seasonal temperature fluctuations occur only at middle latitudes, as in Korea. Describe the phenomena that accompany seasonal temperature changes.

Respondent 1: The Sun gets weaker and then stronger. [After thinking for a while] In Korea, the Sun is low during winter and high during summer. **(Additional observations**)

Researcher: List all possible explanations for these phenomena.

Respondent 1: If we think that the Sun is an object that gives off heat, it would be the changes within the Sun itself, and the changes in the distance between the Sun and the Earth. Um… the tilt of the rotation axis based on before knowledge… **(Conjecture and invention of hypotheses)**

Researcher: Of the explanations you have proposed, is there any explanation that did not explain the observed phenomena adequately? In contrast, what is the most plausible explanation?

Respondent 1: As I understand, change within the Sun itself is unlikely. That is because the Sun is known as a very stable star. If the Earth is closer to the Sun due to the elliptical orbit, then wouldn't it be summer, while at a far distance it would be winter? Additionally, in Korea, um… if the axis of rotation is tilted this way, then it can be explained with the meridian altitude. **(Selection of a hypothesis)**

Researcher: Then, if it is summer in the Northern Hemisphere, would the Southern Hemisphere also be the same summer season? **(Anomalies 1)**

Respondent 1: [Appearing embarrassed] No.[Appearing to be thinking carefully] As I told you a moment ago, the Southern Hemisphere would be further from the Sun due to the tilt of the rotational axis, so it would be a different season.

Researcher: Actually, summer in the Northern Hemisphere corresponds to the aphelion of the Earth's elliptical orbit, so how would you explain that? **(Anomalies 2)**

Respondent 1: [Flustered] Then, it is certain that the elliptical orbit has no effect.

Researcher: Then, can you explain why the meridian altitude is higher and the daytime is longer during the summer compared to other seasons? **(Additional observations)**

Respondent 1: [Confidently] I think that is because the rotational axis is tilted. Obviously, if the meridian altitude is higher, then the day is longer. Additionally, it is natural that a large amount of the Sun's energy comes to the Earth. **(Preliminary Testing of Hypotheses)**

After presenting multiple anomalies, the initial lamp conception and the consistent initial belief in the effect of the changing distance from the Earth to the Sun were discarded. An additional anomaly was presented to illustrate the revision or change in the student's hypothesis.

When suggested hypothesis is more comprehensive, it can be justified as follow:

Reconstruction based on hypothetico-deductive method procedure

(If .....)The reasons of the seasonal change are the tilt of Earth's axis to the plane of its orbit around the Sun is correct (**Tilt of sun's lay hypothesis**),

(and..)Approximately plane wave arrive at surface, and have learned that Earth is nearly circular revolution (**test conditions**)

(then..) the amount of light at same surface we receive from the sun will be varied (expected Results)

(And......) students have learned that Earth is nearly circular revolution, the variation of a amount of sun's light intensity by the Earth's axis tilt are explained(**observation results**).

(Therefore...) the causes of the seasonal change owing to the tilt of Earth's axis to the plane of its orbit around the Sun are correctare supported (**conclusion**).

■**Expansion**: In this step, the addition happens regardless of whether the larger belief set is consistent.

Researcher: Seasonal temperature fluctuations occur only at middle latitudes, as in Korea. Describe the phenomena that accompany seasonal temperature changes.

Respondent 2: The Sun gets weaker and then stronger. The wind blows from the north during winter, and the wind blows from the south during summer. [After thinking further] In Korea, it seems that the altitude of the Sun during winter is low and high in the summer. Is this correct?**(Observation of phenomena)**

Researcher: List all possible explanations for these phenomena.

Respondent 2: If you compare the Sun to an object that gives off heat, I think the reason may be the changes in the Sun's latitude, as well as the changes in the distance between the Sun and the Earth based on life.**(Hypothesis generation)**

Researcher: Of the explanations you have proposed, is there any explanation that did not explain the observed phenomena adequately? In contrast, what is the most plausible explanation?

Respondent 2: If the Sun is at a close distance, wouldn't it be summer, and if the Sun is at a far distance, wouldn't it be winter? Wouldn't the Earth's elliptical orbit of revolution explain it? And, um… also, if the Earth's rotational axis is tilted, the meridian altitude can also be explained. I don't know exactly, but the changes in the latitude do not explain it, except for the effect of the wind.**(Hypothesis selection)**

Researcher: Then, if it is summer in the northern hemisphere, would the southern hemisphere also be the same summer season?

Respondent 2: [Stumped] No, it wouldn't be. [Thinking for a while] In my opinion, the seasons are different because the energy that the southern hemisphere receives from the Sun is different due to the tilt of the rotational axis.

