Impact of Model-Based Teaching on Argumentation Skills

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Abstract
The purpose of this study was to examine effects of model-based teaching on students' argumentation skills. Experimental design guided to the research. The participants of the study were pre-service physics teachers. The argumentative intervention lasted seven weeks. Data for this research were collected via video recordings and written arguments. Results show that construction of concrete models and using them in their discussions and explanations provide learners with more quality (accurate, consistent, appropriate, and relevant) arguments. In addition, models' quality affects the number of claims, evidences and reasoning that are produced during argumentation. The closer learners' models are to the real situations, the more argument components they generate.

Keywords*:* Model-based teaching, argumentation, pre-service teachers

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Introduction

Current research indicates that learning how to engage in productive scientific argumentation to propose and justify an explanation through argument is difficult for students (Sampson & Clark, 2008). Although students must be willing to engage in argumentation, they also must have the skills necessary to do so (Nussbaum, Sinatra & Poliquin, 2008). However, instruction in argumentation has not typically been a part of traditional science instruction (Duschl & Osborne, 2002). In other words, schools do not make an effort to foster students' argumentation skills (Newton, Driver, & Osborne, 1999). Students are rarely asked to take positions and to develop arguments to justify those positions (Zohar & Nemet, 2002).

Various studies aimed to stimulate argumentation and used some strategies to increase the quality of students' arguments. Some of those strategies were scaffolding (Bell, 2002; Cho & Jonassen, 2002; Nussbaum & Kardash, 2005; Sandoval & Millwood, 2005; Yeh, 1998), writing (Voss & Means, 1991), utilizing video coaches (Crossa, Taasoobshirazib, Hendricksc & Hickeya, 2008), and using authentic problems (Jiménez-Aleixandre, Pereiro-Muñoz & Aznar Cuadrado, 1998; Patronis, Potari, & Spiliotopoulou, 1999). The purpose of this study was to examine the effects of model-based teaching on students' argumentation skills.

Background

Argument and Argumentation

Zohar and Nemet (2002) state that an argument consists of either assertions or conclusions and of their justifications, or of reasons or supports. Thus, argumentation is held to be a reasoning strategy and, thus, comes under the reasoning domains of informal logic and critical thinking (Jiménez-Aleixandre, Rodríguez & Duschl, 2000).

Scientists, the public and students need argumentation for different purposes. Scientists engage in argumentation to develop and improve scientific knowledge (Erduran, Simon & Osborne, 2004; Kitcher, 1988; von Aufschnaiter, Erduran, Osborne & Simon, 2008). The public has to use argumentation to evaluate information deriving from different sources and to assess the validity and reliability of evidence (Simon, Osborne & Erduran, 2003; von Aufschnaiter et al., 2008). And finally, students need argumentation to learn science by articulating reasons behind their views and presenting alternative ideas to or claims about others' views (Newton et al., 1999; von Aufschnaiter et al., 2008).

Models and Modeling

A model can be taken to be a representation of an idea, object, event, process, or system (Gilbert & Boulter, 2003). Models can have different types of modes: visual, verbal, gestural, mathematical, and concrete (Boulter & Buckley, 2000). Modeling includes construction, use, evaluation, and revision (Schwarz et al., 2009). Because modeling is an important constructivist teaching strategy, it is important to explore the ways students construct, manipulate, and interpret the scientific models in school science lessons (Harrison & Treagust, 2000).

Model-Based Teaching and Learning

Model-based learning focuses on each individual's construction of mental models of the phenomena under study (Boulter, Buckley, & Walkington, 2001). It involves the formation, testing and subsequent reinforcement, revision, or rejection of mental models of some phenomenon (Buckley, 2000). Model formation is the construction of a model of some phenomenon by integrating pieces of information about the structure, function/behavior, and causal mechanism of the phenomenon, mapping from analogous systems or through induction (Gobert & Buckley, 2000).

When model-based learning is embedded in a particular context, factors in model-based teaching come into play (Buckley, 2000). Model-based teaching focuses on the patterns of participation, persuasion and model-building in the learning environment during which individuals construct their understanding of some phenomenon (Boulter, Buckley & Walkington, 2001).

