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The aim of this study was to reveal whether there were differences in the understanding of scientific models according to their conceptions of lunar phases. The participants were 252 10th grader in South Korea. They were asked to respond SUMS (Students Understanding of Models in Science) instrument and to draw and explain why the different lunar phases occur. Students' conceptions of lunar phases were analyzed qualitatively based on established criterions and the differences in the perception of scientific models, a one-way ANOVA was conducted. Results indicated that Korean students' conceptions of the lunar phases were classified into five types: scientific, alternative, incomplete, eclipse explanation, and naïve conception. The participants appeared to have different epistemological perceptions concerning each of the five sub-factors in the scientific models. The students with a scientific conception of lunar phases tended to understand that multiple representations could be used to express the different dimensions of an object. It was found that Korean students have a good understanding of the role of models as explanatory tools(ET) and the changing nature of scientific models(CNM). There was statistically significant differences were shown in ET, USM(uses of scientific models) and CNM factors depending on the types of conceptions of the lunar phases.

Keywords: alternative conception, epistemological perceptions, lunar phases, scientific models, sums instrument

INTRODUCTION

A model can be defined as a system of objects or symbols that represents some aspect of another system and it can be often compared to a 'bridge' or regarded as a 'mediator' since a model plays a role of making a connection or transition between theory and phenomenon(Gilbert & Ireton, 1993, Koponen, 2007; Morrison & Morgan, 1999).

Besides considering models as science's products and as presenting its thinking and working methods, they also provide its major learning and teaching tools (Crawford & Cullin, 2004; Harrison & Treagust, 2000;Treagust et al., 2004) and they facilitate the understanding of the nature of science and the scientific enterprise (Coll, France & Taylor, 2005). Thus, understanding the nature of models and model building in science should be a fundamental component of scientific literacy (Gilbert, 1991; Gobert & Buckley, 2000).

The diversity of roles possible for models in science has been widely recognized. More straightforward functions are considered such as the representation of entities in descriptions and/or simplifications of complex phenomena (Ingham & Gilbert, 1991; Duit & Glynn, 1995). Each scientific model is a representation of a specific pattern of the natural phenomenon it models, and multiple models of the same phenomenon

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State of the literature

- Scientific models have been recognized as a valuable teaching tool that changes alternative conceptions into scientific conceptions.
- Current researches focused on classifying students' perception and understanding of the scientific models into different levels.
- Conceptions of lunar phases have been a central focus for various studies from different countries and various misconceptions with regard to this has been reported.

Contribution of this paper to the literature

- This study empirically examines whether there were differences in the perception of the scientific models according to students' subject matter knowledge.
- A survey called SUMS and the lunar phase description test were administered, the data were analyzed quantitatively and qualitatively.
- The results of the study showed that Korean students appeared in a different pattern in the epistemological perceptions of the scientific models depending on their types of lunar phases conception.

relate to one another and to specific patterns in the real world (Halloun, 2007). Other functions are: to make abstract entities visible (Francoeur, 1997); to provide a base for the development of explanations (Gilbert et al., 1998a,b); and to be a means of communication between scientists (van Driel & Verloop, 1998). At the opposite extreme we find more complex functions such as: the provision of a basis for the formulation of predictions (Erduran, 1999; Treagust et al., 2004; Shen and Confrey, 2007). As an integral part of the scientific process, models are used in a variety of ways within the science classroom. Teachers use models as aids to help explain scientific phenomena and students often make their own models of scientific phenomena to display their understanding. Indeed, scientific models are often the only way to explain an abstract scientific theory and scientists' consensus models are taught as fact as a result of being the accepted model of a scientific theory, for example, the model of the atom, different type of waves, electric circuits and DNA.

According to a recent study, scientific models have been recognized as a valuable teaching tool that changes alternative conceptions into scientific conceptions, and leads to an active learning attitude among students (Treagust & Harrison 2000). In order to utilize scientific models in a learning environment, it is important for teachers to first examine the students' perception and understanding of the models. Treagust and Harrison (2000) classified scientific models into the scale model, pedagogical analogical model, and concept-process model. Scale models, such as a toy-size model of the space shuttle and plaster model of a volcanic mountain, are built as perceptually similar to their targets by enlarging or reducing the external shapes and structures of the targets at different rates (Gilbert & Ireton, 1993). The concept-process models in particular include iconic and symbolic models, mathematical models, theoretical models, simulation models, and complex and/or multiple models. Scientific models become a useful tool for supporting the constructivist process, in which learners form their own schema to assimilate new concepts. Scientific models can be used to convey difficult and abstract concepts that cannot be observed from the explainer to the listener (Treagust & Harrison, 2000). Marquez, Izquierdo and Espinet (2006) consider scientific models as semiotic hybrids that are best represented by different communicative modes. Scientific models are expressed either physically (e.g.demonstrations or three-dimensional models), visually (e.g. pictures, diagrams or maps), verbally (e.g. oral descriptions) or symbolically (e.g. equations or formulae; Gilbert, Boulter & Rutherford, 1998).

