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Interplay between content knowledge and scientific argumentation

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This research study aimed to analyze the relationship between content knowledge and argumentation by examining students' prior subject matter knowledge and their production of arguments as well as by comparing students' arguments with their knowledge-in-use during scientific argumentation sessions. A correlational research design was carried out for this research by using qualitative and quantitative methods. The participants of the study were 13 senior pre-service physics teachers studying in a large urban state university. Six scientific argumentation sessions in different contexts under different contents were implemented in the methods course where pre-service teachers meet for 5 h per week. Written and oral data were collected by using a variety of methods for different purposes. Toulmin's Argument Pattern was used to evaluate the arguments while content knowledge was analyzed by the model developed by Chi and Roscoe (2002). Some of the conclusions drawn from the study are as follows: First, a positive relationship exists between individuals' content knowledge they use and quantity of arguments they produce during a scientific argumentation. Second, some conditions influence the relationship. Third, there are number of interactional factors affecting production of arguments. Fourth, learners' characteristics has an impact on their engagement with argumentation. Suggestions and implications have been made.

Keywords: Argumentation, content knowledge, interaction, physics

INTRODUCTION

Argumentation is a form of discourse, includes a reasoning process and promotes critical thinking (Ogan-Bekiroglu & Eskin, 2012). Students need argumentation to learn science by articulating reasons behind their views and presenting alternative ideas or claims to others' views (Newton, Driver & Osborne, 1999; von Aufschnaiter, Erduran, Osborne & Simon, 2008). Consequently, "the adoption and development of

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argumentation frameworks has gained in importance over the last two decades as researchers and curriculum developers seek ways to either nurture dialogic discourse or to analyze the development of students' reasoning with evidence and theory" (Duschl, 2008, p. 160). However, research focusing on the interplay between science understanding and argumentation practices is very rare although such research is very helpful to recognize how argumentation improves learning (Ogan-Bekiroglu & Eskin, 2012). Hence, this research study aimed to analyze the relationship between content knowledge and argumentation by examining students' prior subject matter knowledge and their production of arguments as well as by comparing students' arguments with their knowledge-in-use during scientific argumentations. Students' dialogues and their engagement were explored to understand the causal connections between knowledge and argumentation.

State of the literature

- Reviewing of the research indicates some inconsistent results about the relationship between prior knowledge and argumentation. The reason for the inconsistency can derive from how the researchers measured prior knowledge, how they evaluated argumentative skills and how the relation between the two was assessed.
- There have been only a few studies regarding content knowledge assessment during scientific argumentation process. These studies did not perform statistical analysis to search for a relationship and they revealed somewhat controversial results.
- More research exploring students' knowledge with the reasoning behind and their engagement with argumentation is needed to understand the causal connections between knowledge and argumentation.

Contribution of this paper to the literature

- This study examined how prior knowledge made a difference in argument production and how argumentation had impacts on knowledge construction by implementing both quantitative and qualitative methods.
- Conclusions of this study propose that learners' prior knowledge affects their arguments in the beginning of the argumentation; however, learners' content knowledge may expand while they are constructing, communicating, and evaluating knowledge claims during the argumentation. This knowledge change during the argumentation may result increase in their production of arguments. Familiarity with the content, content and context of the argumentation, dynamism and characteristics of the interaction, and learners' characteristics are critical in influencing the interwine between knowledge and argumentation.

Conceptual Underpinnings: Argumentation and Knowledge

Argument includes producing an idea and giving the reason or the evidence behind that idea while argumentation is the process of arguing (Eskin & Ogan-Bekiroglu, 2013). Dialogic argumentation is used in this study. Dialogic argumentation involves in scientific reasoning and science discourse practices, both of them essential in science learning (Garcia-Mila & Andersen, 2008). When learning is generated by argumentation in dialogic forms, the externalization of the dialectical processes plays an essential role in the development of argumentation (Kuhn, 1991).

Knowledge refers to content knowledge in this study. According to Shulman (1986), content knowledge is the amount and organization of knowledge per se in a learner's mind. However, to think properly about content knowledge requires going beyond knowledge of the facts or concepts of a domain and requires understanding the structures of the subject matter (Shulman, 1986).

Conceptual underpinnings of this study is based on the relationship between knowledge and argumentation framed in more detail elsewhere (Ogan-Bekiroglu & Eskin, 2012). According to this framework, argumentation involves with critical thinking and reasoning. Additionally, there are two-sided relationships between critical thinking and knowledge and between reasoning and knowledge. Therefore, argumentation and knowledge are related as can be represented in Figure 1.

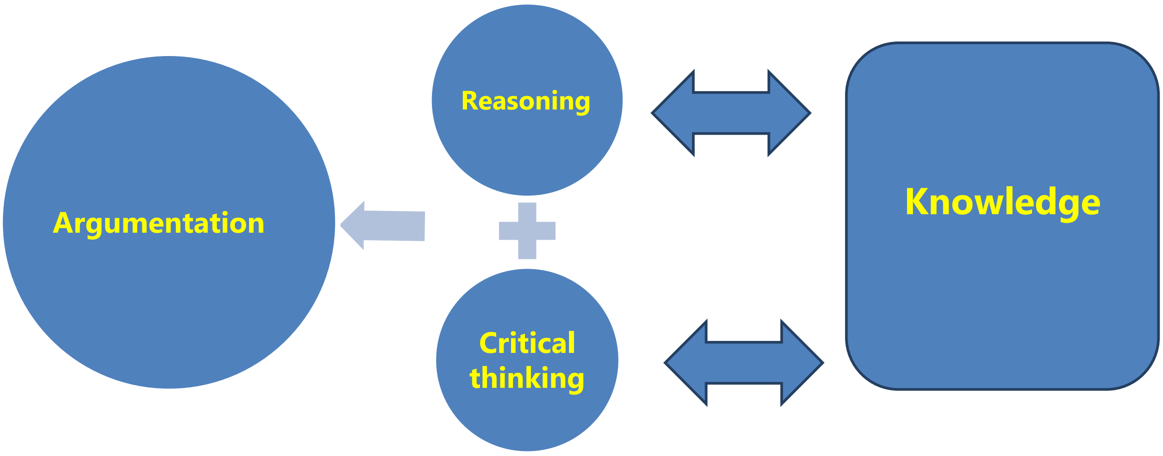

Figure 1. The relationship between argumentation and knowledge.

Certainly the relationship between argumentation and knowledge is not limited with the facets of this figure because argumentation also supports the access to metacognitive process, the achievement of scientific literacy and the development of epistemic criteria (Jiménez-Aleixandre & Erduran, 2008), which are somehow related to knowledge.

Prior knowledge is learners' existing knowledge prior to instruction (Hewson and Hewson, 1993). Billett (1996) suggests that "co-construction is achieved through the deployment of higher order procedural knowledge, acting to overcome the problem presented by the reciprocal interaction between the individuals' prior knowledge and social circumstances" (p. 272). Hence, learners' contributions to the argumentation may be affected by their prior knowledge of the subject discussed.

RESEARCH ABOUT BUILDING AN ARGUMENT FOR THE RELATIONSHIP BETWEEN KNOWLEDGE AND ARGUMENTATION

Numerous studies have shown that embedding argumentation in an instruction increase student science learning (Bell & Linn, 2000; Eskin & Ogan-Bekiroglu, 2013; Mason, 1998; Niaz, Aguilera, Maza & Liendo, 2002; Nussbaum & Sinatra, 2003; Zohar & Nemet, 2002). However, this is not the scope of the current study. In accordance with the purpose of this study, the following research contents are addressed here: relationship between prior subject matter knowledge and argumentation, and knowledge during scientific argumentation process.

Relationship between Prior Subject Matter Knowledge and Argumentation

Among the research studies, some of them did not find a positive relationship between prior knowledge and argumentation while some of them did. For example, the research conducted by Kuhn (1991) declared that experts in a domain did not show better forms of argumentative thinking in the domain of their expertise than they did about other topics. In addition, Perkins, Farady and Bushey (1991) presented that there was no difference in students' argument quality between students having prior knowledge and students who did not have any prior knowledge about the subject discussed.