Theoretical Framework

In order to involve with scientific argumentation and produce quality arguments, students need to learn more about the types of claims that scientists make, how scientists advance them, what kinds of evidence are needed to warrant one idea over another, and how that evidence can be gathered and interpreted in terms of community standards (Kelly & Chen, 1999; Osborne, 2002; Sampson & Clark, 2008). Since models are essential as both content products of science (Gilbert & Osborne, 1980) and in the process of coming to understand the world scientifically (Boulter, 2000; Crawford & Cullin, 2003; Harrison & Treagust, 2000; Viennot, 2001), it is argued that modeling can be a useful tool to facilitate argumentation skills.

Argumentation is a form of discourse, includes critical thinking and a reasoning process (Author, 2012). Willard (1989) states that

> Argumentation's epistemic interests inhere in a concern for the social constitution of knowledge, its analytical interests reside in a concern for the coherence, structure, processes, and environments of reasoning and utterance, and its critical interests reside in a concern for the conditions and possibilities for shared discourse (p. 11).

Model-based teaching covers all the aspects of argumentation mentioned above. Put differently, the elements of model-based teaching involve students in critical use of representations in problem solving, promote classroom discourse for reasoning with models and representations, and encourage students to think with chains or networks of causal relationships that are larger than a single A causes B relation (Clement, 2000; Kindfield 1993; Mandinach 1989, Marsh, Willimont & Boulter 1999). Hence, this study suggests model-based teaching as an environment that provides an opportunity for students to engage in argumentative discourse around a scientific phenomenon, form a reasoned argument, and assess evidence and claims critically.

The Practice Framework proposed by Passmore, Stewart and Cartier (2009) supports our rationale about fostering argumentation with the help of modeling. According to Passmore and Svoboda (2012), embedded within the Practice Framework there are at least four points at which curriculum and instruction can be arranged to promote argumentation. That is, argumentation (1) may be fostered when students are engaged in determining what to investigate or when they try to bound the problem in some way, (2) may occur as students wrestle with issues associated with research or investigative design, (3) may happen when students are attempting to use a model to explain a phenomenon, and (4) is a natural outcome when students are confronted with judging between models or ideas. Therefore, it can be said that the act of modeling in science is inherently an argumentative one (Passmore & Svoboda (2012).

Literature Review

Even though the theoretical underpinning for implementing model-based teaching to improve argumentation skills, research investigating the outcome is very rare. Only two studies were come across by reviewing the literature; however, they were not examining the effects of modeling on argumentation. Buty and Mortimer (2008) presented that teaching activities explicitly based on modeling processes favored the emergence of dialogic discourse in the physics classroom. Aduriz-Bravo (2011) found that pre-service science teachers chose to use theoretical models from science as a key component of their arguments in order to increase their argumentation skills. Consequently, we need research that explicitly explores the role of model-based teaching in supporting scientific argumentation (Passmore & Svoboda, 2012).

Methodology

True-experimental design using qualitative data was carried out for this study (Krathwohl, 1997). Control and experimental classes' argumentations were compared to measure the impact of implementation of model-based teaching on argumentation. The experimental class was randomly selected by drawing lots.

Participants and Settings

Participants in this study were pre-service teachers recruited from a physics teacher education program having two phases. The physics teacher education program lasts five years and is structured similarly to the Holmes model. According to this model, pre-service physics teachers must take a sequence of undergraduate physics courses for three and a half years during the first phase of the program. Then, they spend one and a half year taking pedagogy courses and completing their practicum experiences in local schools to develop their pedagogical content knowledge during the second phase. Consequently, pre-service teachers have two roles (i.e., learners and teachers). As learners, they try to construct scientific understanding of concepts while as teachers they try to develop teaching strategies to facilitate learning. The participants consisted of 24 pre-service physics teachers, 14 of whom were females. Their ages ranged from 20 to 22. They were in their fourth year.

The study took place in a methods course. The Instructional Methods in Physics is one of the main courses of the physics teacher education program where pre-service teachers meet five hours a week and have opportunities to build theories of physics teaching and learning, do teaching activities, examine their own teaching, observe and examine peer teaching, and experience different teaching and learning approaches. The course professor, who is also the first author of the study, taught the course. The participants took the course as two equal classes. One was the control class and the other one was the experimental class.

Intervention

Before starting to the argumentative intervention, the participants in both classes discussed about definitions as well as theoretical foundations of argumentation and components of an argument. They were also engaged in different argumentation contexts before the intervention in order to be familiar with various forms of argumentation. This initial process lasted one and a half hour per week in five consecutive weeks.