Learners' perceptions of scientific models

Scientific models have long been used and appreciated as useful tools that enhance learning; however, most elementary and junior high school students regard scientific models as concrete replicas of the real thing, with few students regarding scientific models as representations of ideas or abstract entities(Grosslight et al. 1991, Ingham & Gilbert 1991).Grosslight et al. (1991) found that students have conceptions of scientific models that are basically consistent with a naive realist epistemology. They are more likely to think of scientific models as physical copies of reality that embody different spatio-temporal perspective than as constructed representations that may embody different theoretical perspectives (Treagust et al., 2002). Grosslight and colleagues (1991) interviewed seven graders, 11 graders and experts. Then classified their responses into three levels in order to examine the perception and understanding of the models used in learning science. Those who were classified as 'Level 1' regarded scientific models as replicas depicting concrete objects or actions and perceived them as simply toys. In level 2 students recognized that scientific models were constructed based on the perspective and specific purpose of the modeler, but they still believed that the models reflected certain aspects of a real-world object being modeled. 'Level 3' had the most sophisticated perception of scientific models, and recognized them as a tool for expressing and developing one's thinking. In level 3, models are thought to be constructed for the developing and testing of ideas or theories about the world rather than as a copy of reality itself. The modeler evaluates several designs to decide which could be used to serve the purpose of the model. The majority of seventh graders were at level 1, while the remainder fell between level 1 and 2. Students Understanding of Models in Science(SUMS), an investigative instrument used to examine the students' understanding of scientific models in this study, was developed by Treagust et al. (2002) and is comprised of 5 subfactor categories: multiple representation (MR), exact replica (ER),explanatory tools (ET), the uses of scientific models (USM) and the changing nature of models (CNM). Students' interpretation of the term 'scientific model' will depend on their experiences and personal understanding. Models as multiple representations (MR) were recognized as being necessary and useful by the majority students, and they appreciated the visual value of scientific models in helping to generate their own mental models. Students showed a good appreciation for the changing nature of scientific models (CNM), which was linked to the changing nature of scientific knowledge. However, there are inconsistencies in the percentage of students' responses, in that some students clung to the understanding that a model is an exact replica (ER) supporting the descriptive concept of a model (Treagust et al., 2002). The categorization of a model as a precise representation or an imprecise representation helps to explain some of the conflicting ideas that students have about scientific models. When dealing with more abstract concepts it is assumed that students would adopt a more abstract nature of scientific models, but this is not necessarily true. Students have their own personal and unique understanding of the role of scientific models in science built up through their life experiences. These understandings may not always be scientifically correct and may lead to alternative conceptions; teachers' assumptions about the degree of students' understandings of scientific models also may not always be correct. Consequently, a more accurate picture may be obtained through the administration of a pencil-and-paper instrument so that science teachers can be more aware of the range and variety of students' understandings of the role of models in learning science.

Literature review about conceptions of lunar phenomena

Lunar phases are taught in middle school in Korea and is one of the concepts in Earth Science that students have difficulty understanding. Many studies that examined student understanding in this field reported that misconceptions persist once they are formed (Dai & Capie, 1990; Liu, 2005; Stahly et al., 1999; Trundle et al, 2007; Vosniadou & Brewer, 1992,1994). The concept of lunar phases is often encountered in real life and this has been reported to be the cause of various misconceptions among students (Liu, 2005; Vosniadou, 1991a; 1991b). Children's (Barnett & Morran, 2002; Dove, 2002; Sharp, 1996; Taylor, Barker, & Jones, 2003; Trumper, 2001), science and non-science university students' (Zeilik, Schau, & Mattern, 1998) and pre-service teachers' (Bekiroglu, 2007; Suzuki, 2003; Trumper, 2003) conceptions of the Moon have been a central focus for various studies from different countries. In this study, we will examine high school students' conceptions of the lunar phase changes, which students have been found to have difficulty understanding in previous studies. In particular, astronomical phenomena that occur over a long period of time in a vast space and thus are difficult for learners to actually observe, analyze and understand. Also, because they characteristically take place in nature, it is nearly impossible to reproduce them in a laboratory. Due to these characteristics, scientific models play an important role in teaching astronomy.

According to the study that investigated whether seventh and eighth graders' mental models of the Sun-Earth-Moon system, all four phases of the general strategy were necessary and effective in that most pupils were able to successively and successfully to critique their mental models of the Sun-Earth-Moon system while also achieving traditional astronomy knowledge goals (Taylor et al., 2003). They suggested that pupils' understanding of the nature of science might be promoted by a mental model building intervention. Baxter (1989) investigated the understanding of basic astronomy concepts among English fourth to tenth graders (9 to 16 years old). The questions were extended to the explanations of the phases of the moon and the seasons. Most of the students involved in the study explained the moon's phases on the account of an object either covering part of the moon or casting a shadow on its surface. The typical responses were clouds covering part of the moon and the shadow of some planet or even the sun falling on the moon. There seemed to be confusion regarding the cause of a lunar eclipse with that of the moon phases, as the earth casting a shadow on the moon was the most common explanation of the moon phases in all age groups. Only very few students could explain the phases of the moon as a result of the varying illuminated part of the moon to be observed from the earth. Vosniadou and her colleagues conducted a series of studies cross-culturally to investigate children's and adults' knowledge in the domain of observational astronomy. Their subject included pre-school, elementary school and high school students, college undergraduates and illiterate adults (Vosniadou, 1991a, 1994; Vosniadou & Brewer, 1992,1994).

Purpose of the study

It is necessary to find the linkage between students' content knowledge and understanding of scientific model, based on which a method of improving teaching and learning for the meaning and role of the model itself is expected to be found. There has not been research on the relationship between the level of conceptions in science among students and their understanding of scientific models. The purpose of this study is to examine the relationship between South Korean students' astronomical conceptions and their perception of scientific models.

Therefore, this study was performed to examine students' conceptions of the lunar phases and reveal whether there were differences in the perception of scientific models according to their conceptions. Under the purposes of this research, the following questions were addressed:

- *What are the Korean students' alternative conceptions of the lunar phases?*
- *What is the perception of Korean students concerning each of the five sub-factors in the scientific models?*
- *Are there differences between the perception of scientific models according to students' conceptions of the lunar phases?*

METHODS

Participants

This study was performed with a total of 252 10th grade high school students between the ages of 15 and 16, of whom 115 were from a science high school and 137 from a regular high school in South Korea. The education system in South Korea is divided into 6 years of elementary school, 3 years of middle school and 3 years of high school, and the two target schools, which the participants attended, are located at the heart of the second largest city in Korea. From the science high school, 83 male students and 28 girl students participated in this study, while the students from the regular high school were all male. Generally, students admitted to science high schools must pass strict document and interview screening processes, and are known to have top academic achievements with a keen interest and excellence in math and science. On the other hand, students attending regular high schools show a normal distribution in terms of middle school grades. The units related to the lunar phases, which is the topic of this study, include 'Earth and the Moon' taught to 5th grade elementary school students and 'The Solar System' taught to 3rd grade middle school students. In South Korea, new school year annually begins in March and the survey for this study was administered in early March. Therefore students did not learn to the relevant sections in the high school curriculum.

