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Using Teaching Strategies of Model-Based Co-construction of Pre-service Elementary Teachers about Seasonal Change

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ABSTRACT

The **main purpose** of this study is to develop teaching strategies for "Model-Based Co-construction" to promote students' understanding of a scientific model of seasonal change. In particular, the **research method** is cognitive conflict strategies and teacher feedback in interaction with the students a reexamined in the context of pre-service elementary teachers at J. National University of Education in South Korea. The **research results** show that prompting learners' scientific model reconstruction through cognitive conflict strategies and teacher-student interaction could be a promising tool to enhance science teaching of astronomical subject matter that is resistant to conceptual change. The **research implication** is that Model-Based Co-construction provides a graduated approach to learning that is highly applicable to the history of science and its ongoing evolution.

Keywords: Teaching strategy, Kuhn's philosophy, pre-service elementary teachers, Model-Based Co-construction, seasonal change

INTRODUCTION

"Teachers often feel that these goals are incompatible" (Clement 2008c, pp.1–2). The main strategy takes an intermediate explanatory model. The strategy is one of student-teacher co-construction that elicits student generated model elements by contributing some from the teacher (Rea-Ramiraz, 1999; Steinberg & Clement, 2001; Clement & Steinberg, 2002). Therefore, our research aims to develop teaching strategies of what has been referred to as "Model-Based co-construction," involving teacher-student interaction for transitional conceptual change. Low perceptions of student abilities can act as a barrier to student-centered

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instruction such as inquiry and negatively impact student achievement (Mulvey, Chiu, Ghosh, and Bell, 2016).

Recently Ucar and Demircioglu(2011) have stated that the astronomy course for pre-service elementary teachers should be spread over four programs, using modules with fewer credit hours, instead of one course with a large number of credit hours, for the reason that astronomical preconceptions are resistant to conceptual change as scientific concepts. Several researchers (Kikas 1998a; Duschl, Schweingruber, & Shouse 2007; Lee, 2010) have suggested that commonly used orbit diagrams, which depict the earth's orbit as an exaggerated elliptical shape to render perspective, produce the common misconception that the colder seasons on the earth are due to the greater distance of the earth from the sun.

Aims of the article:

In this paper, we will address the reason – the nature of teaching – by showing the findings from using a strategy of Model-based Co-Construction. The basic research question concerns how students' models change with questions and activities from their teacher in a Co-constructive process. This involves providing pre-service teachers with opportunities: (1) to examine their preconceptions in the light of specific teaching and facilitating them to construct firstly an intermediate model, and (2) then will hopefully move to the scientific model about the medium group for seasonal change.

Theoretical Framework

According to Clement(2008b, p.270), the teaching strategies of Model-Based Co-construction have all been concerned with the problem of how to get students to actively engage with the cognitive activity of generating, evaluating, and modifying mental models to attain deeper levels of scientific conceptual understanding. This activity is seen as lying at the core of learning science through understanding. Some general teaching strategies were found that appear to cut across science curricular and grade levels: model evolution, fostering GEM cycles, co-construction, building on positive preconceptions, etc. The theory of Model-based Co-construction developed in this research attempts to integrate social and cognitive perspectives to explain science instruction (cf. Billet, 1996; Bulgren et al. 2000).

Classical Conceptual Change theory (Posner, et al., 1982) arose from the work of both Piaget's theories of children's individual learning and Kuhn's science studies(Kuhn, 1970), as well as work in science education on student's preconceptions. Posner et al (1982) suggest that the student must be dissatisfied with their present conception, by anomalies or conflicts.

While Piaget and many in the classical conceptual change field sought to describe the cognitive change taking place within individual learners, Vygotsky (1978) suggest that knowledge is negotiated as learners interact with each other and share ideas and experiences. However, Vygotsky's sociocultural theories are very broad and often have little empirical support (Anderson, et al., 2001, p.2).

Collins and Gentner (1987. P.243) argued that individuals, when reasoning about simple unfamiliar domains, use analogical mapping "to create new mental models that they can then run to generate predictions about what should happen in various situations in the real world". Moreover, Clement (1988) documented the use of analogies by experts in constructing explanatory models while solving explanation problems. The origins of mental modeling theories as an alternative view of reasoning can be traced to criticisms of positivist views of science made by historico-critical philosophers, such as Kuhn and Lakatos (Rea-Ramirez et al. 2008c).

If these conflicts are resolved, the pre-conceptions of students can reorganize scientific concepts to set a goal. However, the conceptual change of students can be said to occur gradually rather than drastically. Therefore, on the basis that gradual conceptual change occurs, a viewpoint of a revised conceptual change has been put forward.

Dissonance can be the result of the teacher or students using a discrepant question, a thought experiment, negative feedback, or other techniques. As a product of the evaluation process, a competing model that is not compatible with the target can be disconfirmed in the sense that it does not reappear in the classroom discussions. Thus, this teacher-student interaction pattern is called the Disconfirmation Mode (Núñez-Oviedo & Clement, 2008, p.119).

After engendering a conflict to initiate the students' alternative model through a first discrepant event as an experiment or new perception, the new core theory should be suggested to resolve this conflict.