During the first step of the initial process, the participants were asked to define argumentation. After the participants shared their understanding of argumentation with the course professor, the course professor exposed them to various definitions of argumentation and explained the theoretical foundations of argumentation. In the second step, the professor made various components of an argument explicit to the participants through examples. After she explained Toulmin's (1958) argumentation framework, she distributed letters including the communications between Newton and Hook about their arguments of physics to the participants. She then asked the participants to identify the components (i.e., claim, data, warrant, qualifier, and rebuttal) of each scientist's argument and to assess their plausibility and validity. The participants completed this assignment in groups of three**.** In the third step, the professor specifically explained the potential role that the argumentation could play in bringing about conceptual change in students' learning of science concepts. The participants also discussed how a teacher's and students' roles change during argumentation-based teaching. During the final step, the participants involved with different argumentation contexts.

In one of these argumentations, the course professor showed a video of wing-suit athletes. Then, she engaged them in argumentation around four problems related to the topic of dynamics. The first problem was related to the initial velocity of the athletes. The participants' arguments focused on the question of "Does starting with an initial velocity help the sportsmen fly faster?" The second problem was about the forces exerted on the sportsmen during their movements. The participants argued over whether the net force was constant or not. The participants also argued about how the athletes could determine their directions and how they could get on the ground. After the participants discussed solutions of these four problems presented to them, the professor engaged them in a whole class argumentation for each problem. One week after, the professor challenged the participants to participate in argumentation by using concept cartoons related to the topic of electromagnetic waves. This argumentation took place in a structured whole class discussion format where they wrote their ideas and reasoning in their worksheets. The participants also engaged in a whole class argumentation related to the matching theories of optics.

The argumentative intervention lasted seven weeks. Both classes engaged in argumentations but the experimental class argued through model-based teaching sequences. The subjects of the argumentations were related to the Moon and various lunar phenomena some of which were about the moon phases, seeing the same face of the Moon, daytime moon, lunar eclipse, rise and set times of the Moon, and location of the full moon.

The participants in both classes were assigned for Moon observations and Moon records prior to the intervention to recognize the phenomena discussed during the argumentations and to have some observational data. Since keeping written records allows students to test their theories and build new ones based on nature and aids them learn the content (Sadler, Haller & Garfield, 2000), the participants were asked to keep their observational records such as date, angle, time, and Moon's shape in a journal. As a result, they had five-week observational data in their journals before starting to argue about lunar phenomena.

The participants in both classes engaged in argumentations as groups first, and then whole-class discussions were carried out. The member number in each group was three. The group members remained unchanged through the intervention in order to keep the factor of group dynamics constant. Additionally, the participants were required to write their initial ideas as well as their changed ideas with their reasons into the worksheets individually during both the group work and the whole class discussion.

Boulter et al. (2001) reveal that model-building sequences begin with students expressing initial models. Then, students face challenges to their existing models in the field along with the need to negotiate new group models, and finally, they report models in their presentations and endure more challenges (Boulter, Buckley & Walkington, 2001). These sequences were provided in the modeling context of the intervention in the experimental class. Therefore, the pre-service teachers in the experimental class were asked to construct a simple model before coming to the class to discuss moon events by using it. As a result, at the first week of the intervention, they came to the class with their initial models. Suzuki (2003) assumed two barriers for studying the Moon: to visualize the relationship among the Sun, Earth, and Moon in three dimensions, and to realize from where observers view the Moon in three dimensions. In order to remove these barriers, the pre-service teachers were asked to construct three-dimensional models at the end of the project. While the groups in the experimental class were arguing about moon events, they also discussed and decided about how their model would be better. Thus, the participants in the experimental class argued by using their models, found the strengths and weaknesses as their models were used to explain the phenomena and revised their models throughout the intervention. Examples including the differences in the control and experimental classes from the first and the third argumentations are given in Appendix. The counter claims in the argumentations were created by using pre-service physics conceptions about the Moon and lunar phenomena determined by Author (2007).

Data Collection and Analysis

Both classes were videotaped during their involvements with the argumentations. Data for this research were collected via the video recordings and the written arguments. Comparisons were made within as well as between the classes' first-week argumentation and the last-week argumentation for this research. The first-week argumentation was related to moonrise, moonset, and seeing the same face of the Moon and the last-week argumentation was about appearance of the Earth from the Moon.