The students had received no special teaching on scientific models in science, so their responses reflect their understanding based on the general science curriculum they have experienced.

The instruments

Students' Understanding of Models in Science(SUMS) instrument used to this study, was developed by Treagust et al.(2002) and is comprised of 5 sub-factor categories: items related to multiple representation (MR) examine the recognition of diversity, i.e., multiple models can be used for one scientific fact; exact replica (ER) related items examine the perception of models as a precise replica of real-world object; explanatory tools (ET) related questions examine the perception of models as explanatory tools; questions related to the uses of scientific models (USM) examine the recognition that scientific models have purposes beyond explanation and have functions in theory formulation, prediction and verification; and questions related to the changing nature of models (CNM) examine the understanding of variability of models. The items in the instrument have been written based on data from a study into the use of chemical models in teaching organic chemistry (Treagust et al., 2001) and from Grosslight *et al.*'s (1991) study into students' understanding of models and their use in science. The instrument was designed to gain some insight into students' understanding of what a model is, the role of models in science, including how and why models are used and what causes models to be changed. The SUMS instrument is a 27-item pencil-and-paper questionnaire which requires students to respond on a five-point Likert-type scale, with a choice of responses: strongly disagree (1), disagree (2), not sure (3), agree (4) and strongly agree (5).

The survey was administered by science teachers from their respective schools, and students were given 20 minutes to complete the survey. To ensure the uniformity of administration of the survey in all classrooms, teachers were instructed not to provide students with any clarification or additional information beyond what was written in the survey. The instrument presented in this article was translated from English to Korean and reviewed by three independent researchers fluent in English.

In the lunar phase description test, all participants of this study were asked to write regarding why the Moon keeps changing its shape in a 1-month cycle. The researchers completed drawing test regarding the changes in the lunar phase based on the contents of several South Korea's middle school textbooks. In the drawing tests, students were given an incomplete drawing, depicting the Moon's orbit around Earth, with empty boxes for each of the positions of the Moon, and were then asked to complete the drawing.

Data analysis

Korean Students' Alternative Conceptions of Lunar Phases

The researcher and two Earth Science teachers analyzed the students' responses as raters. First, all the responses were reviewed to develop a set of analysis criteria. The student conceptions were classified into 5 types based on the criterions of analysis summarized in Table 1.

Student responses were analyzed based on the analysis criterions to determine the type of conception to be classified into, and the frequency of each of the schools was calculated. In order to increase the inter-rater reliability, three researchers cross-checked the analysis results and in order to increase inter-rater reliability, the researchers shared and discussed the analysis criterions derived from repetitive analysis to increase consistency.

Perception of the Korean Students on the Scientific Models

In order to examine the perception of Korean students concerning each of the five sub-factors in the scientific models the percentages of responses about all items of SUMS instrument were analyzed. The difference in the perception of scientific models between the group with a scientific lunar phases conception and the group with a naive lunar phases conception was compared. The results of SUMS based on the responses of 'agree', 'not sure', and 'disagree' are counted. The percentage of 'disagree' was obtained by summing the number of students who responded to 'strongly disagree' and 'disagree' in a five-point Likert-type scale. Also percentage of 'agree' was obtained from total responses of 'strongly agree' and 'agree'.

Relationship between Students' Perception of the Scientific Models and their Conceptions of Lunar Phases

To examine whether student perceptions of the scientific models were related to their subject matter knowledge, the mean scores of SUMS by five groups having different lunar phases conceptions were analyzed. In order to analyze the differences in the perception of scientific models, one-way ANOVA was conducted and Scheffé's post hoc test was performed in case of differences among the groups. Statistical analyses were performed by means of the Statistical Package for Social Scientists (SPSS) Statistics 20 a program for the Windows operating system.

RESULTS AND COMMENTS

The aim of this study was to investigate the differences in the perception of scientific models according to the students' alternative conceptions of the lunar phases. The results of this study are as follows:

Table 1. Student conceptions of the lunar phases and the analysis criteria

Type of conception	Analysis criteria
Scientific conception (group 1)	· Correctly draws the part of the Moon that the sunlight reaches. · Correctly demonstrates the cause of lunar phases.
Alternative conception (group 2)	· Some misconceptions are shown in the drawing of the part of the Moon that sunlight reaches. · Explains the cause of lunar phases in terms of the difference between the portion receiving the sunlight and revolution of the Moon.
Incomplete conception (group 3)	· The drawing of the part of the Moon that sunlight reaches is incomplete. · Explains the cause of lunar phases in terms of the Moon's revolution or the locations of the Sun, Earth and Moon.
Eclipse explanation (group 4)	· Misconceptions are shown in the drawing of the part of the Moon that sunlight reaches. · Explains the cause of lunar phases in terms of the lunar eclipse or the solar eclipse.
Naïve conception (group 5)	· Cannot draw the part of the Moon that sunlight reaches · Explains the cause of lunar phases in terms of Earth's rotation and the difference between period of the revolution.

Korean students' alternative conceptions of lunar phases

The Lunar phases are due to people on Earth seeing different fractions of the half that is lighted by the Sun. Based on the results of the analysis of the students' explanations of the lunar phases and their cause as well as their drawings, their conceptions were classified into five types (refer to Table 1). First, learners with a scientific conception correctly drew the parts of the Moon that were illuminated or not illuminated by the Sun and gave a correct response with respect to the cause of the lunar phases.

The responses given by students with a scientific conception were as follows:

- ✓ *The phases of the Moon depend on its position in relation to the Sun and Earth. As the Moon makes its way around the Earth, we see the bright parts of the Moon's surface at different angles.*
- ✓ *As the Moon revolves around the Earth, a portion receiving sunlight stays constant but the part that is viewed from the Earth changes.*
- ✓ *As the Moon orbits the Earth, the surface of the Moon that is visible from the Earth changes.*

Figure 1 shows the images drawing depicting the lunar phases by students with a scientific conception. The student responses in this study can be compared to the concept codes used in the study performed by Trundle et al.(2007) as they are consistent with the following codes: the Moon orbits the Earth(SciOrb); half of moon illuminated that half toward the sun (SciHaf); and part of the illuminated half we see determines phase (SciSee).