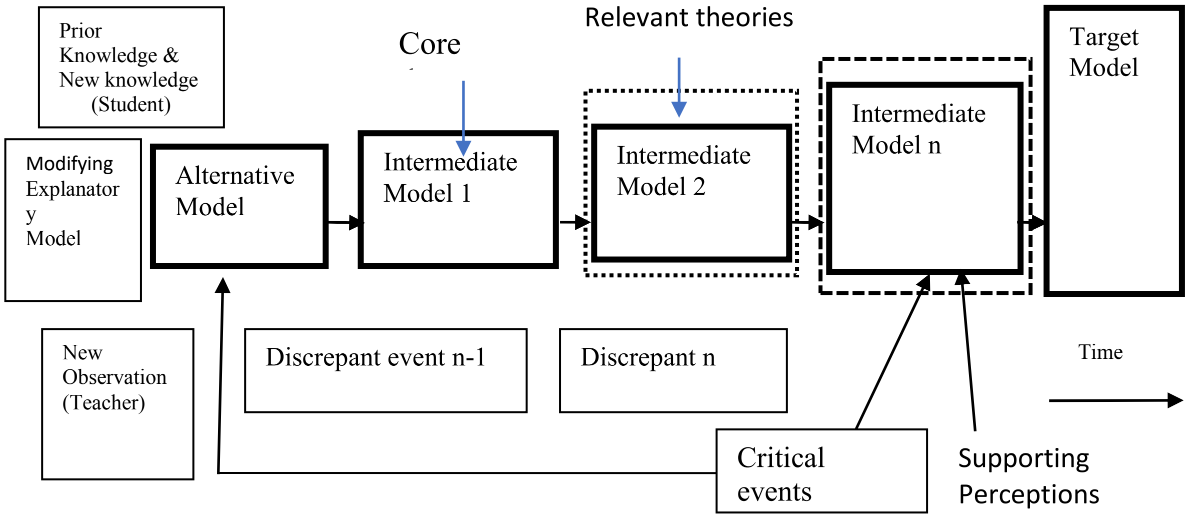

Figure 1. *Modifying Explanatory Model*

METHODS

a) Participants

This study was conducted during the fall semester of 2011, and participants included freshman preservice elementary teachers from National university of Education in Chonju City, South Korea. None of the participants had any previous experience in modeling-related learning or instructional activities. Participants were selected from two different classes taught by the same professor and teachers by purposive sampling. The students were then classified into two groups based on their same freshman during the fall semester in 2011.

Participants were selected from two different classes taught by the same professor and assistant teacher by purposive sampling. The students were then classified into two groups based on their same freshman during the fall semester in 2011.

One comparison group (n=20 students) was assigned to the pre-service elementary teachers' group as the traditional instruction group. The experimental group (n=21 students) was assigned to the pre-service elementary teachers group as the co-construction group. The students completed written questionnaires and recoding in the practical classroom to identify their ideas regarding the causes of seasonal changes.

A male science professor with twenty years of teaching experience, who was assisted by a female science teaching assistant with two years of teaching experience, taught both classes. The professor held a Bachelor of Science degree and a Master of Science degree in astronomy, as well as a doctoral degree in science education and the philosophy of science.

b) Procedures

In the pretest questionnaire, the test situation was described in sufficient detail to allow respondents to answer the questions. The structure of the students' alternative model as well as the discrepant events, critical events, and relevant concepts were based on the results of this pretest. Thus, we had two groups (approximate 20 pre-service elementary teachers).

Table 1. *The teaching sequence and strategies of the Model-Based Co-construction for seasonal change*

	Stage of model-building process	**Time taken to accomplish this stage & how this is done**
	Diagnosis of pre-service teachers' initial alternative model and their reasoning (Strong Distance Variation)	One class period for teachers to do a pre-test requiring written answers Follow-up interviews in …
M1	Discrepant Event 1(Conflict 1) – learning opportunities provided i.e. experiences which cause dissatisfaction with their initial alternative model After engendering conflict 1, Building Intermediate Model1 by New core theory (Plane wave+ weak distance variation)	One class period to do the flashlight experiment: In an experiment of Eratosthenes' calculation of the circumference of the earth by plane waves (parallel line rays), and not spherical waves, plane waves reach the earth's surface because the Sun is far away from the Earth. Teacher's Question: If the flashlight experiment is recalled, is it possible to explain the seasons with distance changes? Building Model 1 by New core theory
M2	Discrepant Event 2(Conflict 2) – learning opportunities provided i.e. experiences that cause dissatisfaction with their intermediate model 1. After engendering conflict 2, Building Intermediate ModeL 2 by The relevant theories supporting the new core theory. (Tilt of light ray theory)	One class period to do the flashlight experiment (elaborate on this here or below) After engendering another conflict for Intermediate Model1 (n-1), with the next discrepant event as an experiment (drawing the revolution orbit of Mars with that of Earth; assumption: near-circular revolution of the earth), relevant theories (tilt of Earth's rotational axis, the near circular revolution, and the rotation of the earth) supporting the new core theory should be suggested to resolve another conflict. The relevant theories supporting the new core theory represent the construction of the next intermediate model 2 (possible high level intimidate model).

TM	Critical Event – learning opportunities provided difference between initial model and possible high level intermediate model. After engendering Critical Events, Building <u>possible target Model</u> by additional perceptions of seasons through experiments (Strong tilt of light ray theory)	1. To make matters worse for people in Korea (the middle latitude of the nort hern hemisphere) who hold this dista nce hypothesis, the earth is actually c losest to the sun in January, when the Northern hemisphere is in the middl e of winter. If distance were the governing factor, why would the two hemispheres have opposite seasons? 2. As we shall show, the seasons are in f act caused by the 23˚ tilt of the earth' s axis relative to the plane in which we circle the sun. Specifically, we ca n explain only the southern hemisphe re using the distance theory that most of the students hold.
TM	Target Model for Seasons	

After classroom instruction using two discrepant events (experimental: individual 50minutes), especially two discrepant events were conducted to engender cognitive conflicts with the learners' previous thinking. Final test were used after the critical events and supporting perception in the experiment. A paradigm is not refuted instantaneously by a rival paradigm, so conceptual changes were investigated one month after instruction in the classroom. The questionnaire was used as the second pretest and final posttest without modification, and recoding in the practical classroom and interviews were conducted to provide supplementary information. In contrast, the traditional approach involved a direct lecture and explanations of the cause of seasonal change, and the teaching procedure excluded discrepant and critical events. Also, the second test was taken after the first test, because the learners' thinking was beyond the knowledge of the classroom (at elementary or secondary school).

c) Model formulation by core theory

Fig. 2 shows that, at the starting point, after engendering a conflict with the students' initial alternative model by the first discrepant event as an experiment (Eratosthenes' evaluation of the earth's magnitude: assumption of the sun's rays arriving via near plane waves), the new core theory (tilt of sun's ray theory) should be suggested to resolve this conflict. This new core theory then represents the construction of the first intermediate model 1, However, the new core theory should be suggested by students and be responded to by the teacher with "Yes" or "Good," as positive feedback in the classroom.