The participants' scientific argumentations were analyzed by using the combinational framework constructed by the authors based on McNeill (2006)'s and Sampson (2007)'s works. Toulmin's (1958) framework was not used because accuracy in other words compatibility with scientific knowledge in the participants' arguments was assessed. The combinational framework consisted of the following argument components: claim, evident, and reasoning. The names of the components belong to McNeill. Sampson used explanation instead of claim. A scoring rubric was developed and each component was evaluated from zero to four. Claims were evaluated according to their internal consistency, completeness, and accuracy. Evidences were evaluated in terms of their relevancy with the claims, accuracy, and appropriateness. Criteria used in evaluation of reasoning were relationship between the claim and the evidence, explanation made for why the evidence supported the claim, and existence of an argument component (i.e., warrant, backing or a qualifier). Some of the criteria in the rubric were taken from McNeill's work while some of them were received from Sampson's work since none of them seemed to cover all the aspects of the arguments in the Moon argumentations. For instance, Sampson emphasized the relevancy with the claims whereas McNeill gave importance on accuracy (scientifically correctness) when an evidence came into play. On the other hand, both of them used appropriateness (gathering by using a scientific method) as a criterion for evidence. As a result, the rubric for evaluation of evidence contained all the three criteria (i.e., relevancy with the claim, accuracy, and appropriateness) (see Figure 1).

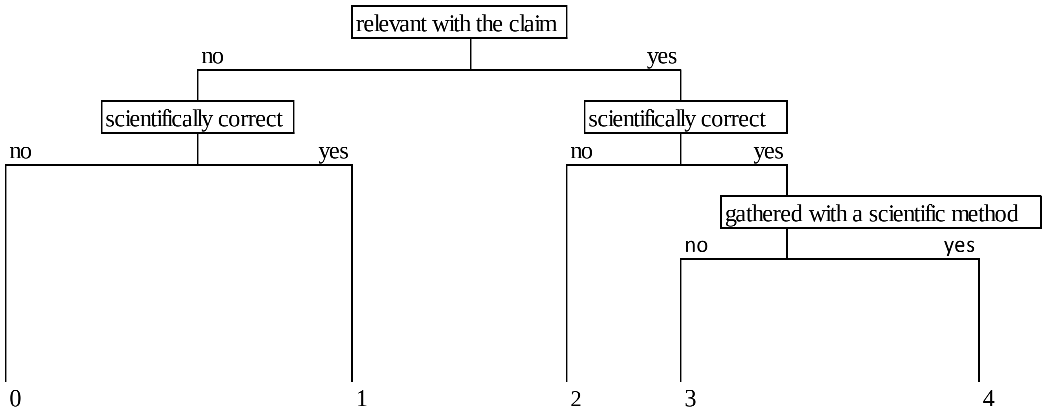

Figure 1: The rubric for evaluation of evidence.

Each participant's number of arguments that s/he produced was found. Additionally, each participant's argumentation score was calculated by summing of the points given to his/her claims, evidence, and reasoning. In order to determine quality of the argumentation, the participants' argumentation scores were summed.

The participants' argument components were coded by two researchers separately, and then compared. The agreement between the coders was 89 %. The reliability measured by Cohen's κ was 0.77. There seems to be general agreement that Cohen's κ value should be at least 0.60 or 0.70 (Wood, 2007). Consequently, the coding done for the participants' argumentation had adequate reliability. The authors re-coded the argument components that they could not have agreement on and the final coding scheme was constructed by reaching consensus.

Results and Discussion

The four groups from the experimental class were named as Group A, Group B, Group C and Group D. The four groups from the control class were named as Group E, Group F, Group G and Group H. Table 1 shows the participants' argumentation scores and the number of argument components they generated. For example, while Student 1 in Group A got 17 as argumentation score and produced six argument components during the first week, she got 31 as argumentation score and created 10 argument components at the end. Student 13 in Group E received 11 as argumentation scores and generated five argument components before the intervention while she received 16 as argumentation scores and created seven argument components after the intervention. In general, the participants did not have much difficulty in engaging argumentation and generating argument components from the beginning to the end. Their observational data might help them in this involvement. Students' observational drawing may be an important part of challenging student's argumentation.