Learners classified as having an alternative conception showed some misconceptions in the drawings depicting a portion of the Moon that is illuminated by the Sun, and explained the cause of the phases of the Moon in terms of the difference between a portion receiving the sunlight and the revolution of the Moon. A number of these students illustrated the Sun's rays reaching the Moon in a radial form because they did not understand that the Sun is distant and the light rays from the Sun which strike the Earth and the Moon are parallel. The responses given by students with an alternative conception were as follows:

- ✓ *Because the Moon orbits the Earth, a portion of which is illuminated by the Sun varies continually.*
- ✓ *The revolution of the Moon around the Earth makes the Moon appear as if it is changing shape in the sky.*
- ✓ *Depending on the Moon's position, a portion that receives the light rays from the Sun is different.*
- ✓ *The part that receives the sunlight becomes different.*
- ✓ *As the Moon orbits the Earth, the part receiving the sunlight changes depending on its position.*

Some of the students classified as having an alternative conception, however, drew the lunar phases correctly although they gave wrong explanations. It was revealed that these students had an inaccurate understanding of the cause of the lunar phases, but gave correct drawings by recalling the figures they had seen in textbooks. Figure 2 shows the drawings by students with an alternative conception, who depicted the Sun's rays in a radial form. This is consistent with the concept code, AltPrl in the study by Trundle et al.(2007) indicating a drawing of the Sun's rays in the Earth-Moon system as being radial. This misconception of the Sun's rays being radial was shown in a large number of students providing an eclipse explanation (see Figure 3).

Learners who were categorized as having an 'incomplete conception' simply explained the cause of the lunar phases in terms of the Moon's revolution or the positions of the Sun, Earth and Moon. The following responses that focused on the spatial relationship of the Sun, the Earth and the Moon without further explanation of other factors correspond with this type of conception:

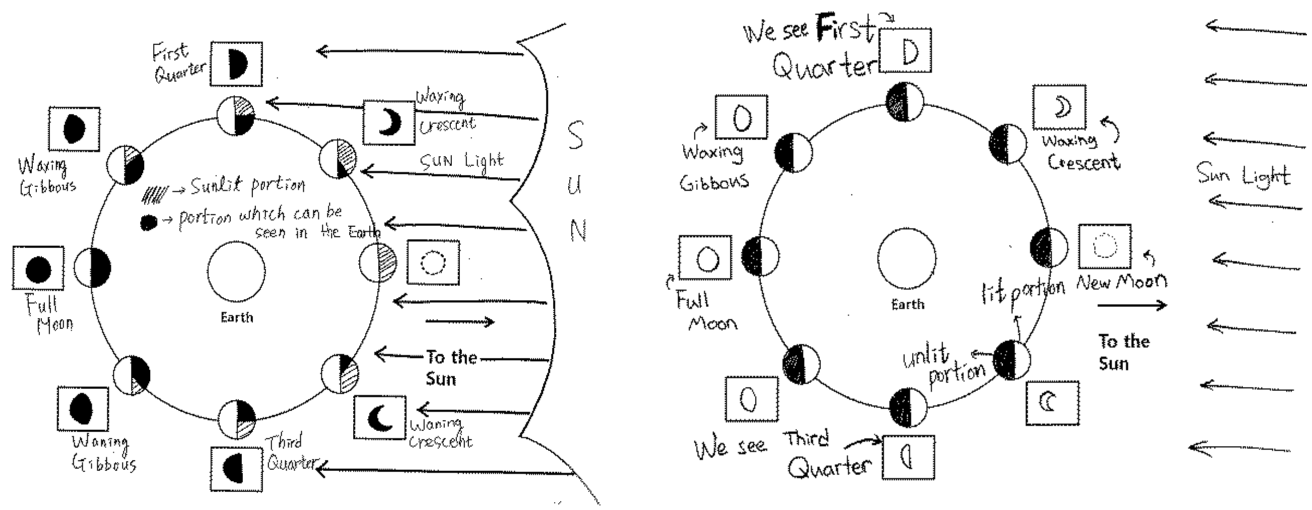

Figure 1. Drawings representing the lunar phases by students with a scientific conception

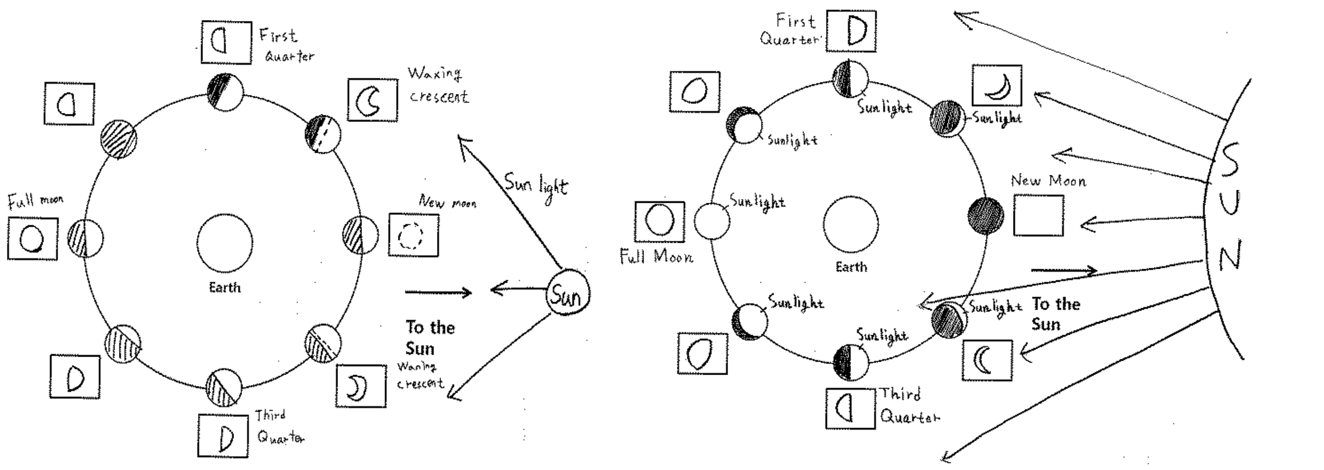

Figure 2. Drawings representing the lunar phases by students with an alternative conception