Most learners believed that the cause of the seasons' changes was due to the distance variation based on the conception of a spherical light wave with the relevant theories of the earth's elliptical orbit and/or the tilt of the earth's rotation axis (A2, or A3d, see Table1, Initial Students' alternative model in this study).

Discrepant event 1

Teacher Question: For example, in an experiment of Eratosthenes' calculation of the circumference of the earth by plane waves (parallel line rays), and not spherical waves, plane waves reach the earth's surface because the Sun is far away from the Earth. If the flashlight experiment is recalled, is it possible to explain the seasons with distance changes?

Student Responses: In our opinion, although the sunlight reaches the earth as plane waves, because the earth revolves around the sun on an elliptical orbit, seasonal changes are possible with distance changes. Ah… the tilt of the earth's rotation axis is possible (A3c, see Table1, initial intermediate model 1 in this study).

Teacher's Positive Feedback: "Good." That explanation appears to be persuasive.

d) Model's formulation by relevant theories

After engendering another conflict for Intermediate Mode(1), with the next discrepant event as an experiment(drawing the revolution orbit of Mars with that of Earth; assumption: near-circular revolution of the earth), relevant theories(tilt of Earth's rotational axis, the near circular revolution, and the rotation of the earth) supporting the new core theory should be suggested to resolve another conflict. The relevant theories supporting the new core theory represent the construction of the next intermediate model (2), shown in Fig. 4.

All recordings were used in the classroom and selected according to categories of classifying students' ideas.

Discrepant event 2

Teacher's Question: Because the eccentricity of the earth is very small compared to that of Mars, we find that the earth orbit is nearly a circle. Figuratively, the flashlight experiment shows no significant intensity variation in a circle orbit. Do you have another idea to change distances? The elliptical one does not work as an astronomical explanation of seasonal change.

Students' Responses: An idea came to mind. According to the lighting angles of the flashlight, they differ… Not the revolution orbit of the earth… Naturally, seasons change according to tilt angles of sunlight owing to the tilt of the rotational axis of the earth (S2, see Table1, intermediate model(2) in this study).However, when the earth is closer to the sun, is it summer? (A3b, see Table1).

Teacher's Positive Feedback: "Yes, good." You are explaining it better and better.

e) Justification of formulated model by supporting perceptions

The learning process should involve a critical event (to address Conflict 2 directly between the students' initial model and intermediate model (2). The difference between a discrepant event and a critical event is that a discrepant event uses some percepts to challenge the students' alternative model, while critical events (the earth is actually closest to the sun in January, when the northern hemisphere is in the middle of winter) seek to directly justify the conflict between the students' initial alternative model and a plausible intermediate model (n).

Critical events

Teacher's Question: By the way, if your initial thought is correct, as the revolution orbit of the earth is not a perfect orbit, when the earth is a little nearer to the sun, it can be summer. In addition, if the northern hemisphere is warm, is it possible to predict that the southern hemisphere is also warm? Or, merely if we say the sunlight tilts somewhat, are other phenomena predicted?

Students' Responses: They may be possible, oh! I do not think they are. We are confused.

Teacher's Positive Feedback: Yes, you are right to be confused about it. In fact, it is summer in Australia during our winter, and further, the conclusive point is that the northern hemisphere is in January when the earth is nearest to the sun.

Students Re-responses: Ah…I see, for these two perceptions to turn out, the earth revolves around the sun with the tilt of the Earth's rotation axis(S1, see Table1).

f) Synthetic target scientific model reconstruction

There are some other perceptions or thought experiments to support and justify the plausible intermediate model (2). Also these other perceptions or thought experiments are used as related support the resolution of Conflict 2. Eventually the fruitful intermediate model (n) is constructed.

Practical experiment

Teacher's Question: Let us perform a practical experiment.

Students' Response: With the seasonal change experiment, meridian transit altitudes with the tilt of the earth's rotational axis during its revolution around the sun are measured directly; also, the lengths of days can be measured according to individual seasons.

Teacher's Positive Feedback: "Yes," on condition that the earth's rotation axis tilts, by changes of the meridian transit altitudes owing to the revolution of the earth around the sun, it can be said that energy changes received from the sun per unit time and area are possible. Therefore, it can be said that seasonal changes are possible due to the changes of lengths of days.

Teacher Follow-up Question: "You all are really excellent." We can say that the cause of seasons changing can result from changes of the meridian transit altitudes due to the Earth's revolution with the tilt of its rotation axis. What do you think are turned by the Earth's rotation with the tilt of this rotation axis?

Students' Re-responses: The length variations of the day due to the rotation of the earth with its rotation axis turn out (S1, see Table 1) the fruitful intermediate model (n) in this study.

g) Instruments

Questions developed by Feigenberg et al. (2002) and Kikas (1998a; 1998b) were used to measure the students' understanding of the nature of the sun's rays and the causes of seasonal change (see Appendix). All of the questions were translated into Korean.

This instrument could be used as a pre- and post-test in physics and astronomy courses to determine the improvement in students' conceptual understanding of the sun's rays. The questionnaire consisted of six items related to the sun's rays (Q1, Q2) and the seasons (Q3, Q4, Q5, Q6). The validity and reliability of the inventory was not assessed because the study involved content developed by the researcher.