Researcher: Then, can you explain why the meridian altitude is higher and the daytime is longer during the summer compared to other seasons?

Respondent 2: I think that is due to the tilt of the rotational axis. If the meridian altitude is high, then the day would obviously be long. Additionally, a lot of the Sun's energy comes to the Earth.

Researcher: Are you saying that the distance from the Sun and the tilt of the rotational axis have effects?

Respondent 2: [Hesitant again, but appearing satisfied] Yes, I think the tilt of the rotational axis has an effect, but the effect of the distance must also be present. (**Preliminary evaluation of the hypothesis**)

Pre-service teachers who initially had an in-depth **(entrenched presupposition)** lamp conception were interviewed according to the abduction strategy. The transcript below illustrates that when a new tilt theory was simply added without changing the distance variation; the inconsistent event was not recognized as above and instead was used to justify the distance theory.

Reconstruction based on hypothetico-deductive method procedure

(If .....)the reasons of the seasonal change are the distance between Earth and Sun and the tilt of Earth's axis to the plane of its orbit around the Sun are correct **(distance variation hypothesis),**

(and..) Spherical wave (lamp conception)arrive at surface, and have learned that Earth is elliptical revolution**(test conditions)**

(then..)the amount of light at same surface we receive from the sun will be varied owing to ecliptic revolution around the sun **(expected Results**)

(And......)students have learned that Earth is nearly circular revolution rather than extreme ecliptic revolution **(observation Results).**

(Therefore...)the reasons of the seasonal change owing to distance between the sun and Earth is not supported (**conclusion).**

Thus teacher show the need of a new hypothesis generation procedure to students.

■ **Contraction:** In this process, the initial belief set became so small that it could no longer be maintained without adding any new facts.

Researcher: Seasonal temperature fluctuations occur only at middle latitudes, as in Korea. Describe the phenomena that accompany seasonal temperature changes.

Respondent 3: It seems that the Sun's altitude is low during winter and high during summer. Am I correct? The Sun becomes weaker and then stronger. **(Observation of phenomena)**

Researcher: List all possible explanations for these phenomena.

Respondent 3: If you compare the Sun to an object that gives off heat, I think the reason would be the changes in the Sun's latitude, as well as the changes in the distance between the Sun and the Earth based on the intensity variation of lamp light.**(Hypothesis generation)**

Researcher: Of the explanations you have proposed, is there any explanation that did not explain the observed phenomena adequately? In contrast, what is the most plausible explanation?

Respondent 3: If the Sun is at a close distance, wouldn't it be summer, and if the Sun is at a far distance, wouldn't it be winter? Wouldn't the Earth's elliptical orbit of revolution explain it? And, um… also, if the Earth's rotational axis is tilted, the meridian altitude can also be explained. There is a change due to the distance, but wouldn't the changes in energy due to the tilt of the rotational axis be a more likely possibility?**(Hypothesis selection)**

Researcher: Can you explain the reason for indicating the position of the Earth on the orbit for each season and the cause of seasonal changes? Additionally, why is it wintertime when the Earth is closest to the Sun? **(Presentation of anomaly)**

Respondent 3: I knew even before this interview that it is winter when the Sun is close and summer when it is far. However, couldn't the reason for this be that …… the change in the distance caused bythe elliptical orbit is small?

Researcher: Then, can you explain why the meridian altitude is higher and the daytime is longer during the summer compared to other seasons?

Respondent 3:[Awkwardly] I just know that the Earth's rotational axis does not stand straight but is tilted. Now that I think about it, I think I learned in the past that it has an effect of changing the meridian altitude and so there is a change in the energy received. Um…. Um… Perhaps the seasonal changes may be caused more by the tilt in the rotational axis rather than the effect of the Earth's elliptical orbit …probable the elliptical orbit seem to be more explored.**(Confirmation of the hypothesis through preliminary evaluation of the hypothesis)**

Participants had an in-depth**(entrenched presupposition)**plane wave, but they did not explicitly endorse the distance theory (main hypothesis).

Evidence of eccentricity challenges the distance theory, leading students who hold this theory to question their chosen explanation.

However, additional effort (data) is required because emotional uncertainty is expressed to some extent. And then, teachers must show that justification of hypothesis was completed after additional data suggestion to students

(If .....) the cause of the seasonal change are the tilt of Earth's axis to the plane of its orbit around the Sun rather than Earth's ecliptic revolution around the Sun is correct **(tilt of sun's lay Theory)**, (and..) Approximately plane wave arrive at surface, and have learned that Earth is nearly circular revolution(**test conditions**)

(then..)the amount of light at same surface we receive from the sun will be varied (**expected results**)

(And......)students have learned that Earth is nearly circular revolution, the variation of a amount of sun's light intensity by the Earth's axis tilt are explained (**observation Results**).