In contrast, Means and Voss (1996) found that prior knowledge was related to some aspects of argumentative thinking, such as generating more reasons or stating more qualifiers but not all of them. Zohar and Nemet (2002) pointed out that prior knowledge was one of the factors that affected ninth-grade students' argument quality. Besides, Sadler and Fowler (2006) examined how individuals studying in different majors made use of scientific content knowledge for socioscientific argumentation. They suggested that science content knowledge could affect the manner in which individuals defended and justified their positions. Cross, Taasoobshirazi, Hendricks and Hickey (2008) reported that high school students tended to feel more comfortable and be more competent in arguing about concepts when they were sufficiently knowledgeable about that subject. von Aufschnaiter and her colleagues (2008) showed that the main indicator of whether or not a high quality of argument was likely to be attained was junior high school students' familiarity and understanding of the content of the task. Finally, Ogan-Bekiroglu and Eskin (2012) presented that the more tenth-grade students had experience with the concepts that they came across during the argumentation; the more they produced argument components including quality rebuttals. Reviewing of the research mentioned above indicates some inconsistent results about the relationship between prior knowledge and argumentation. The reason for the inconsistency can derive from how the researchers measured prior knowledge, how they evaluated argumentative skills and how the relation between the two was assessed. Only a few research measured prior knowledge by looking at the reasoning behind the learners' responses. In addition, half of the six research that found a relation did not explore the relationship whether it was significant or not. More statistical research is needed to find out if prior knowledge makes a difference in argument production by examining prior knowledge in more detail.

Knowledge during Scientific Argumentation Process

There have been only a few studies regarding knowledge assessment during scientific argumentation process; thus, they are discussed in more detail here. The first research was done by Tavares, Jiménez-Aleixandre and Mortimer (2010), who examined high school students' oral arguments while the students were solving tasks related to evolution. Their purpose was to look at the process of articulation of conceptual knowledge and argumentation practices. They showed that understanding evolution was necessary for constructing arguments. They also documented that argumentation practices could support a better understanding of evolutionary processes. On the other hand, von Aufschnaiter et al. (2008) investigated junior high school students' processes of argumentation and cognitive development in science and socio-scientific lessons. They could not found direct relation between the quality of argumentation and the level of students' understanding of science. Therefore, they reached the conclusion that high-level argumentation can be developed with low-level knowledge.

Ogan-Bekiroglu and Eskin (2012) observed the changes in tenth-grade students' quantity and quality of arguments and their knowledge of scientific concepts to look for a relationship between their engagement in scientific argumentation and their conceptual knowledge. Five argumentations promoted in different contexts were embedded through the ten-week dynamics subject. They presented that although there was a gradual increase in students' quality and quantity of arguments as they spent more time in arguing, there was no ongoing conceptual growth in their knowledge during five argumentations.

Whereas there has been substantial amount of research regarding the positive effects of argumentation on science knowledge development, research exploring the relationship between knowledge and argumentation during the argumentation process is not ample. Moreover, three studies explained above did not perform statistical analysis to search for a relationship and they revealed somewhat controversial results. Therefore, in order to make inferences about how argumentation has impacts on knowledge construction, there is a need for statistical studies tracing students' involvement with scientific argumentations and their knowledge in use while they are arguing.

PURPOSES OF THE STUDY

Students' willingness to acknowledge and deal with situations that may involve argument depends on their learning situation (Perret-Clermont, Perret & Bell, 1991). During argumentation, attention must be paid to the cognitive capacities of the individuals (Kuhn, Shaw & Felton, 1997) as well as to the ecology of relations that develops within interactions allowing group members to access and functionally express knowledge and arguments (Barron, 2003). Consequently, the research questions addressed in this current study are as follows:

1. Is there a statistically significant relationship between students' prior subject matter knowledge in physics and their production of scientific arguments?

2. Is there a statistically significant relationship between students' production of arguments and their physics knowledge in use during the scientific argumentation process?

3. What are the processes that contribute to the emergence of arguments and are associated with the relationship between content knowledge and arguments?

4. What is the role of content knowledge in the individual students' contributions to the arguments?

METHODOLOGY

A correlational research design (Creswell, 2008) was carried out for this research to examine the relationship between participants' arguments and their knowledge. Both qualitative and quantitative methods were used to analyze the data in order to explain the possible relationship.

Participants and Settings

Zohar (2008) emphasizes that teachers' lack of pedagogical strategies to support students' argumentation have been identified as a major barrier to routine application of argumentation in school science. Teacher education programs should provide ample opportunities for their students to engage in challenging argumentation, so that teachers would have the pedagogical knowledge in the context of argumentation (Zohar, 2008). Hence, the participants of the study were 13 senior pre-service physics teachers taking the methods course and studying in a large urban state university. "Instructional Methods in Physics I" is one of the main courses in the physics teacher education program. It is a one-semester course where pre-service teachers meet for 5 h per week. In this course, pre-service teachers have opportunities to build theories of teaching and learning, do microteaching activities, examine their own teaching, observe and examine peer teaching, and experience different teaching and learning approaches. They had already completed all the necessary physics courses. Their average age was 21 and four of the participants i.e., Student 2, Student 4, Student 5 and Student 12, were female. It was the first time that the participants were being a part of argumentation context in the class. The students worked as groups in the beginning of the argumentations and then, each group expressed their ideas in a whole-class discussion. There were two or three students in each group. Groups' members were changed each week. The reasons for this procedure were to construct heterogeneous groups in terms of their prior knowledge, to provide students for working with different peers, and to prevent students' participation become routine.

Implementation of Argumentations

Six scientific argumentations were promoted. The subjects of the argumentations were dynamics and heat-temperature. The first three argumentation sessions were related to dynamics. The duration of each argumentation session was approximately 50 minutes. The participants had not had any experience with argumentation as a teaching strategy. Due to the fact that the pre-service teachers had completed the physics courses and had previous knowledge of the physics subjects, the aim of the course professor was not to teach physics to the students. The goal was to provide opportunities for them to involve in argumentation process and to argue about scientific concepts.

Activities that encourage dialogic argumentation can provide a context whereby individuals are able to use each other's ideas to construct and negotiate a shared understanding of a particular phenomenon in light of past experiences and new information (Clark & Sampson, 2008). Thus, all of the argumentations were dialogic where different perspectives were being examined and the purpose was to reach agreement on acceptable claims or courses of action (Driver, Newton & Osborne, 2000). Since the context and content of argumentation affect participants' argumentation quality (Duschl & Osborne, 2002; Kelly, Druker & Chen, 1998), six argumentations were implemented in the different contexts under the different contents. Table 1 shows the content and context of argumentation sessions, materials that were provided to the students, and the main concepts that were discussed during the sessions.

Table 1. Content, concepts, and context of the argumentation sessions and the materials used during these sessions.

	Argumentation Sessions					
	First	**Second**	**Third**	**Fourth**	**Fifth**	**Sixth**
Subject	**Dynamics**			**Heat-Temperature**		
Content	Motion of a truck in two dimensions.	Projectile motion of stones.	Motion of flying sportsmen.	Thermometers.	Mechanism of a hot-air balloon.	Daily life phenomena about heat and temperature.
Main Concepts	Speed, velocity, acceleration and force.	Range, height and flight time.	Free fall, speed, velocity, force and air friction.	Expansion, temperature, heat, boiling, melting and freezing points.	Buoyancy force, gases and pressure.	Heat, expansion, conductivity and specific heat.
Context	Explanation for a phenomenon.	Eliciting alternative conceptions.	Prediction-observation-explanation.	Controversial dialogues.	Prediction-observation-explanation.	Matching of a theory with a phenomenon.
Materials	Worksheet and video recording.	Worksheet	Worksheet and video recording.	Concept cartoons, ethanol alcohol thermometer and fuel thermometer.	Worksheet, video recording and power point slides.	Worksheet