This study analyzed students' responses to the questions, as follows:

- Q1 and Q2 investigated the type of wave produced by the arrival of the sun's rays at th e earth's surface. (Entrenched presuppositions, Core theory)
- Q3 and Q4 (Discrepant Event 1) discussed the earth's movement around the sun and th e earth's position on the orbit. (Relevant Theories)
- Q5 (Discrepant Event 2) investigated the students' astronomical theories and their expl anations of the causes of the seasons. (Relevant Theories)

- Q6 (Resolution of discrepant events) investigated the observed phenomena on the earth's su rface related to the seasons. (Supporting Perceptions, Critical events, & Resolving Critical eve nts)

h) The Constructing teaching strategies of Model-Based Co-construction about seasonal change

Several studies (Atwood & Atwood 1996; Trumper 2001; Tsai& Chang 2005) have found that most students—including graduates of pre-service teaching programs—adopt the common alternative conception that the seasons are dependent on the earth's distance from the sun. This widespread explanation for seasonal change is termed the "distance theory" (Kikas, 1998a; 1998b). Research on the distance theory found that children's mental models of astronomy were similar to ancient and medieval theories (Kikas, 1998a; 1998b). In the present study, we refer to" distance variation" rather than the "distance theory" because the use of the expression "distance theory" might suggest that it provides a scientifically accepted explanation.

i) Discrepant events(experiments)

The Earth Science curriculum in South Korea consists of a course of experiments, including measuring the size of the earth by Eratosthenes' method, and drawing the Mars orbit based on Earth's orbit. Thus, they are used in suggesting discrepant events for the conceptual variation of seasonal change.

First experiment: The evaluation of the radius of the earth by Eratosthenes' method

The purpose of this experiment is to present not the extreme spherical wave concept that most students hold in support of their distance theory, but the near plane wave of the sun's rays arriving at the surface of the Earth (Feigenberg et al., 2002). Eratosthenes, who lived and worked in Alexandria, Egypt, made the following assumptions when designing his famous experiment of measuring of the earth's circumference:

(1) the shape of the Earth is a perfect sphere;

(2) the cities of Syene (modern Aswan) and Alexandria are situated on the same meridian;

(3) the sun's rays that reach the earth are parallel.

Second experiment: Drawing Mars's orbital tract through the earth's orbital tract (Kyung, et al. 2010)

The goal of this experiment is to present the near circular track of the Earth's orbital tract, rather than the extreme elliptical circular track concept that most students hold to support their distance variation theory (Kikas 1998a; 1998b).

j) Critical events and discrepant events

The discrepant events may provide new empirical data to challenge the core and relevant supporting concepts of the students' alternative conceptions, and may cause some dissatisfaction (cognitive conflicts) with their initial ideas. However, the critical events are intended to critically address the more partial inadequacy of alternative models, rather than that of the target scientific concept, drawing on the students' other well-known cultural experiences.

The resolution of Conflict 1 does not necessarily clarify Conflict 2. Conflict 1 may be resolved through discrepant events, and resolution of Conflict 2 may be achieved using "critical events or explanations" and relevant perceptions and concepts that explicate the scientific conception (Tsai 2000).

RESEARCH TREATMENT

Based on students' prior conceptions of rotation of the earth on its axis and its revolution around the sun, the instructor and the other researcher estimated that students understood the target concept presented in the conflict map in approximately three stages, with each stage lasting 50 minutes. Consequently, the researcher proposed a third instructional plan for teaching the target concept in the traditional way, which followed the instructional sequence provided by the conflict map presented in Fig.1. The study researchers collaboratively developed the instructional materials on the topic of seasonal change for the conflict map.

In the first process, which included the first pretest, the researcher asked students to respond to Q1 and Q2 to explain the position of the sun at noon. However, Q1 only tested students' understanding of the rays of the sun, and Q2 only tested auxiliary material. Then, the researcher asked both student groups to identify the possible causes of the seasons by responding to Q3, Q4, Q5, and Q6. Preservice elementary teachers presented their ideas through questionnaire responses, recoding in the classroom, and interviews.

In the second process, which included a second pretest, the researcher introduced the discrepant events as experiments one week after the initial questionnaire and interviews in order to investigate the structure of students' alternative conceptions. First, drawing Mars' orbital track based on the earth's orbital track created cognitive conflict with the notion that the earth's orbit was extremely elliptical. Second, using Eratosthenes' method to estimate the Earth's radius (Feigenberg et al. 2002) created a cognitive conflict with the idea that the sun's rays arrive at the earth's surface as a spherical wave. The results were used to investigate the structure of two groups of students' alternative conceptions through the first and second pretests. No discrepant events were introduced to the traditional instruction group.

In the third process, which included a final posttest, the researcher reviewed the discrepant events presented in the second stage of instruction (one week after the discrepant events were presented) to investigate students' conceptual change one month after instruction involving the critical events. After investigating the structure of students' alternative conception to later student ideas, the researcher provided the scientific explanation that seasonal changes in temperature are due to the 23.58-degree tilt of the earth's axis, which is a core scientific concept.

a) Data collection

The participants provided their ideas about the causes of seasonal change by completing written questionnaires and recoding in the classroom. In addition to responses to questionnaire items, students were interviewed immediately after the questionnaires were administered, and the interview content was transcribed.