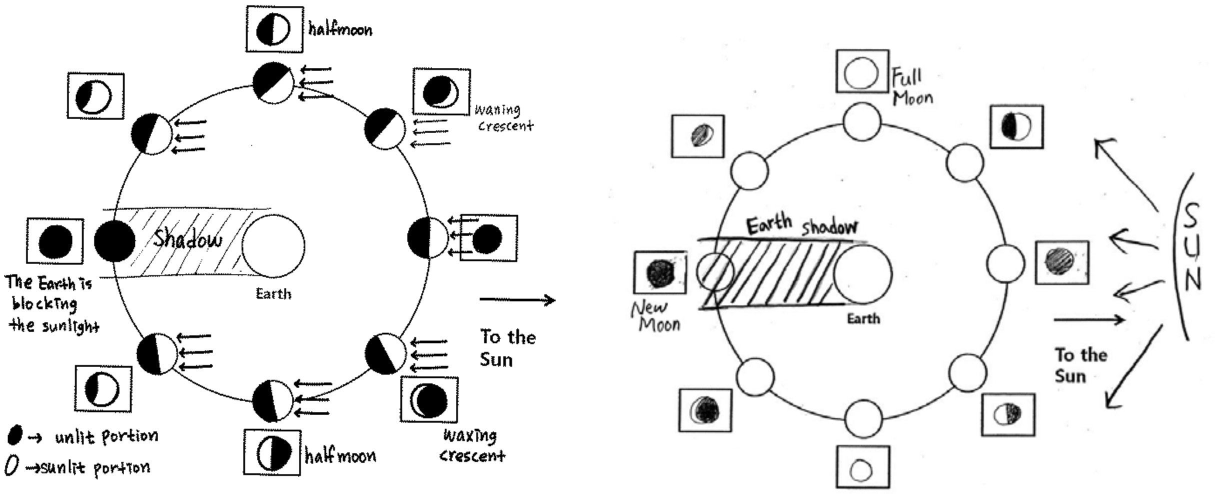

Figure 3. Drawings representing the lunar phases by students who provided an eclipse explanation

- ✓ *The shape of the moon observed changes because the Moon orbits the Earth and the Earth rotates.*
- ✓ *It's because of the positions of the Moon and the Sun change.*
- ✓ *It's because the Moon reflects the sunlight as it orbits the Earth.*
- ✓ *It's because the Moon orbits the Earth.*
- ✓ *It's because of the orbit of the Moon and the Earth.*
- ✓ *The angles of the Earth, Moon and Sun change and the shape of the moon observed changes.*

Students classified as having provided an 'eclipse explanation' explained the cause of the changes in the phases of the Moon in terms of the principles of the lunar eclipse and a small number of them explained in terms of the solar eclipse. The responses given by students classified under this type were as follows:

- ✓ *The shape of the Moon changes because the Earth's shadow falls on it depending on the time.*
- ✓ *The shape of the Moon changes because the Earth's shadow falls on it.*
- ✓ *It's because the Moon enters Earth's shadow.*
- ✓ *It's because a portion of the Moon on which the Earth's shadow falls changes.*
- ✓ *When the sunlight gets blocked by the Earth because of the Earth's orbit, it causes a shadow to fall on the Moon and changes its phase.*
- ✓ *The shape of the Moon changes because it gets hidden by the Sun.*

These types of misconceptions have been revealed to be based on the occultation theory by a number of previous studies (Dai & Capie, 1990; Oh & Kim, 2006). There seemed to be confusion regarding the cause of a lunar eclipse with that of the moon phases, as the earth casting a shadow on the moon was the most common explanation of the lunar phases in all age groups(Stahly, Krockover, & Shepardson, 1999). The examples of the drawings by students who provided an eclipse explanation for the cause of the lunar phases are shown in Figure. 3.

Table 2. Frequencies and percentages of Korean 10th graders' conceptions of lunar phases

	Science High School		Regular High School		Total (%)	
	Number	Percentage	Number	Percentage	Number	Percentage
Scientific conception (Group 1)	45	39.1	12	8.8	57	22.7
Alternative conception (Group 2)	24	20.8	31	22.7	55	21.8
Incomplete conception (Group 3)	20	17.4	34	24.8	54	21.4
Eclipse explanation (Group 4)	20	17.4	35	25.5	55	21.8
Naïve conception (group 5)	6	5.2	25	18.2	31	12.3
Total	115	100	137	100	252	100

The majority of students who were classified as having a naïve conception could not complete the drawings. This pattern was observed in a previous study (Trundle & Troland, 2005) on which a number of elementary students do not understand the cause of the lunar phases and associates the relevant concepts illogically.

The responses given by students with a naïve conception were as follows:

- ✓ *It's because the Earth is rotating.*
- ✓ *It's because the Earth is orbiting around the Sun.*
- ✓ *It's because the Earth is rotating with an axial tilt.*
- ✓ *The shape of the Moon observed varies because of the difference between the orbit periods of the Earth and the Moon.*

Table 2 describes the frequency of each of the conceptions of participants from a science high school and a regular high school.

There were substantially more students with a scientific conception among science high school students than regular high school students, whereas the number of students with an alternative conception was higher among regular high school students than science high school students. Students from the regular high school generally seemed to have some difficulties in forming a scientific mental model regarding the cause of the lunar phases compared to the students from the science high school.

Perception of the Korean students on the scientific models

The results of SUMS based on the responses of 'agree', 'not sure', and 'disagree' are summarized as percentages in Table 3.

MR is used as a measure of an understanding that multiple models can be used for a single phenomenon. In case of the group with a scientific conception of the lunar phases (Group 1), nearly or more than 90% of them agreed to the MR factor statements, particularly items 1, 2, 4 and 5. This revealed that students with a scientific conception tended to have an understanding that multiple models could be used to represent the different dimensions of the subject. In contrast, the percentage of students with a naïve conception (Group 5) who agreed to the same statements was lower than that of Group 1 but it was still over 70%. This suggested that overall Korean students have higher awareness on the models as multiple representations regardless of their level of conception of the lunar phases.