The first argumentation session was about the motion of a truck in two dimensions in the context of explanation for a phenomenon. The students watched a video recording and discussed the speed, velocity and acceleration of the truck as well as the forces exerted on the truck while it was both moving on a flat road and around a curve on the road. Worksheets including open-ended questions were distributed to the students. The following question is an example from the questions in the worksheet: What are the forces exerted on the truck while it was rounding a curve on the road? The second argumentation session was related to the projectile motion of stones in the context of eliciting alternative conceptions. There was a sketch about three children who were throwing three stones with different weights and different throwing angles to a lake. The students argued about the range, height and flight time of the stones. They were also asked what would happen if the children threw the stones in the Moon. The worksheet of this argumentation is given in the appendix to provide an example for the argumentations. The third argumentation session was about the motion of flying sportsmen wearing wingsuits in the context of prediction-observation-explanation. The students were shown a video recording of sportsmen and asked questions about their flight, landing and velocity. Some questions are as follows: "In which situation do these sportsmen fly longer: Starting their flight with an initial velocity or starting their flight by releasing themselves freely. Why?", "What are the forces exerted on them during their flight?", "How is it possible for them to land?". After the students' final answers were taken, they were shown images from the video recording to obtain their explanations. The fourth argumentation session was related to the decision about how to make the most efficient thermometer in the context of controversial dialogues. Concept cartoons including dialogues among three pupils working in a laboratory to determine which material they should use in the thermometer were presented in the worksheet. The students decided on which pupil was right about the material and gave their reasons for their decision. The students also tried to measure the same liquid in two caps with an ethanol alcohol thermometer and a fuel thermometer, and compared the differences between two measurements. The fifth argumentation session was about the mechanism of a hot-air balloon in the context of prediction-observation-explanation. After the students discussed how a balloon could fly and how it could land, they watched a video recording about a man living in the ancient time, who was trying to launching and flying a hot-air balloon. They predicted what could be wrong in the mechanism of the balloon by declaring their reasons and argued about how they could fly the balloon. Then, the students compared their predictions with some information giving in the presentation and explained how their predictions changed. The sixth argumentation was about finding correct theories for daily life events in the context of matching of a theory with a phenomenon. The students were given 11 daily phenomena and asked to match each of them with one of the four theories related to heat, expansion, conductivity and specific heat by justifying their answers. Some of the phenomena are as follows: we feel cold after we sweat in a chilly day; when we put a thermometer in a hot liquid, the level of mercury in the thermometer decreases at the beginning, then increases; we place a jar upside-down in the hot water to open the stuck jar lid.

Mason (1998) found that when argumentations were promoted as both verbal and written, students became more willing to participate. Therefore, worksheets were distributed to the students at the beginning of each argumentation. They wrote their ideas and explanations in their argumentation worksheets before participating in the whole class discussion.

Role of the Researchers

The authors of this paper are the physics educators. The second author was the professor of the course and she observed the students during the argumentations.

Hogan, Nastasi and Presley (1999) presented that when a teacher guided students during argumentations, they produced more quality arguments. Hence, the first author observed the groups, directed the students to the next step, facilitated argumentations, started and led the whole class discussion, and prevented irrelevant talk during the argumentation sessions. Before implementing the argumentations, she had been participated in the class as an observer for seven weeks. This situation enabled her to establish a good communication with the students and to create an environment where the students felt comfortable about stating their views. In addition, she was an instructor in a community college and had been using the argumentation strategy in her classes for a while. As a result, she was quite confident in her abilities to promote argumentations in the class. Both authors had roles in planning the research and data analysis.

Data Collection Methods

Data were collected by using a variety of methods for different purposes. First, a questionnaire about the subjects of dynamics and heat-temperature was developed by the researchers to determine the participants' prior subject matter knowledge, and administered to the students before starting to argumentation sessions in the class. Individuals' prior knowledge is the product of their personal histories or ontogeny, comprising the organization of concepts and procedures underpinned by dispositions (Billett, 1996). Thus, the types of the questions were determined as open-ended to be able to evaluate the participants' reasoning behind their answers. The questionnaire included 30 factual, explanation, and generative questions to clearly and thoroughly identify the pre-service teachers' prior knowledge. Factual questions test the learner's knowledge of theoretically important facts (Vosniadou, 1992). They can be answered by repeating acquired information without necessarily understanding it (Buckley & Boulter, 2000). Explanation questions, on the other hand, lead the learner to explain the facts (Vosniadou, 1992). Generative questions capture the learner's generative model (Vosniadou, 1992). These kinds of questions do not refer directly to observable situations nor can they be answered promptly by repetition. To answer generative questions, students need to refer to and use whatever relevant knowledge/experience they have, so as to create a mental representation that can help them form an answer (Buckley & Boulter, 2000). Examples are given below for each type of the question in the questionnaire.

Factual question. The liquids of K and L have specific heat values of 0.2 cal/gr°C and 0.8 cal/gr°C respectively. 500 gr from K and 250 gr from L are mixed and the initial temperatures of K and L are 40°C and 70°C respectively.

a) What is the heat capacity of K and L in terms of cal/ °C?

b) What is the final temperature of the mixture in terms of °C?

Explanation question. Is a car able to drive at every speed safely through a curve? What is to be considered in order to adjust its speed? Please explain with your reasons.

Generative question. What would you do to open a tight jar lid? Please explain with your reasons.

Table 2 presents the frequency of the questions in the questionnaire based on their types.

Table 2. Frequency of the questions in the questionnaire based on their types.

Subject	Factual	Explanation	Generative	Total
Dynamics	4	5	4	13
Heat and Temperature	6	6	5	17

The questionnaire assessed the students' understanding of the concepts mentioned and discussed during the argumentation sessions. Some of the questions measured the students' understanding of more than one concept. The questionnaire was developed by the two authors, who are physics educators. The content validity of the questionnaire was ensured with one physicist, one physics teacher and the third physics educator. After a few minor changes, the questionnaire was pilot tested with 11 undergraduate students studying in the physics department in terms of readability and understandability. Then, the questionnaire was administered to 36 pre-service physics teachers. Internal consistency of the questionnaire computed by the Cronbach's Alpha was high, with reliability coefficients of 0.77.

The participants were videotaped during the argumentation sessions in order to analyze their arguments. Their worksheets were used as the second data source. Small conversations were done with the students about their participation just after the argumentation sessions and anecdotes were filled.

Data Analysis

Analysis of Argumentation. Toulmin's Argument Pattern (TAP) has been used to evaluate the arguments. Numerous researchers (Bell & Linn, 2000; Blair & Johnson, 1987; Erduran, Simon & Osborne, 2004; Jiménez-Aleixandre, Rodríguez & Duschl, 2000; McNeill, Lizotte, Krajcik & Marx, 2006; Osborne, Erduran & Simon, 2004; Sadler & Fowler, 2006; Simon, Erduran & Osborne, 2006; von Aufschnaiter, Erduran, Osborne & Simon, 2007; Zohar & Nemet, 2002) used Toulmin (1958)'s framework in their studies. The Toulmin model was used in this study because it is primarily analytical and foundational in establishing that arguments are unfold in dialectical question; therefore, the applications of the Toulmin model have allowed it to be used somewhat productively in educational research (Nussbaum, 2011). Besides, the researchers considered to use other models such as Clark and Sampson (2008)'s approach, the Toulmin's model fit best to the data.

Despite its frequent use, TAP presents a number of methodological limitations (Sadler & Fowler, 2006). First, TAP does not allow assessing students' science content knowledge during argumentation process (Sampson & Clark, 2008). Therefore, the participants' scientific knowledge during the argumentation was analyzed in detail by using Chi and Roscoe (2002)'s model. Another complication encountered by researchers in applying Toulmin's framework involves reliably distinguishing between claims, data, warrants, and backings because the comments made by students can often be classified into multiple categories (Sampson & Clark, 2008). Erduran et al. (2004) minimized this problem by focusing heavily on the emergence of rebuttals since rebuttals force participants to evaluate the validity and strength of that argument (Erduran, 2008). This limitation was eliminated in the current study by revealing rebuttals and calculating the reliability of coding of arguments. Regardless of the components of Toulmin's Argument Pattern, data supports the claim, warrant provides a link between the data and the claim, backing strengthens the warrant, qualifier is a phrase that shows what kind of degree of reliance is to be placed on the conclusions, and rebuttal points to the circumstances under which the claim would not hold true (Erduran et al., 2004). In order to code the arguments, video recordings of six argumentation sessions were transcribed. The participants' written arguments were used as a support when their arguments were not understood clearly due to the unfinished sentence or interruptions.

Argument components in all of the sessions were coded by the first author. The second author randomly selected the second and fifth argumentation sessions and coded the participants' arguments. Then, the two authors compared their codes and reached to 93% of agreement. The reliability measured by Cohen's κ was .77. There seems to be general agreement that Cohen's κ value should be at least .60 or .70

(Wood, 2007). As a result, the coding done for the participants' arguments had adequate reliability. The authors re-coded the argument components that they could not have agreement on and final coding scheme was constructed by reaching consensus. The first author then revised all the codes of the participants' arguments one more time.

Excerpts from three different argumentation sessions are given below to present examples for argument components.