The interview questions (e.g., "Could you tell me what you wrote on the answer sheet about the causes of the seasonal change? Do you have any other ideas or theories about what causes this phenomenon?") further probed the student responses to the written questionnaires.

b) Data analysis

Each individual student's data were classified into a main category (i.e., "Scientific," "Alternative," or "No Conception") and one subcategory (except for the category of "No Conception"). The categorization process was conducted by a science education university professor and a secondary school science graduate student. They read the entire set of written questionnaires and interview transcripts independently and decided on a conceptual category and subcategory for each participant's ideas. The researchers then reviewed the transcripts again and discussed them, case by case, to determine a final categorization.

c) Categories for classifying students' ideas

Students' responses to the written questionnaires, recoding in the classroom, and interviews were classified into three primary categories: alternative conceptions, scientific concepts, and no conception. The alternative conception category and the scientific category also included subcategories. A university professor of science education and a graduate student in science education each independently read the written questionnaires and interview transcripts and decided on the primary conceptual category and subcategory that characterized each participant's ideas. Cohen's kappa, which was used to measure agreement regarding categorization agreement between the two researchers, was 0.91.

Alternative model of the cause of seasonal change

Student responses were subcategorized based on the auxiliary protective belts that supported the "core theory" of distance variation. Several studies have found that many students adopt the alternative conception that the seasons are determined by the Earth's distance from the sun (Atwood & Atwood, 1996; Trumper, 2001; Tsai, 2005; Lee, 2010).

(A1) Distance variation

Students believed that the cause of seasonal change in temperature was the varying distance of the earth from the sun. Students in this subcategory did not mention the orbit of the earth's revolution to reinforce their alternative conception.

However, most students in this subcategory mentioned the earth's elliptical orbit, the tilted earth's circular orbit, or the tilted earth's rotational axis, and the concept of light's spherical or plane wave as auxiliary hypotheses that reinforced and supported the core theory of distance variation (A2. A3).

(A2) Orbit supporting distance variation based on the conception of a spherical light wave.

These students believed that the cause of the seasons was based on the earth's elliptical orbit supported the distance variation with an auxiliary hypothesis based on the conception of a spherical light wave. The energy variation due to the variations in the distance of the street lamp that diverged on an illuminated surface were assimilated to the upper figure presentations on written paper by the spherical wave (initial students' alternative model in this study).

Students who not only believed that the distance of the earth from the sun caused the seasons, but also mentioned the orbit of the earth's revolution and the ideas of Earth's tilted rotation axis based on Sun's spherical wave to reinforce their alternative conception.

Other distance variation support (Distance & Orbit & Rotation axis) based on Spherical wave.

- (A3a) Earth's elliptical orbit based on spherical wave sunlight supporting distance variation(initial students' alternative model in this study).
- (A3b) Leaned Earth's circular revolution and tilt of its rotation axis, supporting distance variation: as shown in Tables 2 and 3.
- (A3c) Earth's elliptical orbit and tilt of its rotation axis based on both plane wave and weak spherical wave sunlight supporting distance variation (after individual discrepant or critical events).
- (A3d) Earth's elliptical orbit and tilt of its rotation axis based on spherical wave sunlight supporting distance variation.

These relevant theories are considered as an intermediate model. When the sun is at a high altitude in the sky, the sun heats us with more direct rays and has more time to heat the surface of the earth each day, and the sun makes it warmer for us. Thus, these perceptions are considered as the elements of the intermediate model for a high frequency of correct response ratio (perceptions).

The structure of students' representations of alternative models was identified based on students' initial and later responses to the two discrepant events. Study results indicated that "distance variation," which was the core theory of students' initial conceptions, could not be altered without abandoning the entire theory. However, other relevant astronomical concepts, such as the meridian altitude and the length of day and night observable on the earth's surface, as well as supporting perceptions, were components of the protective belt that supported the core theory.

No models

When the sun is at a high altitude in the sky, it not only heats us with more direct rays, but also has more time to heat the surface of the earth each day. Thus, when the sun's altitude of these facts is represented, we considered them as" a part of soft core," but when all these facts were not represented, this category was classified as "No Models."

Scientific models

The seasons depend on the angle between the sun's rays and the earth's surface. At high noon in equatorial regions, the angle is similar to a vertically held flashlight; and high noon at higher latitudes is similar to a flashlight held at an angle. When the sun's rays are most perpendicular, the region experiences summer. Six months later, when the rays fall at a lower angle, the region experiences winter with the intervening seasons of fall and spring. Another effect of the change in the angle of the sun's rays is a change in the length of daylight of each day. During the summer, a location will have more daylight during the earth's daily rotation than during the winter, when the earth is on the opposite side of the sun. This effect is most pronounced at high latitudes (Hewitt et al., 1994, pp. 651–652).

Table 2. *Categories of Classifying Students' Ideas*

Category		**Core theory**	**Auxiliary hypotheses and perceptions**								
		theory (or Conception)	**Relevant theories**							**Supporting facts**	**Note**
		Tilt of light	**Distance variation**	**Arriving sun's ray**		**Orbit of earth revolution**			**Tilt of rotation on axis**	**Altitude of meridian, Length of night**	
				plane	**Spherical**	**circular**	**elliptical**	**Leaned circular**			
Scientific intermediate model (n+1)	**S1**	○	×	○	×	○	×	×	○	○	
Transitional Scientific intermediate model (n)	**S2**	○	×	○	×	○	Weak	×	○	○	from elliptical To circular, Perihelion on winter
Scientific intermediate model (n)	**S3**	○	x	○	x	x	○	x	○	○	Perihelion on winter
Alternative	**A3a**	×	○	○	×	×	○	×	○	○	
	A3b	×	○	○		×	×	○	○	○	
	A3c	×	○	○	Weak	×	○	×	○	○	from spherical To plane wave **initial intermediate model (n-1)**
	A3d		○	x	○						**initial model**
	A2	×	○	×	○	×	○	×	×	○	
No Conception										×	etc

The scientific conceptions category consisted of students who stated that the cause of seasonal change was the angle of the sunlight reflected due to the 23.5-degree tilt of the Earth's axis. There were various subcategories based on other conceptions, such as the plane wave, axis tilt, earth's orbit, and earth's rotation that were included in the auxiliary protective belts that supported the "core theory" of the angle between the sun's rays and the earth's surface (Hewitt et al. 1994, pp. 651–652).