Table 1. *The participants' argumentation scores and their numbers of argument components.*

Class	Group	1. Week				7. Week		
		Students	**Argumentation Score**	**Number of Argument Components**		**Students**	**Argumentation Score**	**Number of Argument Components**
Experimental Class	Group A	1	17	6	Group A	1	31	10
		2	15	8		2	32	11
		3	13	7		3	23	12
		Group's Total	45	21		Group's Total	96	33
	Group B	4	26	12	Group B	4	38	12
		5	10	7		5	22	7
		6	25	9		6	19	7
		Group's Total	61	28		Group's Total	79	26
	Group C	7	3	2	Group C	7	12	4
		8	24	8		8	22	6
		9	28	11		9	41	13
		Group's Total	55	22		Group's Total	75	23
	Group D	10	22	10	Group D	10	29	12
		11	23	12		11	39	14
		12	20	11		12	37	13
		Group's Total	65	33		Group's Total	105	39
		Class's Total	**226**	**104**		**Class's Total**	**355**	**121**
Control Class	Group E	13	11	5	Group E	13	16	7
		14	10	4		14	16	6
		15	6	3		15	8	3
		Group's Total	27	12		Group's Total	40	16
	Group F	16	16	8	Group F	16	25	10
		17	21	9		17	23	9
		18	9	4		18	13	5
		Group's Total	46	21		Group's Total	61	24
	Group G	19	15	6	Group G	19	25	9
		20	14	9		20	18	9
		21	9	5		21	17	7
		Group's Total	35	20		Group's Total	60	25
	Group H	22	15	8	Group H	22	20	9
		23	23	11		23	25	12
		24	18	10		24	26	11
		Group's Total	56	29		Group's Total	71	32
		Class's Total	**164**	**82**		**Class's Total**	**232**	**97**

At the first week of the intervention, the experimental class produced more arguments (104) than the control class produced (82). Likewise, the experimental class's total argumentation score (226) was higher than the control class's total score (164) at the beginning. The reason for this finding might be the experimental class's initial models which created more argumentative environment.

Findings were similar at the end. That is, the experimental class's total number of arguments (121) and argumentation score (355) were both higher than the control class's total number of arguments (97) and argumentation score (232) at the last week of the argumentative intervention. These findings indicate that in virtually all aspects of modeling, an individual is engaged in sense-making, articulating, and persuasive acts (Berland & Reiser, 2009).

As far as the control class is concerned, their total argumentation score increased from 164 to 232 from the first week to the last week. Similarly, the number of arguments they generated in total improved from 82 to 97 from the first week to the last week. This finding is expected because research shows that both quantity of arguments and argumentation quality develop as the participants involve with argumentation more and spend more time in arguing (Author, 2012). However, the participants who constructed three-dimensional models and used their models while arguing raised their number of arguments in 16.3 % ratio while the participants in the control class raised their number of arguments in 14.1 %. Whereas the participants engaging in model-building sequence improved their quality of argumentation in 57 %, the participants arguing without models improved their quality of argumentation in 41.5 %. There is a possibility that the control class might get bored of arguing about the Moon events for seven-week long while the experimental class did not lose their interest in argumentation sequences due to their involvement with their models. The model provides an important anchor to which argumentation can be attached and made productive (Passmore & Svoboda, 2012).

According to Table 1, the highest increase occurred in Group A in terms of both argumentation score and the number of arguments they produced from the first week through the last week. The reason for this increase might be their concrete model which represented the real situations quite well. Their final model consisted of a light source representing the Sun, a globe, and a table tennis ball representing the Moon. The Moon and the Earth could rotate from west to east. The Moon could revolve around the Earth from west to east and the Moon–Earth system could revolve around the Sun with the help of the wheels. Group A connected the Moon to the Earth with a small angle.

Although Group B increased their argumentation scores, in other words the quality of their arguments, they decreased the number of arguments that they generated from the first week through the last week. Their premature models might cause this result because they could not discuss how astronaut would see the Earth from the Moon by using their models. The final model constructed by Group B was made up of a tennis ball representing the Sun, eight different phases of the Moon made from black and white play dohs and a table-tennis ball representing the Earth. These findings support the idea belongs to Garcia-Mila and Andersen (2008) that arguments are indicators for or against the fitting of a model according to its logical coherence or in comparison to empirical data. The better a model represents the focused aspects of reality, the better arguments for its appropriateness can be found (Garcia-Mila & Andersen, 2008).

Conclusions and Implication of the Study

This study was conducted to find if there is any relationship between model-based teaching and argumentation. The following conclusions can be drawn from the results: First, construction of concrete models and using them in their discussions and explanations provide learners with more quality (accurate, consistent, appropriate, and relevant) argumentations. Second, model-based teaching help learners increase the number of arguments they create.
Last, models' quality affects the number of claims, evidences and reasoning that are produced during argumentation. The closer learners' models are to the real situations, the more argument components they generate.