Instructor: *How can the sportsmen wearing wingsuits land safely?*

Student A: *They can use parachute [claim].*

Student B: *Or, they can land on water [claim].*

Student A: *But the effect of water after high height can be very hurtful [rebuttal]. I think they should open a parachute before coming through a certain distance to the land [claim] to slow down [data].*

Instructor: *Why does the outer surface of a cold lemonade glass sweat in a hot day?*

Student C: *The outer surface of the glass and the lemonade will exchange heat [data] and the water will evaporate [claim].*

Student D: *There will be no lemonade left if the water in it evaporates [rebuttal]. Because water molecules outside of the glass are vapor [data], they hit the outer surface of the glass [warrant] and will condense [claim].*

Instructor: *Should the bulb used in thermometers be big or small?*

Student E: *The bulb should be big and the liquid should be small [claim]. This way it can translate the heat into temperature [data] and the change in the temperature difference becomes high [warrant].*

Student F: *We do not care about the change in the heat [counter claim], we try to measure temperature difference [claim]. It begins with m.c.ΔT [data]. Therefore, mass of the water we measure should also be considered [rebuttal]. The heat given and taken are equal [data], whatever change you do to the mass, the change in the temperature is the same [rebuttal].*

According to Nussbaum (2011), one major misconception that has grown about the Toulmin model is that it posits that all arguments have the six components. However, Toulmin asserted that some argument components may be absent or left implicit; in fact, warrants typically are left implicit (Nussbaum, 2011).

In order to make the statistical analysis, each participant's contribution to the argumentation was found out by counting and summing up the argument components s/he produced.

Analysis of Knowledge. The model developed by Chi and Roscoe (2002) was chosen to analyze and to code the participants' prior knowledge as well as their knowledge-in-use during the argumentation sessions. Chi and Roscoe (2002) distinguish knowledge for its coherence and completeness. Regarding the coherence of knowledge, they describe incoherent or fragmented knowledge where propositions are not interconnected in some systematic way and coherent knowledge where the constituent propositions are related in an organized manner. An incoherent knowledge cannot be used to give consistent and predictable explanations. On the other hand, a coherent knowledge can be used to generate explanations, make predictions, and answer questions in a consistent and systematic fashion. Chi and Roscoe (2002) present a further categorization of coherent knowledge as correct coherent knowledge and flawed coherent knowledge. A flawed coherent knowledge is a knowledge in which a coherent structure is organized around a set of beliefs or a principle that is incorrect. This kind of knowledge may share a number of propositions, but they are interconnected according to an incorrect organizing principle. Hence, students having this knowledge are able to answer questions adequately and consistently.

Regarding the completeness of knowledge, Chi and Roscoe (2002) describe complete knowledge that has a majority of the key propositions and incomplete knowledge having many missing pieces. Their knowledge categorization can be summarized in Figure 2.

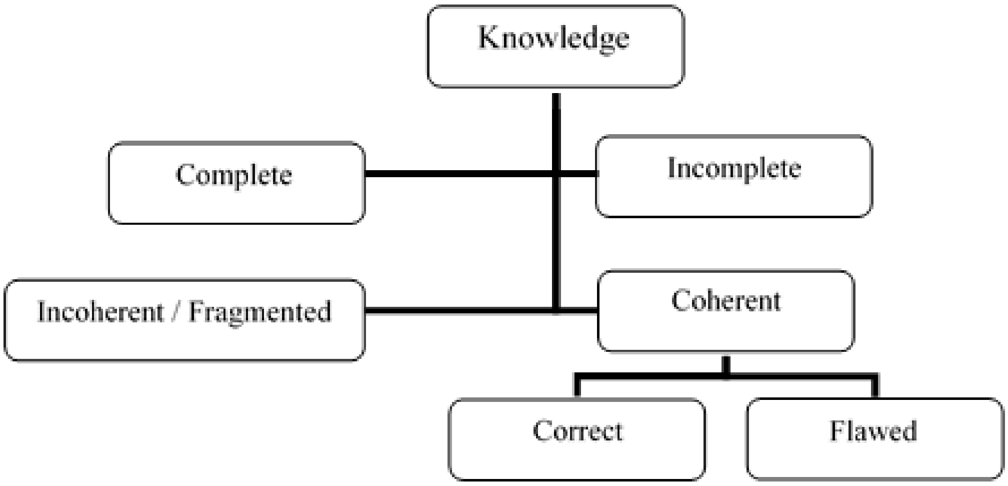

Figure 2. The knowledge categorization done by Chi and Roscoe (2002).

The participants' responses to the questionnaire was analyzed according to Chi and Roscoe (2002)'s model to be able to code their prior knowledge. The data was re-examined a few times to detect any response that did not fit into one of the knowledge categories. Explanation and examples for each knowledge code are given in Table 3.

The coding scheme of the students' prior knowledge was made by the first author. To assess the reliability of this coding, the second author randomly selected six questions (3 questions related to the subject of dynamics and three questions related to the subject of heat-temperature) out of 30 and coded the participants' prior knowledge. Then, the two authors compared their coding and were able to reach 92% agreement. The reliability measured by Cohen's κ was .80. Consequently, the coding done for the participants' prior knowledge had good reliability. The authors re-coded the knowledge levels that they could not have agreement on and the final coding scheme was constructed by reaching consensus. The first author then revised all the codes of the participants' prior knowledge one more time.

In order to do data reduction and make comparison between knowledge and argumentation statistically, numbers were assigned to the knowledge codes. Based on the Chi and Roscoe (2002)'s model, the highest knowledge level is "complete correct". The code of "incomplete correct" can be considered as the second highest knowledge level while the code of "incomplete flawed" can be considered as the lowest knowledge level. Therefore, the following numbers were assigned to the codes: 6 = complete correct, 5 = incomplete correct, 4 = complete fragmented, 3 = incomplete fragmented, 2 = complete flawed, 1 = incomplete flawed.

For the purpose of determination of one participant's prior knowledge of dynamics, average score of her/his knowledge codes of 13 dynamics questions were calculated. The same procedure was followed to determine one participant's prior knowledge of heat-temperature.

Table 3. Explanation and examples for each knowledge code.

Codes	**Explanation**	**Examples**
Complete Correct	The response was consistent with the scientifically accepted perspective and had a majority of the key propositions.	The liquid in the thermometer should have high coefficient of expansion so that even in small temperature values, we can measure it accurately. If coefficient of expansion is high, a certain heat will expand the liquid to a higher level in the tube compared with that of liquid with low expansion coefficient. This way, we can read the change in the liquid more easily.
Incomplete Correct	The response included some correct scientific terminology but the explanation was not sufficient enough and had some missing pieces.	I found the vertical component of the velocity and the largest vertical component in Jack's throw, then the highest maximum height belongs to Jack's.
Complete Flawed	The response had a majority of the key propositions but it was not scientifically correct.	Melting point will drop due to pressure. Pressure makes the melting harder. When it melts, it tries to expand. For instance, if we step on the snow, it will melt easier. When it is easy to melt, then it is possible to melt at higher temperature.
Incomplete Flawed	The response was not consistent with the scientifically accepted perspective and there was not enough explanation.	The heats taken by two objects in the same medium are not different; they are the same. There are two different things in the same medium. Even the initial temperatures of them are the same.
Complete Fragmented (Incoherent)	The response had some scientifically correct propositions and complete explanation from the beginning to the end, but the propositions were inconsistent from each other.	First of all, I assumed the velocity 10V, I derived its components. V_y is 8V, as a route, if here is h_{max} and ascending time is t, then descending time will also be t. As of energy, I did the following for the energy of mass: the energy at $h_{max}=E_p+E_k$=the energy on the ground (E_p+E_k), V_0 i.e., vertical velocity is zero and there is only potential of h_{max}, when the velocity here is zero, then Ek=0
Incomplete Fragmented (Incoherent)	The response had some scientifically correct propositions but it had incomplete explanation and interconnected propositions.	In order to find the longest range, we need to find the time spent in the air. The longest time spent in air is that of Jack's. The vertical component is the biggest, so is the flight time. And when we multiply that with the longitudinal component, we can find that it will have the longest range. When we apply all these, the answer is George's.
None	No response	

Chi and Roscoe (2002)'s coding scheme was also used to analyze the participants' knowledge in use during the argumentation process. Each participant's knowledge level for each concept s/he discussed during the argumentation was coded and numbered; then, average score of her/his knowledge in use codes was calculated for that argumentation. Then, the knowledge code for the number was assigned. For example, the following discussion occurred between Student 9 and the teacher during the third argumentation session:

Instructor: *Does the velocity have any effect on the air friction?*

Student 9: *It has an effect but not directly related. I mean, change in the velocity occurs because of that (friction) [claim]. Thus, it is a result of friction. That is, friction does not depend on velocity [counter claim]. But, velocity changes due to friction [claim].*

Due to the fact that Student 9's knowledge in use levels for the concepts of velocity and friction were in complete correct level, they were numbered as 6. Later in the argumentation he also said that "these flying sportsmen accelerate through downward [claim] because their motion is free fall [data] as they are under the influence of gravity [warrant]." Consequently, his knowledge in use for the concept of free fall was in complete correct level. Therefore, the average score for his knowledge in use levels during the third argumentation session was 6 regarding complete correct.