(S3) Earth's 23.5° axis: tilted based revolution and rotation of earth; elliptical orbit perihelion on winter

Students could not only provide the scientific fact, but also mention the different seasons based on the revolution and rotation of the Earth (intermediate model (n) in this study).

(S2) Earth's 23.5° axis: weak elliptical Orbit perihelion on winter tilted based revolution and rotation of earth;

Students could not only provide the scientific fact, but also mention the different seasons based on the revolution and rotation of the earth. Subcategory (S2) was classified into the transitional scientific model, because it holds both circular (after individual discrepant or critical events) and weak elliptical motion.

(S1) Distance negligible by a circular motion and Earth's 23.5° axis: tilted based revolution and rotation of Earth.

Subcategory (S1) was classified into the correct scientific model.

RESULTS AND DISCUSSION

a) Students' responses in the first test

In the pretest, which was performed before the first discrepant event experiment, three of the 21 students in the co-construction group, and two of the 20 students in the traditional instruction group provided the scientific model of the cause of seasonal change. In contrast, about n[(17(A2(10)+A3d(6)+A3b(1)/21] of the students in the Co-construction group expressed an alternative model, and about n[(16(A2(12)+A3d(3)+A3b(1)/20] of the students in the traditional instruction group held an initial alternative model (see Figure 6 and Figure 7). The cause of seasonal change is often associated with a very particular alternative conception, distance variation, with most categories (A2) and (A3d) resulting in variations in temperature. From this perspective, both groups had similar responses for students' ideas about the cause of the seasons. Their responses show that the initial structures of students' alternative conceptions about the cause of the seasons are the distance variation with spherical waves as an auxiliary hypothesis and the earth's elliptical revolution and tilted rotation axis(perihelion on summer) as relevant theories.

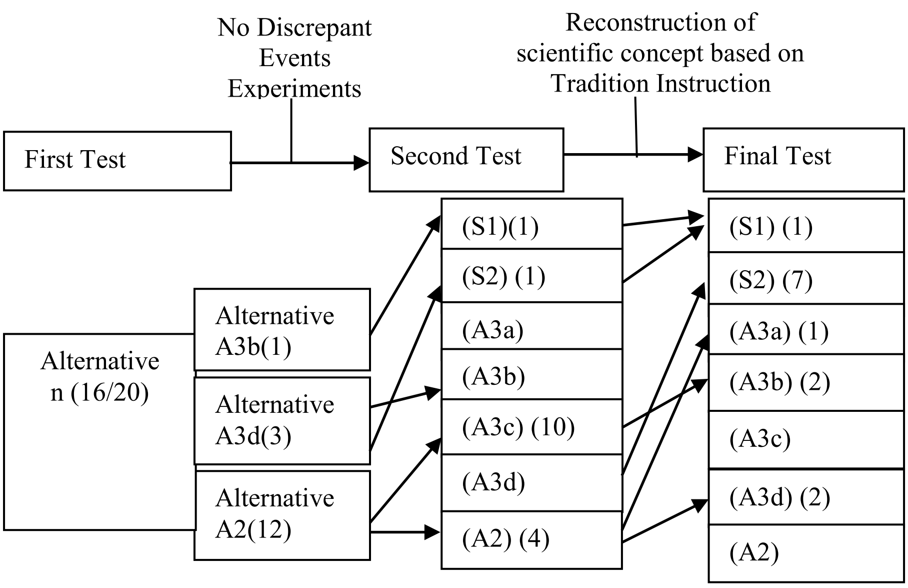

Figure 2. *The process of conceptual change based on traditional instruction group*

b) Students' responses to the second test (core theory and relevant theories after presentation of the discrepant events)

The second test was conducted after the discrepant events were presented. These discrepant events included the assumption of the arrival of the sun's light plane wave using Eratosthenes' method to measure the earth's magnitude, and the comparison of Mars' revolution with that of the earth.

In the second test, the results were similar to the results of the first test. Most of the students in the traditional instruction group (14 out of 16 students) who initially held the alternative conceptions remained in the "distance variation" category, although they were thinking beyond the knowledge of the classroom (elementary and secondary).

The second test revealed that conceptual change occurred in almost all of the theories related to the alternative model in both groups. Most of the supporting facts were changed to those that supported the scientific theory, although approximately 58% (n, 19/33) of the students continued to hold the distance variation view in both groups. These results indicate that it is an oversimplification to assume that students operate as Kuhn's scientists, because students adopt a range of conceptions that are associated with different issues and contexts. It would be rare for any instructional method to fundamentally change all of the students' alternative models.

c) Students' responses on the final test (after perorations supporting main theories instruction with critical event)

In the final test after the research treatment, eight out of 16students (50%) in the traditional instruction group expressed transitional intermediate scientific concepts (S2) regarding seasonal change. In contrast, 16 out of 17 students (94%) in the Co-construction group adopted an intermediate model (S1 and S2). These results indicate that the research treatment improved performance over approximately two months of the current study.