The responses to the Exact Replica (ER) factor of SUMS instrument revealed that a few students of Group 1(5.3%) agreed that a model must be an exact replica of the object, whereas much more students of the Group 5 (38%) agreed (Table 3, Item 9). In contrast, more students of the Group 5 (54.8%) agreed to item 14. These results contrast with those of Treagust et al.(2002) where, 75% of students agree that a model needs to be close to the real thing by giving the correct information and showing what the object looks like.

Based on the results of this study, it is deemed that the naïve conception group has a tendency to perceive scientific models as scale replicas, whereas the scientific conception group understands that scientific models are not replicas and rather, they present a certain mechanism. The difference in the perception of scientific models is considered to be the cause of the differences in the understanding of scientific concepts.

Students have indicated a good understanding of the role of models as explanatory tools (ET) in their responses to SUMS instrument with 94.7% of Group 1 students and 83.9% of Group 5 students agreeing that 'Models are used to physically or visually represent something (Table 3, Item 17). This can be interpreted as both two groups valuing the explanatory aspect of scientific models and recognizing the value of visual representations provided by scientific models. Students use models to connect the observed phenomena and scientific explanations, and through this process, they form their own mental models. Approximately 80% of the Group 1 students agreed to the statements: 'Models are used to explain scientific phenomena (Item 19, 94.7%)'and 'Models help create a picture in your mind of the scientific happening (Item 18, 84.2%)'. These results show that students understand the roles of models as explanatory tools. The variety of forms that can be represented were appreciated by the majority of Group 1 with 75.4 % agreeing that a model can be a

Table 3. Results of SUMS of two groups with different conceptions of lunar phases (*N*=252)

Factor*/ Item Number	Item	%					
		Disagree**		Not sure		Agree***	
		G1	G5	G1	G5	G1	G5
MR/1	Many models may be used to express features of a science phenomenon by showing different perspectives to view an object	1.8	6.5	1.8	16.1	96.5	77.4
MR/2	Many models represent different versions of the phenomenon	0.0	9.7	1.8	16.1	98.2	74.2
MR/3	Models can show the relationship of ideas clearly.	1.8	12.9	28.1	29.0	70.2	58.1
MR/4	Many models are used to show how it depends on individual's different ideas on what things look like or how they work.	7.0	9.7	3.5	16.1	89.5	74.2
MR/5	Many models may be used to show different sides or shapes of an object.	1.8	6.5	10.5	9.7	87.7	83.9
MR/6	Many models show different parts of an object or show the objects differently.	5.3	6.5	21.1	18.8	73.7	74.7
MR/7	Many models show how different information is used.	0.0	6.5	32.7	28.1	67.3	65.4
MR/8	A model has what is needed to show or explain a scientific phenomenon	15.8	9.7	19.3	16.1	64.9	74.2
ER/9	A model should be an exact replica.	80.7	45.2	14.0	16.1	5.3	38.7
ER/10	A model needs to be close to the real thing.	35.1	29.0	22.8	19.4	42.1	51.6
ER/11	A model needs to be close to the real thing by being very exact, so nobody can disprove it.	73.7	41.9	8.8	25.8	17.5	32.3
ER/12	Everything about a model should be able to tell what it represents.	0.0	0.0	1.8	9.5	98.2	90.3
ER/13	A model needs to be close to the real thing by being very exact in every way except for size.	57.9	41.9	17.5	19.4	24.6	38.7
ER/14	A model needs to be close to the real thing by giving the correct information and showing what the object/thing looks like.	45.6	12.9	19.3	32.3	35.1	54.8
ER/15	A model shows what the real thing does and what it looks like.	7.0	3.2	19.3	12.9	73.7	83.9
ER/16	Models show a smaller scale size of something.	54.4	12.9	21.1	9.7	24.6	77.4
ET/17	Models are used to physically or visually represent something.	1.8	6.5	3.5	9.7	94.7	83.9
ET/18	Models help create a picture in your mind of the scientific happening.	7.0	12.9	8.8	25.8	84.2	61.3
ET/19	Models are used to explain scientific phenomena.	3.5	3.2	1.8	16.1	94.7	80.6
ET/20	Models are used to show an idea.	0.0	12.9	17.5	25.8	82.5	61.3
ET/21	A model can be a diagram or a picture, a map, graph or a photo.	5.3	19.4	19.3	21.6	75.4	59.0
USM/22	Models are used to help formulate ideas and theories about scientific events.	0.0	16.1	7.0	9.7	93.0	74.2

Table 3 (*contioued*). Results of SUMS of two groups with different conceptions of lunar phases (*N*=252)

Factor*/ Item Number	Item	%					
		Disagree**		Not sure		Agree***	
		Group1	Group5	Group1	Group5	Group1	Group5
USM/23	Models are used to show how they are used in scientific investigations.	1.8	19.4	14.0	9.7	84.2	71.0
USM/24	Models are used to make and test predictions about a scientific event.	8.8	6.5	21.1	32.3	70.2	61.3
CNM/25	A model can change if new theories or evidence prove otherwise.	3.5	3.2	3.5	12.9	93.0	83.9
CNM/26	A model can change if there are new findings.	0.0	3.2	7.0	9.7	93.0	87.1
CNM/27	A model can change if there are changes in data or belief.	0.0	6.5	5.3	9.7	94.7	83.9

*MR (Models as multiple representations); ER (Models as exact replicas); ET(Models as explanatory tools); USM (The uses of scientific models); and CNM (The changing nature of models).
**Disagree= Strongly Disagree and Disagree. ***Agree=Strongly Agree and Agree*

Table 4. Means and standard deviations on SUMS of five groups with different conceptions of lunar phases

	group 1(n=57)	group 2(n=55)	group 3(n=54)	group 4(n=55)	group 5(n=31)	total(n=252)
	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)	M(SD)
MR	3.87(.42)	3.79(.45)	3.77(.43)	3.78(.43)	3.58(.37)	3.78(.43)
ER	3.11(.56)	3.22(.56)	3.24(.50)	3.12(.62)	3.24(.42)	3.18(.54)
ET	4.02(.36)	4.01(.45)	3.86(.61)	3.88(.54)	3.69(.50)	3.91(.50)
USM	3.97(.48)	4.07(.55)	3.94(.57)	3.99(.59)	3.61(.58)	3.95(.56)
CNM	4.54(.60)	4.34(.56)	4.22(.60)	4.34(.58)	4.01(.58)	4.32(.60)

diagram, picture, map, graph or photo (Table 3, item 21). A relatively lower percentage of Group 5 students (59.0%) agreed to item 21, while the remaining 41% responded as either 'disagree' or 'not sure.' to this description of a model.