Kendall's Tau coefficient was used to investigate the correlation between argumentation and knowledge because p values are more accurate in small sample sizes. Gibbons (1993) states that Kendall's Tau has more attractive qualifies over Spearman's rho and better estimates of the corresponding population parameter.

Besides quantitative analysis, qualitative analyses were carried out and comparisons were made between the argumentations as well as within the argumentation. The participants were examined both individually and within the groups. During the qualitative analyses, any pattern was looked for in order to detect any relationship between the students' argumentations and their content knowledge (both prior knowledge and knowledge in use) and to explain the relationship. In order to do that, the participants' engagement in argumentations and the interactions among the participants were examined. Their arguments were compared with the highest number of arguments generated within the argumentation session. Moreover, average score of each argument component and average knowledge in use level were found for each session. The average knowledge in use level was calculated by dividing the total knowledge in use level to the number of participants (N) for the related argumentation session. Furthermore, argumentation sessions were compared with each other in terms of the content and context of the argumentations to be able to make inferences about the participants' engagement, their productivity and the role of knowledge in their contributions. Qualitative findings were compared to quantitative findings.

RESULTS AND DISCUSSION

Results are presented and discussed below according to the research questions as well as to the quantitative and qualitative findings.

Quantitative Results

Relationship between prior subject matter knowledge in physics and scientific arguments. Table 4 and Table 5 present the correlation values between prior knowledge levels (both about dynamics and heat-temperature) and argument components based on Kendall's Tau coefficient analysis. There was a strong positive correlation between the participants' prior knowledge level of dynamics, as measured by the open-ended questions, and the number of claims they produced in the second argumentation session, which was statistically significant ($\tau_c = .667$, $p < .05$). There was also strong positive correlation between the participants' prior knowledge level of dynamics and the number of data they presented in the second argumentation session ($\tau_c = .556$, $p < .01$). That is, the more prior knowledge of dynamics learners had, the more claims and data they created while arguing about the range, height and flight time of the throwing stones. The students' prior knowledge level of dynamics and the number of warrants they generated were moderately related; however, this relation was not significant (τ_c = .407). The students could create neither rebuttal nor counter claim during the second argumentation session. That is to say, the students produced 61 claims, 58 data and only nine warrants during the second argumentation session because they gave their answers based on the formulas that they already knew well and did not need to pursue argumentation any further. Moreover, the content of the second argumentation session was about throwing stones which all the participants stated that they had previous experience with at least once in their lives.

Moderate correlations were also explored between the students' prior knowledge level of heat-temperature and the number of rebuttals they produced in the fourth argumentation session (τ_c = .315) as well as between their prior knowledge level of heat-temperature and the numbers of claim (τ_c = .370) and data (τ_c = .401) they created during the sixth argumentation session. The fourth argumentation session was related to thermometers that the students had used before and the sixth argumentation session was related to the daily phenomena that the students already had experiences with. However, these correlations were not significant and they were likely occurred by chance. There was not any relationship between the prior subject matter knowledge and the arguments for the other three argumentation sessions. Specifically, the students did not necessarily use scientific and complete prior knowledge while producing ideas and providing reasoning behind their ideas for those three argumentation sessions.

Comparing to the other argumentation sessions' contents, the students were more familiar with the contents of the second, fourth and sixth argumentation sessions. Therefore, familiarity with the content might be the factor in defining whether prior knowledge makes a difference in argument production. Argumentation supports the development of communicative competences, particularly critical thinking and the development of reasoning, particularly the choice of theories or positions based on rational criteria (Jiménez-Aleixandre & Erduran, 2008). The contexts of the fourth and the sixth argumentation sessions were controversial dialogues and matching of a theory with a phenomenon respectively. Therefore, critical thinking and reasoning activities in these two debatable argumentation sessions might stimulate a nonsignificant relation between prior knowledge and arguments. Contents and contexts of the argumentations will

Table 4. Correlation values between prior knowledge level of dynamics and argument components based on Kendall's Tau coefficient analysis.

	First Argumentation Session (N=11)				**Second Argumentation Session (N=9)**			**Third Argumentation Session (N=10)**				
	Claim	Data	Counter Claim	Rebuttal	Claim	Data	Warrant	Claim	Data	Counter Claim	Warrant	Rebuttal
PKL of dynamics	-.022	.353	.198	.022	.667*	.556**	.407	.053	-.213	.270	.120	-.107

Note: PKL: Prior Knowledge Level, *: $p < .05$, **: $p < .01$, ***: $p < .001$

Table 5. Correlation values between prior knowledge level of heat-temperature and argument components based on Kendall's Tau coefficient analysis.

	Fourth Argumentation Session (N=12)					**Fifth Argumentation Session (N=12)**					**Sixth Argumentation Session (N=9)**				
	Claim	Data	Counter Claim	Warrant	Rebuttal	Claim	Data	Counter Claim	Warrant	Rebuttal	Claim	Data	Counter Claim	Warrant	Rebuttal
PKL of Heat - Temperature	.204	.185	-.146	.093	.315	.278	.295	.278	-.021	-.087	.370	.401	-.037	.296	.278

Note: PKL: Prior Knowledge Level, *: $p < .05$, **: $p < .01$, ***: $p < .001$

be discussed more in the next section.

The result of this study is consistent with the result of the research done by Means and Voss (1996) in a way that prior knowledge somehow affected argument production. The finding of the current study does not exactly match with the findings of the research that examined the relation between prior knowledge and argumentation by performing statistical analysis. However, those studies generally used multiple choice questions to determine prior knowledge and did not assess all the argument structures identified by TAP. Hence, the current study is slightly different from those studies.

Table 6. Correlation values between knowledge level and argument components based on Kendall's Tau coefficient analysis.

First AS (N=11)	Claim	Data	Counter Claim	Warrant	Rebuttal
Knowledge Level during the First AS	.289	.165	.099		.207
Second AS (N=9)	Claim	Data	Counter Claim	Warrant	Rebuttal
Knowledge Level during the Second AS	.658**	.626***		.560***	
Third AS (N=10)	Claim	Data	Counter Claim	Warrant	Rebuttal
Knowledge Level during the Third AS	.000	.175	.000	.150	.000
Fourth AS (N=12)	Claim	Data	Counter Claim	Warrant	Rebuttal
Knowledge Level during the Fourth AS	.444**	.519***	-.188	.481***	.370*
Fifth AS (N=12)	Claim	Data	Counter Claim	Warrant	Rebuttal
Knowledge Level during the Fifth AS	.583***	.646***	.042	.417*	.396*
Sixth AS (N=9)	Claim	Data	Counter Claim	Warrant	Rebuttal
Knowledge Level during the Sixth AS	.093	.216	.037	.185	.154

Note: *: $p < .05$, **: $p < .01$, ***: $p < .001$, AS: Argumentation Session

Relationship between arguments and physics knowledge in use during the scientific argumentation process. Kendall's Tau coefficient values in Table 6 points out significant positive correlations between the students' knowledge in use levels and their argument components for the second, fourth and fifth argumentation sessions. The correlations between the students' knowledge in use level and the number of claims ($\tau c = .658$, $p < .01$) they produced, between the students' knowledge in use level and the number of data ($\tau c = .626$, $p < .001$) they presented, and between their knowledge in use level and the number of warrants ($\tau_c = .560$, $p < .001$) they created during the second argumentation session were strong. That is to say, there was a positive relationship between the knowledge in use and all the argument components generated in the second argumentation session. Specifically, the students' claims, data and warrants about the range, height and flight time of the throwing stones were complete and based on scientifically correct propositions. While the participants were arguing about the projectile motion, they grounded their ideas on the formulas and cut the argumentation short. This situation is supported by the research done by Nussbaum and Bendixen (2003), who found that if students believed in that the knowledge was unchanged, they did not contribute much to the argumentation. The reason for the significant relationship between the arguments and the knowledge in use for this argumentation might be the students' concrete knowledge they used while arguing.