The conclusions present here carry implications for curriculum developers and teacher education. Model-based teaching would be introduced and disseminated through pre-service science teacher education. This study has implication by indicating the relationship between modeling and argumentative discourse.

The second, third, fourth and fifth argumentations will be examined in the further studies. In this way, the interplay between modeling and argumentation would be established strongly. Moreover, this relationship would be discussed in terms of the content of argumentation.

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Appendix-A

First Argumentation: Seeing the Same Phase of the Moon

Robert has been observing the Moon for ten days and concluded that we always see the same face of the Moon from the Earth.

A) Please explain the reason of his conclusion by using the claims below. You can use a different claim other than the givens below.

a) The Moon does not rotate on its axis.
b) Both the Moon and the Earth rotate on their axes in the same period.
c) The Moon rotates once on its axis at the same rate it revolves once around the Earth.
d) Because Robert observed the Moon from the same location in the Earth, he made a mistake in his conclusion.
e) Because Robert observed the Moon everyday at the same time, he made a mistake in his conclusion.
f) The Moon rotates on its axis from South to North.

B) Justify your explanation (individually).

C) Use your initial model for your explanation. You may need to revise your initial model [only in the experimental class].

D) Discuss your explanation with your friends by providing your justification (as group).

E) Use your model in your explanation [only in the experimental class].

F) Finalize your group's explanation.

G) Decide on a model as a group [only in the experimental class].

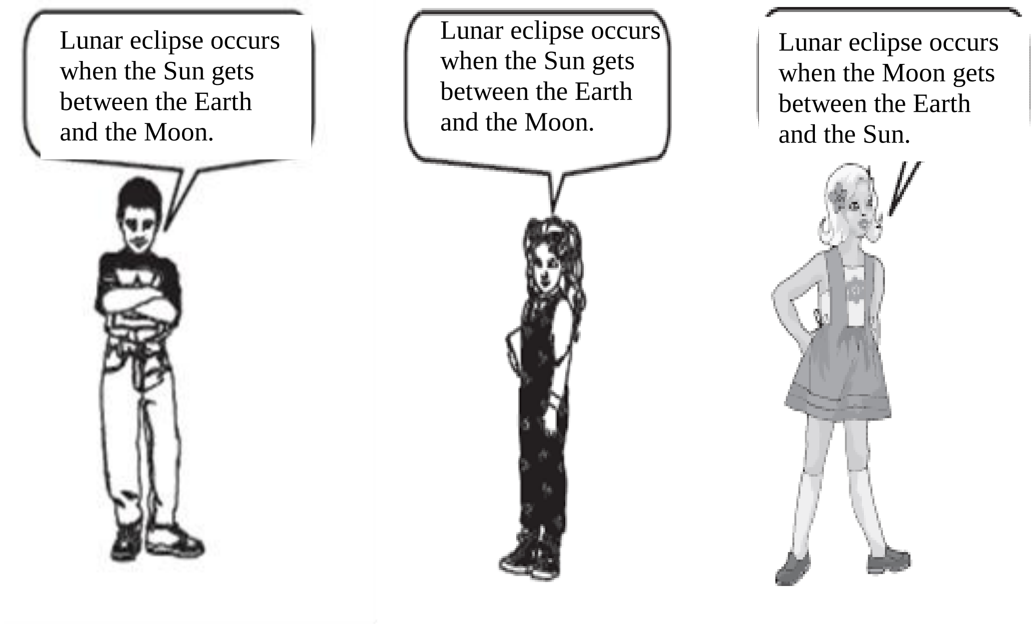
H) If your initial opinion changed, please write why your opinion changed.

I) Explain your final explanation to other groups (by using your model [only in the experimental class]) (whole class discussion).

Appendix-B

Third Argumentation: Lunar Eclipse

Three friends' thoughts about how lunar eclipse occurs are as follows:



A) Who do you think is correct about how lunar eclipse occurs? Is John, Jasmine or Daphne? Why? (individually).

B) Discuss your opinion with your friends by providing your reasons (as group).

C) Use your model in your discussion [only in the experimental class].

D) Can your model help you to explain how lunar eclipse occurs? If not, how can you revise your model [only in the experimental class]?

E) Make your group's decision.

F) If your initial opinion changed, please write why your opinion changed.

G) Explain your final decision to other groups (by using your model [only in the experimental class]) (whole class discussion).