USM factors deal with the perception of how a model can be used beyond its descriptive and explanatory purpose. Through this, one's understanding of the theory formulation, exploration, prediction and verification functions of scientific models is examined. As shown in table 3, the majority of Group 1 students(93%) agreed to the statement, 'Models are used to help formulate ideas and theories about scientific events (Item 22)' contrastively less number of Group 5 students(74.2%) agreed to the same statement. Approximately 70% of Group 1 students and 60% of Group 5 students agreed to the statement, 'Models are used to make and test predictions about a scientific event (Item 24)'. In this instance, that many students of Group 5 do not understand how scientific models are used in the formation of scientific ideas and theories. This is related to the claim made by Grosslight et al. (1991) in a previous study.

The CNM factor deals with the understanding of the changing properties of models. 93.0% of the Group 1 students and 93.9% of the Group 5 students agreed to the statement, 'A model can change if new theories or evidence prove otherwise (Item 25)', 94.7% of the Group 1 students and 83.9% of the Group 5 students agreed to the statement, 'A model can change if there are changes in data or belief (Item 27)'. The percentage of Group 1 students who agreed to this statement in particular was significantly higher than for other items.

Comparison of the perception of scientific models by five groups of lunar phase conceptions

The mean and standard deviation values are shown in Table 4 the ANOVA results are shown in Table 5.

As shown in Table 4, the mean for MR was 3.78, which was lower than those of ET, USM and CNM. This signifies that the conviction that several models can be used for a single subject is relatively weak. The mean value with respect to MR was the highest for Group 1 (3.87) and the lowest for Group 5(3.58), while the mean values for Group 2, 3 and 4 were relatively similar. Thus, there was no significant difference overall in the means for MR (see Table 5). It can be said that students scoring high in the ER factor belong to a group with a narrow and naive understanding of the concept. The mean value with respect to ER was the lowest for Group 1 (3.11) and the highest for Group 5 (3.24). Thus, the more naïve the student's conceptions in science, the more they perceived that scientific models should resemble the real thing. The mean values for Group 2, 3 and 4 were relatively similar, and thus there was no significant difference overall in the means for ER (see Table 5).

As shown in Table 5 and Figure 4, significant differences were shown in ET, USM and CNM depending on the 5 types of conceptions of the lunar phases. The mean value with respect to ET was the highest for Group 1(4.02) and the lowest for Group 5 at

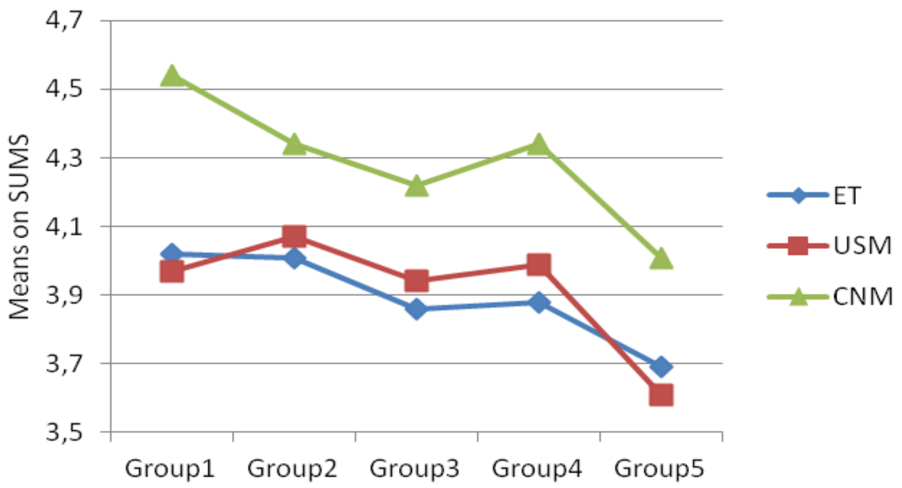

Figure 4. Means on SUMS of the 5 groups with different conceptions of lunar phases (*N*=252)

Table 5. ANOVA results on SUMS of five groups with different conceptions of lunar phase

		Sum of Squares	*df*	Mean Square	*F*	Sig.
	Between Groups	1.647	4	.412		
MR	Within Groups	45.420	247	.184	2.239	.065
	Total	14.552	251			
	Between Groups	.918	4	.229		
ER	Within Groups	74.942	247	.303	.756	.555
	Total	75.860	251			
	Between Groups	3.057	4	.764		
ET	Within Groups	61.859	247	.250	3.051*	.018
	Total	64.916	251			
	Between Groups	4.506	4	1.127		
USM	Within Groups	76.178	247	.308	3.653**	.007
	Total	80.684	251			
	Between Groups	6.411	4	1.603		
CNM	Within Groups	85.535	247	.346	4.628**	.001
	Total	91.946	251			

Note: *p <.05 **p <.01

3.69. This shows that students with a scientific conception of the lunar phases understand the role of models as explanatory tools. As shown in Table 5, the mean for Group 4(3.88) was higher than the mean for Group 3(3.86). This shows that the group of students, who provided an eclipse explanation, had a better understanding of models as explanatory tools than the group of students, who simply explained the lunar phases in terms of revolution. As a post-test, the means for ET were analyzed using the Scheffé's post hoc, and the results showed that the values for Group 1 and Group 2 was higher than Group 5 with a statistical significance ($p < .05$).