Regarding the fourth argumentation session, there were significant correlations between the students' knowledge in use levels and the numbers of claims ($\tau c = .444$, $p < .01$), data ($\tau c = .519$, $p < .001$), warrants ($\tau c = .481$, $p < .001$), and rebuttals ($\tau c = .370$, $p < .05$) they produced. In addition, there were significant correlations between the students' knowledge in use levels and the numbers of claims ($\tau c = .583$, $p < .01$), data ($\tau c = .646$, $p < .001$), warrants ($\tau c = .417$, $p < .05$), and rebuttals ($\tau c = .396$, $p < .05$) they created with regards to the fifth argumentation session. In other words, the more content knowledge learners used, the more claims, data, warrants, and rebuttals they generated while they were arguing about the thermometers and the mechanism of a hot-air balloon. The correlations were strong in terms of the number of data for the fourth argumentation session as well as the numbers of claims and data for the fifth argumentation session. In total, the participants brought up 163 claims and 76 data about the mechanism of a hot-air balloon during the fifth argumentation session and 149 claims and 78 data about the thermometers in the fourth argumentation session. These are the highest numbers for claims and data among the six argumentation sessions. The more students produced claims and data the more they used complete and correct scientific knowledge. The reason for this finding is that when the students generated high number of views about the phenomenon, they might perform more critical thinking. Furthermore, they might develop more logical reasoning to validate their thoughts by showing complete scientific evidence. The fourth and the fifth argumentation sessions had the highest participant numbers with 12 students. As a result, the high participation so that the high interaction among the students might also cause this finding. The correlations were moderate in terms of the numbers of warrants and rebuttals for these two argumentation sessions. Some students linked their claims to their data and refuted their peers' claims by using high level scientific knowledge.

The correlation existed for all the argument components the participants generated apart from the counter claims. That is to say, there was not any relationship between the students' knowledge they used and the number of counter claims they produced in any of the argumentation. The students did not use complete and correct scientific knowledge when they were against another claim. The students might think that just being opposed was enough to show their disagreement; hence, they did not think critically while generating counter claims.

Comparison of Tables 4 and 5 to Table 6 demonstrates that there were more significant correlations between the students' knowledge in use level and the number of arguments they generated than between their prior knowledge and the number of arguments they created. The students could relate scientific knowledge and argumentation better with the knowledge they used during the argumentation sessions. This result was not in line with the result that emerged from the research by von Aufschnaiter et al. (2008), who reached the conclusion that learners' arguments are related with their prior knowledge but not related with their knowledge during argumentation process.

Positive relationship between knowledge in use and arguments was found in three argumentation sessions out of six. Since the similar research did not perform statistical analysis to look for the relationship, it is hard to discuss the findings of this study with the results of them. Nevertheless, the result of the current study is parallel to what Tavares, Jiménez-Aleixandre and Mortimer (2010) revealed.

Qualitative Results

It would be better to explain argumentation qualities, and students' roles and the interaction in the groups in order to present the results for the third and the fourth research questions.

Argumentation Qualities. Table 7 gives the number of participants, number of each argument component, total number of argument components, average score of components and average knowledge in use level for the argumentation sessions.

Table 7. Number of argument components and knowledge level during the argumentation sessions.

Argumentation Sessions	First N=11	Second N=9	Third N=10	Fourth N=12	Fifth N=12	Sixth N=9
Number of Participants	11	9	10	12	12	9
Total Number of Claims	79	61	111	149	163	107
Total Number of Data	36	58	39	78	76	72
Total Number of Warrants	0	9	4	15	6	3
Total Number of Rebuttals	19	0	13	40	22	17
Total Number of Counter Claims	6	0	11	9	11	6
Total Number of Components	140	128	178	291	278	205
Average Score of Components	12.7	14.2	17.8	24.3	23.2	22.8
Total Knowledge in Use Level	40	37	38	57	47	37
Average Knowledge in Use Level	3.6	4.1	3.8	4.8	3.9	4.1

Regarding the first argumentation session, the students could not connect their claims with their data by constructing warrants but they were successful in rebutting their peers' arguments. The average score of components was 12.7 and the average knowledge in use level was 3.6 for the first argumentation session. They were the lowest values among the six argumentation sessions. There was not any significant correlation between the arguments and the knowledge in use level for this argumentation. It is possible that the relation did not occur because the students' knowledge and the number of argument components they created were not high. As a result, the students could not become critical thinkers by developing a respect for reasons; an inclination to seek reasons; and an appreciation of objectivity, impartiality, and honesty in the consideration of evidence and argument (Siegel, 1989). Besides, dialogues with too many challenges were not necessarily productive because the challenges were not always followed by serious consideration of their impact on some viewpoint (Andriessen, 2006). This might be the case for the first argumentation session because there were 11 open-ended questions in the worksheet that the students had to answer and it was the first time that an argumentation implemented in the class. The students might find this argumentation too challenging and could not make connections between their knowledge and arguments.

The participants generated 111 claims, 11 counter claims and just 39 data and four warrants in the third argumentation session. The number of data the students presented was lower comparing to the number of claims and the number of counter claims they created. The content of this argumentation was motion of flying sportsmen and the students did not have free fall experience personally. Therefore, they came up with lots of ideas but could not support most of them with evidence. Most probably this is the reason for an absent significant relationship between the knowledge in use and the arguments for the third argumentation session. The students could neither explain aspects of the problem that were anomalous to their existing conception nor confront with the discrepancy between their point of view and the alternative to develop reasoning (Nussbaum & Sinatra, 2003).

The first three argumentation sessions were related to dynamics and the last three argumentation sessions were related to heat-temperature. Both the average score of components and the average knowledge in use level increased when the subject was changed from dynamics to heat-temperature (see Table 8). Regarding that there were significant correlations between the knowledge in use and the arguments for the fourth and the fifth argumentation sessions; it might be thought that the relationship appeared when both the number of argument components and the level of knowledge in use were high. However, there was not any significant relation in the sixth argumentation although the average score of components and the average knowledge in use level were both high. The participants might get bored in this last argumentation and the dynamism among the students might cause them not to use their higher level knowledge while producing their arguments during the sixth argumentation.

The first and the third argumentation sessions where no significant relationship between knowledge in use and arguments were both about the concept of motion. Moreover, both of them included explanation phase. Consequently, when the students were asked open-ended questions about the explanation of motion, they could not create arguments by using high level knowledge. On the other hand, the context of the fourth argumentation session in which there was a significant relationship was controversial dialogues where concept cartoons were used. The participants were able to produce 15 warrants and 40 rebuttals during the fourth argumentation session. These were the highest numbers among the six argumentations for these two components. Concept cartoons in controversial dialogues might become trigger for the students so that they became very productive in terms of arguments. This finding was similar with the finding that emerged from the research by Chin and Teou (2009), who found that concept cartoons provided a platform for students to articulate their puzzlement, to question, and to challenge each other's ideas which stimulated dialogic talk among students that help them to construct scientific knowledge. Naylor, Downing and Keogh (2001) also illustrated that the concept cartoons appeared to generate argument which frequently went well beyond a superficial level of engagement, involving children in very thoughtful ways.

Argument can be seen to take place as an individual activity, through thinking and writing, or as a social activity taking place within a group (Driver et al., 2000). The findings indicated that there were more significant correlations between the knowledge in use and arguments than the correlations between the prior knowledge and arguments. There might be more issues, other than reasoning and critical thinking, play roles in the relationship between knowledge and argumentation while the students were discussing about the scientific concepts in groups. Recent ethnographic and experimental studies of scientific practice have provided detailed evidence of the consequential ways in which social interactional processes contributed to the generation of theories and the sorting of evidence and warrants (Barron, 2003). Therefore, the interaction in the groups will be examined during the six dialogic argumentation sessions in the next section.