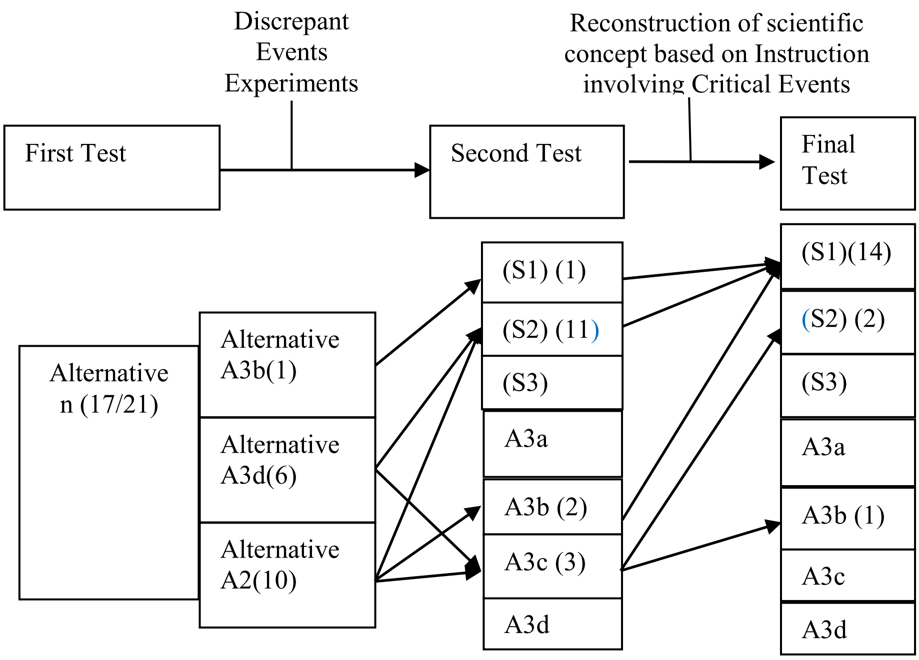

Figure 3. *The process of conceptual change based on co-construction instruction*

These results indicate that it is an oversimplification to assume that students operate as Kuhn's scientists (Maxwell, 2019) , because students adopt a range of conceptions that are associated with different issues and contexts. It would be rare for any instructional method to fundamentally change all of the students' alternative models.

CONCLUSION AND IMPLICATION

In this research, we claim that the use of teaching strategies of Model-Based Co-construction help students to construct a target scientific model through student-teacher interactions.

First, the teaching strategies of Model-Based Co-construction provide a useful instructional framework, not only including a series of discrepant and critical events, perceptions, and theories, but also investigating the structure of an initial model by a series of discrepant events. These enable students to reconstruct conception from initial alternative and intermediate models to the next intermediate model through help of the teacher's positive feedback. Thus, they are better able to construct representations for the better intermediate models. In particular, the presentation of the critical event in a cognitive selection strategy resolves a new conflict between the existing alternative model and most plausible intermediate models.

Second, the elements of teaching strategies based on Model Based Co-construction, as key aspects of the nature of science, lend themselves particularly well to Copernicus Revolution. We present a strategy that begins with the most important core aspects of Model-Based Co-construction and then introduces supportive Science knowledge (SCK) and History of Science (HOS) to explain the cores as *cognitive* earning outcomes through conflict strategies. A number of dissatisfaction episodes in the history of science and revisions may be needed, depending on the distance between the initial model and the target scientific model.

Third, how can pre-service elementary teachers use the teaching strategies of Model-Based Co-construction of seasonal change? Studies such as Atwood & Atwood (1996) and Trumper (2001) have revealed that students, even graduates from prestigious universities and pre-service teachers, usually have a common alternative conception about the causes of seasons—that seasons are determined by the earth's distance to the sun.

Therefore, the widespread explanation of seasonal change adopted by pre-service elementary teachers was "distance variation." The distance variation view of the seasons is an apt example of an alternative conception. Pre-service elementary teachers explained the fact that it is cold in winter and hot in summer based on the altitude of the sun. They provide a coherent explanation of the phenomenon based on the variation in distance between the earth and the sun due to its elliptical orbit around the sun, which is a form of cultural knowledge. Recently Like our approaches to learning, the Causalitic Thinking Approach, aims to construct phenomena that have more than one possible answer (Rokhmat, et al, 2019).

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REFERENCES

Anderson, R. C., Nguyen-Jahiel, K., McNurlen, B., Archoudidou, A., Kim, S., Retznitskaya, A.. (2001). The snowball phenomenon: Spread of ways of talking and ways of thinking across groups of children. *Cognition and Instruction, 19,* 1–46.

Atwood, R.K., & Atwood, V.A. (1996). Preservice elementary teachers' conceptions of the causes of seasons. *Journal of Research in Science Teaching, 33,* 553–563.

Billet, S. (1996). Situated learning: Bridging sociocultural and cognitive theorizing. *Learning and Instruction, 6(3),* 263–280.

Bulgren, J.A., Desher, D.D., Schumaker, J.B., & Lenz, B.K. (2000). The use and effectiveness of analogical instruction in diverse secondary content classrooms. *Journal of Educational Psychology, 92(3),* 426–441.

Clement, J. (1988). Observed methods for generating analogies in scientific problem solving. *Cognitive Science, 12,* 563-586.

Clement, J.J. (2008b). Six levels of organization for curriculum design and teaching. In J.J. Clement, & M. A. Rea-Ramirez (Eds.), *Model based learning and instruction in science*(pp.255–272). Netherlands: SpringerVerlag.

Clement, J.J. (2008c). Model based learning and instruction in science. In J.J. Clement, & M. A. Rea-Ramirez(Eds.), *Model based learning and instruction in science*(pp.1–9). Netherlands: SpringerVerlag.

Clement, J. & Steinberg, M. (2002). Step-wise evolution of models of electric circuits: A "learning-aloud" case study. *Journal of the Learning Sciences, 11(4),* 389-452.

Collins, A. and D. Gentner. (1987). "How people construct mental models", in Holland, D. and Quinn, N. (Eds), Cultural models in language and thought, Cambridge, UK: .*Cambridge University Press*(pp.243-268),

Duschl, R. A., Schweingruber, H. A., & Shouse, A. W. (2007). Taking science to school: Learning and teaching science in grades K-8. Washington, DC: The National Academies Press.