(Therefore...) If students have learned that Earth is nearly circular revolution, the reasons of the seasonal change owing to the tilt of Earth's axis to the plane of its orbit around the Sun are correct are supported **(conclusion**).

The pre-service teachers with an in-depth lamp conception who explained the seasonal changes with distance theory, Respondent 1(6/30)demonstrates a case of withdrawing the distance theory when a type of inconsistent event was present and accepting a new theory

Respondent 2 (10/30)demonstrates case of partially accepting the tilt theory while continuing to adhere to the distance theory. Respondent 3(5/30)initially held the distance variation but later partially withdraw it, with a doubt for his initial conceptions, leaving this student in a transitional stage in which the abduction process is not complete. Additional information is necessary for this student to complete the abduction process.

No classification, Respondent (7/30) demonstrates a case of different types of hypothesis with Respondent 1 and Respondent 2(see The Table 1).

Table 1. *Classification Of Belief Variation Of Pre-Service Elementary Teachers About Seasonal Change Through Abductive Strategies*

Phase	Stage	**Revision <respondent 1>**	**Expansion <respondent2>**	**Contraction <Respondent3>**		**Correct**
Preliminary exploration	entrenched presupposition	**Spherical wave** at lamp at near heating	**Spherical wave** at lamp at near heating	**Nearly plane wave** of the sun's ray arriving at Earth's surface		**Nearly plane wave** of the sun's ray arriving at Earth's surface
Generation of Hypotheses Phase	Surprising observations	Sun's Intensity and , Altitude variation of meridian passage	Intensity of Sun and Wind, and , Altitude variation of meridian passage	Sun's Intensity and , Altitude variation of meridian passage		Altitude variation of meridian passage
	Conjecture and Invention of Hypotheses	Sun's intrinsic energy variation, and the earth's distance variation to the sun **based on everyday experiences**	Earth's Latitude variations of Sun and, distance variation between Sun and Earth **based on everyday experiences**	Earth's Latitude variations of Sun and, distance variation between Sun and Earth **based on everyday experiences**		Earth's revolution about Sun and Earth's axis rotation based on tilt of earth's rotational axis **based on scientific knowledge**
	Selection of Hypothesis	the earth's **distance** variation to the sun	**distance** variation between Sun and Earth	distance variation between Sun and Earth, and **tilt of earth's rotational axis**		Main theory
Testing of Hypotheses Phase	Preliminary Testing of Hypotheses	Give up of distance variation: Altitude variation of meridian passage owing to tilt of earth's rotational axis	The consistent holding of distance variation between Sun and Earth	Through give up of distance variation, tilt of earth's rotational axis- - need to additional data		Classification criteria By suggestion of anomalies
	Hypothetico-Deductive Method	Justification	Falsification	Conditional justification	Expected Results	No classification
Numbers of pre-service teachers (n/30)		6	10	5	2	7

First, what is the abduction strategy for explaining surprising phenomena?

In the first stage of the abduction strategy, by stressing that surprising phenomena only occur in middle-latitude countries like Korea, we were able to naturally draw out the tilt of the rotational axis in interviewees' explanations of the seasonal change.

Second, what background knowledge is used for generating and selecting hypotheses in the abduction process?

During hypothesis generation, which is the second stage in the abduction strategy, the generated hypotheses are not completely different hypotheses but rather hypotheses of the same type (Hanson, 1965). This means that the same elements of background knowledge were used to develop all of the possible hypotheses.

Excluding the transitional period in the model formation, the lamp theory developed from domain-general background knowledge acquired during childhood is found to constitute the core of the current model. Figure 5 shows that a new theory develops gradually based on domain-general background knowledge.

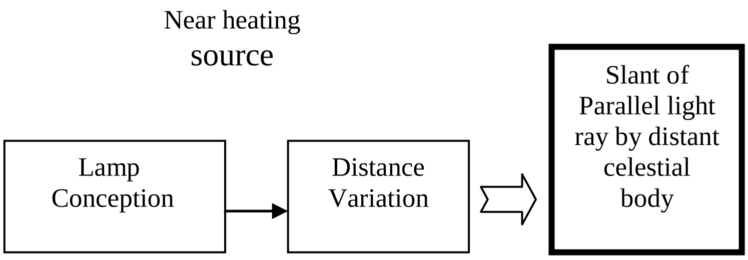

Figure 5. *Pre-Service Elementary Teachers' Conceptual Change Aspects*

Third, what is the students' preliminary evaluation of their main theory and hypotheses?