Students' Roles and the Interaction in the Groups. Kuhn and her colleagues (1997) revealed that sustained engagement involving multiple dialogues with different partners over a period of weeks significantly enhanced the number of two-sided and functional arguments in the participants' reasoning. Consequently, the participants were examined individually and their roles in the groups were discussed. In this way, the quantitative findings were compared to the qualitative findings. Some important cases are given here. Tables 8 and 9 show the students' prior subject matter knowledge, the argument components they produced and their knowledge in use levels during the argumentation sessions. Table 8 is related to the subject of dynamics and Table 9 is related to the subject of heat-temperature. As it can be seen in Tables 8 and 9, Student 1's prior knowledge of dynamics and heat-temperature and his knowledge during the argumentation sessions were in complete correct level. He participated and engaged in argumentations enthusiastically. When he expressed his thoughts, he generally tried to prove them by using scientifically correct propositions. Apart from the second argumentation session, he generated the highest number of argument components during the argumentation sessions. He was not the first one but again very productive during the second argumentation session. Therefore, he could use complete and scientific knowledge while he was stating his ideas, showing evidence for supporting his ideas and trying to change his peers' claims.

Student 2 was an interesting case. She did not join argumentations too much. Whenever she joined, she generated her arguments from mathematical models. When she tried to persuade her peers during the argumentation sessions, she also used formulas. Although her prior knowledge of dynamics and heat-temperature and her knowledge in use during the first and the third argumentation sessions were in complete correct level, she only created one claim and one data for these argumentation sessions (see Table 8). Consequently, there were negative connections between her prior knowledge as well as knowledge in use and her arguments during the first and the third argumentation sessions. S2 was in the same group with S3 and S10 in the first argumentation session. S3 and S10 were also in the same group during the fourth argumentation session in which both of them created high number of arguments with complete correct knowledge and showed a relation between their knowledge in use and arguments. Since we could not see the same involvement from S3 and S10 in the first argumentation session, it might be possible that S2's general attitude of unresponsiveness during the argumentation sessions affected the dynamism so that the communication in the group in a negative way. Barron (2003) analyzed conversations of twelve 6th-grade triads and revealed that partner responsiveness was important correlates of the uptake and documentation of correct ideas by the group.

Student 3 explicated his opinions when he thought that his peers were wrong. He attempted to convince his peers by supporting his ideas with logic. He was in the same group with S1 and S11 when the second argumentation session was implemented. S11 and S3 might find S1 too competitive because they let S1 did all the talking. Nevertheless, S3's prior knowledge of heat-temperature and his knowledge in use during the fourth, fifth and sixth argumentation sessions were in the highest level and the number of arguments he produced in these sessions were high (see Tables 8 and 9). For example, he generated 22 claims, 11 data, and seven rebuttals in the fifth argumentation session. These findings indicated positive relations between his prior knowledge as well as knowledge in use and his arguments related to heat-temperature.

Student 5 was usually quiet during the argumentations. She joined in the discussions by stating her opinion when someone asked her a question. Comparing to other argumentation sessions, the third argumentation session was the one that she was most active in. S5 was in the same group with S6, who were good friends. Experimental research that manipulates the friendship status of collaborating partners has shown that friends engage in more productive dialogue during learning activities than those who are not friends (Barron, 2003).

Student 8 usually stated his ideas but generally did not spend much effort to affect his peers' ideas. He used daily events rather than scientific knowledge when he justified his statements. S8 was in the same group with S1 during the first argumentation session and he was in the same group with S5 during the sixth argumentation session. His knowledge in use level was low in both argumentation sessions. However, unlike the first argumentation session, he was quite productive during the sixth argumentation session and produced 15 claims with 11 data and four rebuttals against to S5's four claims. S5's tendency of low attendance might encourage S8 to be more assertive in arguing. As he believed that the more he used daily life examples in his arguments the more he could convince his peers, he was active during the sixth argumentation session despite his incomplete flawed knowledge. This situation was cited in the research by Jiménez-Aleixandre et al., (2000).

Table 8. The students' prior knowledge levels, their knowledge in use levels and quantity of arguments they produced during the argumentation sessions related to the subject of dynamics.

	Dynamics						
		1. Argumentation Session		2. Argumentation Session		3. Argumentation Session	
S	**PKL**	**KL**	**AC**	**KL**	**AC**	**KL**	**AC**
1	CC 6	CC 6	C(25), D(17), CoC(5), R(8)	CC 6	C(14), D(11), W(1)	-	-
2	CC 6	CC 6	C(1), D(1)	IFR 3	C(5), D(8)	CC 6	C(1), D(1)
3	IC 5	IC 5	C(7), D(5), R(3)	?	?	-	-
4	CC 6	IFR 3	C(7), D(1), R(1)	CC 6	C(13), D(10), W(5)	IC 5	C(22), D(4), CoC(2), R(1)
5	IC 5	IFL 1	C(1), D(1)	IC 5	C(7), D(6), W(1)	IFR 3	C(13), D(6), W(1), CoC(2), R(2)
6	IC 5	IFR 3	C(2), D(1)	-	-	IFR 3	C(12), D(2), R(2)
7	IC 5	IFL 1	C(4), D(3), R(3)	IFL 1	C(4), D(1)	IFR 3	C(15), D(3), CoC(2), R(1)
8	IC 5	CFL 2	C(4), D(3), CoC(1)	CC 6	C(15), D(12), W(2)	-	-
9	IC 5	IC 5	C(10), D(4), R(1)	CC 6	C(3), D(5)	CC 6	C(9), D(6), W(3), CoC(3), R(1)
10	IFR 3	IFR 3	C(14), R(2)	IFL 1	D(5)	CFR 4	C(10), D(4), R(1)
11	IFL 1	IC 5	C(4), R(1)	?	?	CFR 4	C(23), D(9), R(5)
12	IFR 3	-	-	?	?	IFR 3	C(1), D(1)
13	IFR 3	-	-	IFR 3	C(2), D(2)	IFL 1	C(5), D(3), CoC(2)

Note: PKL: Previous Knowledge Level, KL: Knowledge Level during the Argumentation, AC: Argument Components, C: Claim, CoC: Counter Claim, D: Data, W: Warrant, R: Rebuttal, "-": Absent in the class, "?": No participation. CC: Complete Correct, IC: Incomplete Correct, CFR: Complete Fragmented, IFR: Incomplete Fragmented, CFL: Complete Flawed, IFL: Incomplete Flawed

Student 9 engaged in argumentations moderately and told his thoughts even if he was not sure their scientific correctness. He was in the same group with S2 during the second argumentation session. S9's argumentation skills stayed in claim and data level during the second argumentation session while he generated warrants, counter claims and rebuttals in other argumentation sessions. S2's lack of activity in making arguments might affect S9's performance during the second argumentation session. He was in the same group with S1 in the fourth argumentation session and presented his best performance in terms of generating arguments. S1's productivity might be an effective stimulus for this argumentation.

Table 9. The students' prior knowledge levels, their knowledge in use levels and quantity of arguments they produced during the argumentation sessions related to the subject of heat-temperature.

	Heat and Temperature						
		4. Argumentation Session		5. Argumentation Session		6. Argumentation Session	
S	**PKL**	**KL**	**AC**	**KL**	**AC**	**KL**	**AC**
1	CC 6	CC 6	C(33), D(22), W(2), CoC(1), R(12)	CC 6	C(36), D(15), W(1), CoC(1), R(1)	CC 6	C(24), D(21), R(10)
2	CC 6	CC 6	C(15), D(11)	IFR 3	C(7), D(6), R(1)	?	?
3	CC 6	CC 6	C(18), D(10), CoC(1), W(3), R(7)	CC 6	C(22), D(11), CoC(1), R(7)	CC 6	C(20), D(11), W(1), CoC(2), R(2)
4	CC 6	CC 6	C(8), D(4), W(1), CoC(1), R(4)	IC 5	C(27), D(14), W(2), CoC(1), R(3)	-	-
5	CC 6	CFL 2	C(6), D(2), R(2)	-	-	IC 5	C(4), D(3)
6	CC 6	IFR 3	C(6), D(3), CoC(1)	IFR 3	C(1), D(2)	CC 6	C(4), CoC(1)
7	CC 6	CC 6	C(7), D(3), W(1), R(6)	IFR 3	C(11), D(4), CoC(3)	CFR 4	C(25), D(19), W(2), R(1)
8	IC 5	IFR 3	C(3), D(3), CoC(2), R(2)	IFR 3	C(18), D(4), CoC(3), R(4)	IFL 1	C(15), D(11), CoC(1), R(4)
9	IFL 1	IFR 3	C(20), D(7), W(1), CoC(1), R(2)	CC 6	C(14), D(10), W(2), R(2)	-	-
10	IC 5	CC 6	C(25), D(8), W(7), R(5)	IFR 3	C(6), D(2), W(1), CoC(2)	-	-
11	CFL 2	IC 5	C(6), D(4), CoC(2)	IFR 3	C(14), D(7), R(2)	IFR 3	C(2), CoC(2)
12	IFR 3	?	?	IFR 3	C(5), R(1)	IFR 3	C(7), D(5)
13	IFL 1	IC 5	C(2), D(1)	IFR 3	C(2), D(1), R(1)	IFR 3	C(6), D(2)