Feigenberg, J., Lavrik, L., & Shungakov, V. (2002). Space scale: Models in the history of science and students' mental models. *Science & Education, 11,* 377–392.

Hewitt, P.G., Suchlochi, J., & Heweitt, L.A. (1994). Conceptual physical science. New York: Harper Collins College Publishers.

Kuhn T.S. (1970). The Structure of Scientific Revolutions. Chicago: Chicago University Press.

Kikas, E. (1998a). Pupils' explanations of seasonal changes: Age differences and the influence of teaching. *British Journal of Educational Psychology, 68,* 505–516.

Kikas, E. (1998b). The impact of teaching on students' definitions and explanations of astronomical phenomena. *Learning and Instruction, 8,* 439–454.

Kyung, J.B., Yun, I.H., Lee, K.H., Kim, K.Y., Wang, W.G., & Lee, K.H. (2010). *Earth science II*. Seoul: Institute for Better Education.

Lee, V.R. (2010). How different variants of orbit diagrams influence student explanations of the seasons. *Science Education, 94,* 985–1007.

Maxwell, N. (2019). A New Task for Philosophy of Science. Meta-philosophy, 50(3). 316-338.

Mulvey, B.K., Chiu, J.L., Ghosh, R. and Bell, R.L. (2016). Special education teachers' nature of science instructional experiences. *Journal of Research in Science Teaching, 53,* 554–578.

Núñez-Oviedo, M.C., & Clement, J. (2008). A competition strategy and other modes for developing mental models in large group discussion. In J.J. Clement, & M.A. Rea-Ramirez (Eds.), *Model based learning and instruction in science*(pp.117–138). Netherlands: SpringerVerlag.

Posner, G., Strike, K.A., Hewson, P.W., & Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66(2),* 211–277.

Rea-Ramirez, M. A., Clement, J., & Nŭňez-Oviedo, M.C. (2008). An instructional model derived from model construction and criticism theory. In J.J. Clement, & M. A. Rea-Ramirez (Eds.), *Model Based Learning and Instruction in Science*(pp.23–43). Netherlands: SpringerVerlag.

Rea-Ramirez, M. A. (1999). Explanatory need. Proceedings of the National Association of Research in Science Teaching Meeting, Boston, MA

Rokhamat, J., Marzuki, Wahyudi, and Putrie, S. D. (2019). A Strategy of Scaffolding Development to Increse Students' Problem-Solving Abilities: The Case of Physics Learning with Causalitic- Thinking Approach. *Journal of Turkish Science Education, 16(4),* 569-579.

Steinberg, M., & Clement, J. (2001). Evolving mental models of electric circuits. In Behrendt, H. et al, (Eds.), *Research in science education-past, present, and future* (pp.235-240). Dordrecht: Kluwer.

Trumper, R. (2001). A cross-age study of junior high school students' conceptions of basic astronomy concepts. *International Journal of Science Education, 23(11),* 1111–1123.

Tsai, C.-C. (2000). Enhancing science instruction: The use of 'conflict maps'. *International Journal of Science Education, 22(3),*285–302.

Tsai, C.-C., & Chang, C.-Y. (2005). Lasting effects of instruction guided by the conflict map: Experimental study of learning about the causes of the seasons. *Journal of Research in Science Teaching, 42(10),* 316–1111.

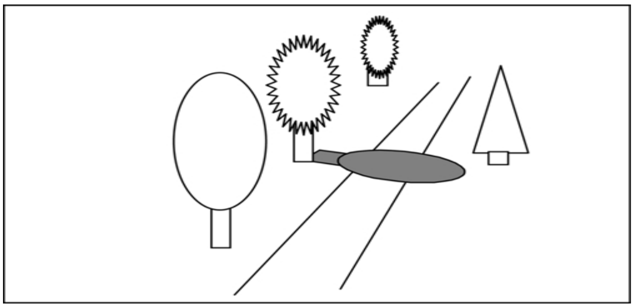
Ucar, S., & Demircioglu, T. (2011). Changes in preservice teacher attitudes toward astronomy within a semester-long astronomy instruction and four-year-long teacher training programme. *Journal of Science Education and Technology*, *20(1),* 65–73.

Vygotscky, L. S. (1978) Mind in society: The development of higher psychological processes. Cambridge: Harvard University Press

APPENDIX

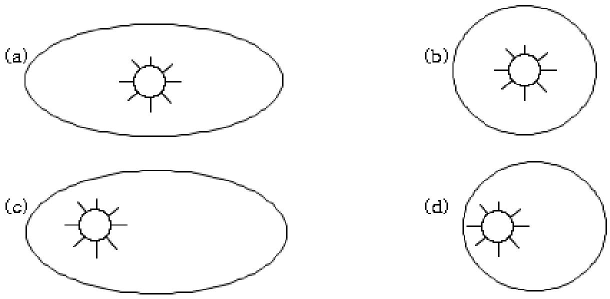
Questions about the acknowledgement of the sun's light rays arriving at the surface of the Earth (Feigenberg et al. 2002)

1. On the summer solstice in Aswan, Egypt, the sunlight at noon comes down from the z enith overhead; while in Alexandria, 800 km north of Aswan, it is 7° from the zenith. Why? Give your explanation with a diagram of this phenomenon.
2. The figure below shows four trees along a road on a sunny day, and the shadow of one of them. Draw the shadows of the other trees.



Questions about the causes of seasonal change (Kikas 1998a; 1998b)

3. Copernicus believed that the earth moves [revolves] around the sun, which of the follo wing figures depict the earth traveling around the sun?



4. Do you present individual positions of the earth on the earth's revolution track about the sun according to the four seasons?
5. Do you attribute the cause of this seasonal change as astronomical facts or theories according to the graphical presentation of question number 3?
6. If the days are longer and hotter in summer than winter, why is this the case?