The fourth stage of the abduction strategy, which concerns the consistency or inconsistency of students' responses during the process of justifying the initially selected hypothesis, asks how the initially introduced point of view changed. To protect their unclear explanation, students may have one theory that becomes the basis for their explanations, and the students may explain the phenomena within the scope of their limitations or enter a transitional state from one theory to another.

With more auxiliary hypotheses, the degree of consistency is lower, and if a new hypothesis was implemented but had little effect on the initial theory, then consistency decreases. Nevertheless, there is consistency because the auxiliary hypotheses within the theory are adjusted. At first, the students believed that the perihelion in an exaggerated elliptical orbit corresponded to summer. When presented with the information that summer in the Northern Hemisphere does not occur concurrently with summer in the Southern Hemisphere, they explained this anomaly with the tilt of the Earth's rotational axis without weakening the distance theory. This alternative model has consistency, albeit less than the scientific model. In sum, students tended to move towards a lower consistency of their beliefs during the process of justifying the hypothesis they selected.

Furthermore, at first, the students believed that the Earth follows an exaggerated elliptical orbit and that the perihelion took place during the summer, but then they began to explain the seasonal changes only with the tilt of the light. Therefore, the distance theory was limited or temporarily suspended and logically incomplete, and the consistency of the explanation was low. We categorized this step of the process as a "transitional mental model."However, the students' thought processes may not have changed completely.

Fourth, Lawson (1995) said that the hypothetico-deductive process and the abduction process have a recursive relationship. Tracing the main hypothesis that constitutes the pre-service teachers' alternative models through HD would obviously result in its dismissal. Therefore, using HD with the abduction process is a good strategy to show that the hypothesis selected by the students is ineffective.

CONCLUSION and SUGGESTIONS

In this study, we examined pre-service elementary school teachers' process of forming alternative models explaining seasonal changes according to abductive reasoning. In addition, based on these results, we constructed an alternative model development process based on the abduction process to understand how the pre-service elementary school teachers generate and justify hypotheses that explain seasonal changes to develop their own alternative mental models.

First, In response to the question of whether seasonal changes occur only in middle-latitude countries like Korea, most pre-service teachers considered the tilt of the Earth's rotational axis, although insufficiently.

Second, Most students demonstrated the lamp theory of a close heat source to explain the Sun's behavior rather than considering it to bea celestial body. They limited the number and structure of their alternative models and used domain-general background knowledge for generating their models. This result is consistent with the suggestion that the hypotheses generated from the students' background knowledge by the abduction strategy are ultimately of the same type

Third, As an explanation for seasonal changes, the pre-service teachers believed that the Sun's energy changed due to the Earth's revolution within the exaggerated elliptical orbit. This explanation strongly supports the "distance theory", which is an offshoot of the "lamp conception". It is more appropriate to discuss the process of belief changes as the "maintenance of the hypothesis (belief) by additional concepts" rather than as "changes in hypothesis (belief)" or "revision of hypothesis (belief)".

The results illustrate the process of using only nonscientific hypotheses while using only one theory consistently without modification. As the beliefs contributing to the model change, "maintenance of the hypothesis (belief) by additional concepts" is shown. Moreover, pre-service teachers who are in the intermediate stage of moving toward a scientific understanding of the phenomenon were found to undergo a transitional period of doubting the belief without showing any change in the belief (theory). Although the existing hypothesis (belief) is significantly restricted in its relevance, additional evidence and learning are necessary to accept the new hypothesis.

Fourth, It is possible to have more than one competing hypotheses to explain a phenomenon. However, teachers can be help their students to know whether their hypothesis is correct or falsified through the hypothetico-deductive method from the students' perspective.

Finally, abduction strategies can trace the students' process of generating hypotheses during problem solving. Because the abduction process emphasizes hypothesis generation via discovery, it is possible to identify the process and the source of hypothesis generation.

Our study used the abduction strategy to describe the stages of the students' alternative model formation, but research identifying more detailed stages of the abduction strategy is necessary. Additionally, seasonal change is a very difficult process to understand when it is taught in elementary school. Hence, we propose that pre-service elementary school teachers learn how to explain seasonal change through abductive reasoning. For teachers to successfully guide elementary school students in scientific activities, teachers must possess both the appropriate scientific knowledge and the necessary abductive inference skills. Therefore, the educational courses for pre-service teachers must recognize problems in scientific inquiry situations and create process to resolve those problems.

Finally, future research should compare the research process of actual scientists to the research process of teachers. This suggestion is based on the assumption that scientists and students use similar processes to develop scientific knowledge.

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