USM consists of items examining the perception of the possibility of scientific models to have theory formulation, prediction and verification functions, in addition to their explanatory purpose. As shown in Table 4, the mean value with respect to USM was the highest for Group 2 at 4.07 and the lowest for Group 5 at 3.61. Of particular note is the fact the mean value for Group 1(3.97) was actually lower than that of Group 2 (4.07) and Group 4 (3.99). This shows that learners with a scientific conception are actually not convinced that models have a function in theory formulation, prediction or verification. The means for USM were analyzed using the Scheffé's post hoc test, and the results showed that the differences between the values for Group 1 and Group 5, Group 2 and Gruop 5, and Group 4 and Group 5 with a statistical significance ($p < .05$). The results of comparing the perception of CNM, the mean was substantially higher for Group 1 at 4.54 and the lowest for Group 5 at 4.01.

The means for CNM were analyzed using the Scheffé's post hoc test, and the mean value for Group 1 with respect to CNM was higher than those of Group 5 and Group 3 with a statistical significance ($p < .05$). This result supports the assertion that the conceptual level of Group 3 is lower than that of Group 2.

CONCLUSION AND DISCUSSION

Scientific models have drawn much attention of science education researchers they exist virtually in all sciences among students, teachers, experts, and play an essential role not only in scientific development but also in science teaching and learning. The current study was intended to explore the link between the students' content knowledge and the perception of the role of scientific models and to find the implications for the utilizing of the model in the science class. A survey called SUMS and the lunar phase description test were administered, the data were analyzed quantitatively and qualitatively.

Five types of the students' conceptions of the lunar phases were found in the study; scientific conception, alternative conception, incomplete conception, eclipse explanation and naïve conception. Learners classified as having an alternative conception showed a mix of a correct understanding that the cause can be explained in terms of the Moon's revolution but with a misconception that a portion illuminated by the Sun varies. Also, students who were categorized as incomplete conception simply explained the cause of the lunar phases in terms of the Moon's revolution or the positions of the Sun, Earth and Moon. In contrast, some students explained the cause of the changes in the phases of the Moon in terms of the principles of the lunar eclipse. Many authors agree that the most commonly held notion for the cause of lunar phases is that the earth casts a shadow on the moon (Baxter, 1989; Liu, 2005; Stahly, Krockover, & Shepardson, 1999). Based on participants' responses on SUMS, they appeared in a different pattern in the epistemological perceptions of the scientific models depending on their types of lunar phases conception. It was revealed that students with a scientific conception tended to have an understanding that multiple models could be used to represent the different dimensions of the object. Contrarily, students with a naïve conception perceived models as being one representation of an actual existence, with each representation revealing a particular perspective or emphasized point. Treagust et al. (2002) examined the perception and understanding of scientific models among high school students in Australia, and they suggested "many students had a misconception that there is only one possible model for each particular phenomenon"(p.363). The overall Korean student regardless of their lunar phases conceptions have higher awareness on the models as multiple representations compared to the students in Australia revealed in the previous study (Treagust et al., 2002). We may argue that the reasons for the difference between the two countries stem from the age of the students, cultural differences, and differences in their respective national curricula.

According to the percentage of responses to the Exact Replica factor of SUMS, it seems that the students with incomplete and naïve conceptions in lunar phases showed naïve realist epistemology regarding scientific models. This corresponds to scale scientific models that are usually representative of more familiar and better understood objects, for example, a model fault and fold or an earth globe, for which accuracy and detail are crucial. It is found that students have a good understanding of the role of models as explanatory tools (ET) in their responses to SUMS instrument. The majority of students agreed that models are used to physically or visually represent something. This can be interpreted as both groups valuing the explanatory aspect of scientific models and recognizing the value of the visual representations provided by scientific models. Relatively less students with a naïve conception agreed that a model can be a diagram, picture, map, graph or photo while the remaining large number of them responded as either 'disagree' or 'not sure' to this description of a model. The results indicate that they do not regard all of these particular items to be models. The results suggest that most students are aware of the value of visual representation that many scientific models provide. Models are often used to represent things that are too small or too big to see with the naked eye, so, in this way, models are the only visual representation that a student can see. The visual aspect of scientific models applies to many forms of scientific models and is described by Gilbert et al. (1998b). USM consists of items examining the perception of the possibility of scientific models to have theory formulation, prediction and verification functions, in addition to their explanatory purpose. According to the results, there is evidence that numerous students having the naïve conception of lunar phases do not understand how scientific models are used in the development of scientific ideas and theories. This is related to the claim made by Grosslight et al. (1991) in a previous study. If the results reflect students' experiences, then it would be suggested that students with a naïve conception have had experience with scale models and descriptive models but have not used models in a quantitative or interpretive fashion. Korean students in particular showed a good appreciation for the changing nature of scientific models, which was linked to the changing nature of scientific knowledge. In other words, students have a greater understanding of the epistemic features of scientific knowledge which means that 'scientific ideas can change in response to new evidence or because a phenomenon is conceptualized in an entirely different way (Windschitl et al., 2008).

In addition there was no statistically significant difference overall in the means for MR and ER, whereas, significant differences were shown in ET, USM and CNM depending on the five types of conceptions of the lunar phases. The group of students who provided an eclipse explanation have higher awareness than the group of students, who simply explained the lunar phases in terms of revolution in ET, USM and CNM factors. More precisely, the students that explained the scientific phenomena with complex factors showed a higher awareness about scientific models, than the students that described a simple factor. Consequently, the results of this study should be valued as empirical evidence about the interrelationship between the students' content knowledge and the perception of scientific model. Thus, there is a need to improve the content knowledge through direct teaching with regards to the goal and role of scientific models. Based on the result of this study, students with a naïve content knowledge were revealed as having awareness regarding the models as multiple representations. Hence, we may suggest that it is appropriate to induce these students to recognize that multiple models are available for a single phenomenon and to invent their own models.

The current philosophical view on science acknowledges that models play key roles in developing scientific understanding of the natural world. Models are also believed to support science instructions in various ways. In the science classroom, not only teachers but also students can take advantage of models as they are engaged in diverse modelling activities(Oh & Oh, 2011). Further study based on collaborative action research can be considered a useful way to introduce students to diverse modelling activities such as exploration, expression, construction, application and revision of models.

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