Note: PKL: Previous Knowledge Level, KL: Knowledge Level during the Argumentation,
AC: Argument Components, C: Claim, CoC: Counter Claim, D: Data, W: Warrant, R: Rebuttal, "-": Absent in the class, "?": No participation.
CC: Complete Correct, IC: Incomplete Correct, CFR: Complete Fragmented, IFR: Incomplete Fragmented, CFL: Complete Flawed, IFL: Incomplete Flawed

Student 11's statements during the argumentations were usually irrelevant and out of subject. He was not a silent student with the jokes he made. He had low level prior knowledge in both subjects. The reason that he did not show any contribution to the second argumentation session might be that he was in the same group with S1, who was ambitious in the argumentations. As mentioned above, S3 and S8 showed the same reaction when they were in the same group with S1. Arguing contributes more effectively to learning when it is not competitive; hence, students need to balance assertiveness in advancing their claims with sensitivity to the social effects of their argument on their opponents (Andriessen, 2006). He was in the same group with S12 and produced the highest numbers of claims, data and rebuttal in the third argumentation session although his knowledge in use was in complete fragmented level. S12's silence might trigger S11 to produce arguments.

Student 12 did not talk much during the argumentations. When she talked, she predicated her thoughts on her daily experiences. She did not show any participation in the second and fourth argumentation sessions. The only argumentation she could involve in little and create only one rebuttal was the fifth argumentation session where she was with S3, who showed his highest performance. According to Andriessen (2006), dialogues where participants conceded their positions too easily were also unproductive because they built on the first claim presented, without seriously considering alternatives. Therefore, it is possible that S12 was unproductive because she was aware that her knowledge was incomplete and nonscientific. This finding seems to be in agreement with the result of Nussbaum and Bendixen (2003). They stated that students whose academic success was low hesitated to argue and did not talk much during the argumentations.

Student 13 was very quiet during the argumentations. He had incomplete fragmented knowledge during the second, fifth and sixth argumentation sessions and produced low number of arguments. Altough he had incomplete correct knowledge when the fourth argumentation session was carried out, he performed his least participation and could only generate two claims and one data where he was in the same group with S5. S5 created two rebuttals against to S13's two claims. S13 might feel aggravated and discouragement because of S5 (Salomon & Globerson, 1989).

Tables 8 and 9 also demonstrate that some students' knowledge in use levels were higher than their prior knowledge levels. Student 8 during the second argumentation session, Student 9 during the second, third, fourth, and fifth argumentation sessions, Student 10 during the third and fourth argumentation sessions, Student 11 during the first, third, fourth, fifth, and sixth argumentation sessions, and Student 13 during the fourth, fifth, and sixth argumentation sessions used higher level knowledge than their prior knowledge while they were discussing the scientific concepts. From Greeno (2006)'s point of view, some processes known to be important in reasoning and problem solving occurred more frequently and more productively in group than in individual performance because of an effect of the presence of other people as a favorable aspect of the social context. Additionally, Schwartz worked with middle and high-school students and found that pairs of students working together included useful abstractions in their conversations more often than was the case for think-aloud protocols of individual students. This situation can be explained by co-elaboration of new knowledge, one of the learning mechanisms that are potentially associated with effective arguing to learn. According to Baker (2003), co-elaboration of new knowledge occurs in argumentation when learners work together so that the interactive, interpersonal nature of verbal interaction helps to scaffold individual learning.

Summary of the Qualitative Results: To sum up the qualitative findings, positive relation between prior knowledge level and number of arguments was observed for three students (S1, S3, and S4) while negative relation between prior knowledge level and number of arguments was identified for two students (S2 and S6). Positive relations were determined for the second, fourth, fifth, and sixth argumentation sessions. Moreover, positive connection between knowledge in use level and number of arguments was observed for nine students (S1, S3, S4, S5, S7, S8, S9, S10, and S11) whereas negative relation between knowledge in use level and number of arguments was identified for three students (S2, S6, and S13). Negative relation always came out when the knowledge in use level was high and the number of arguments was low as can be seen in S2's example. Explicitly, the participants could not present high argumentation skills when they had incomplete and flawed knowledge during the scientific argumentation. Three students (S1, S4, and S8) used the complete correct level knowledge and produced high number of arguments when the second argumentation session was implemented. Similarly, three students (S1, S3, and S10) during the fourth argumentation session, three students (S1, S3, and S4) during the fifth argumentation session, and three students (S1, S3, and S7) during the sixth argumentation session showed the positive correlation by having high level knowledge and creating high number of arguments during these argumentation sessions. These findings are consistent with what Barron (2003) pointed out that more successful groups responded to correct proposals by engaging them in further discussion or accepting and documenting them while less successful groups had a high probability of responding to ideas with silence or by rejecting them without rationale.

The qualitative findings supported the quantitative findings in a way that the students' knowledge was related with their arguments in some argumentations. This relation was found to be significant in the second, fourth and fifth argumentation sessions but not in the sixth argumentation session. Due to the small number of participants of this study, insignificant relationship may be considered as valuable. If so, it may be stated that the more students get involved with their peers in dialogic argumentations the more they relate their knowledge with their arguments because of the interaction. Although studies show that interaction and collaboration among learners can facilitate their reasoning, problem solving and argumentation skills (Dunbar, 1995; Okada & Simon, 1997; Reznitskaya et al., 2001; Greeno, 2006), more research needs to be done to explain how dialogical interaction among learners affects their use of scientific propositions during the emergence of great number of arguments, counterarguments, and rebuttals and their identity roles in groups.

CONCLUSIONS

Students learn when they engage within a community of practice by taking on the discourses of that community (Cross et al., 2008). Therefore, argumentation is expected to not only allow students to consolidate existing scientific knowledge, but also to construct new knowledge for themselves based on the ideas of others (Brown & Campione, 1998). It has been argued that the study of argumentation is still a young field and there is a need for correlational studies to investigate the relationship between argumentation and knowledge in order to analyze the argumentation process and to make inferences about how argumentation has impacts on knowledge construction. This study traced the students' arguments during the scientific argumentation sessions and compared them to their subject matter prior knowledge as well as to their knowledge in use during the argumentation sessions to look for a possible relationship between argumentation and knowledge. Additionally, six argumentation sessions were taken under scope in terms of content and context to understand when the relationship occurred. The students were also examined individually to find under what conditions the students generate arguments. The following conclusions can be drawn from the study: First, a positive relationship exists between individuals' prior subject matter knowledge and their contributions to argumentations. If learners are familiar with the content and have scientific knowledge of the concepts they argue about, they will tend to generate high number of claims and justify their claims with evidence although they do not have much experience with argumentative discourse in their previous instructions. Second, the findings indicate a positive relationship between individuals' content knowledge they use and quantity of arguments they produce during a scientific argumentation. Learners may create many argument components while they are giving scientific explanations including a majority of the key propositions about the subject. However, learners do not always try to alter opposite positions by using scientific knowledge. Third, the relationship is not stable. When production of certain amount of claims and data comes on the scene or familiarity with the content occurs, the relationship likely emerges. Content and context of the argumentation have influence on the link between knowledge in use and arguments. Fourth, there are number of interactional factors affecting production of arguments. For example, friendship among the partners has positive effect on productivity. While in some cases passiveness effects group dynamism and productivity in a negative way during an argumentation, in some cases showing little reaction to the collaborating partner increases him/her productivity. Moreover, whereas sometimes competition in a group generates discouragement in group members, sometimes one partner's ambition encourages to other to argue more. Finally, learners' characteristics such as enthusiasm for arguing about the subject, awareness about their knowledge and epistemological beliefs about certainty of knowledge, and justification of knowing change the numbers of claims and supports they generate during an argumentation process.

When children engage in an argumentation and support each other in high-quality argument, the interaction between the personal and the social dimensions promotes reflexivity, appropriation, and the development of knowledge (Erduran et al., 2004). Conclusions of this study propose that learners' prior knowledge affects their arguments in the beginning of the argumentation; however, learners' knowledge may expand while they are constructing, communicating, and evaluating knowledge claims during the argumentation. This knowledge change during the argumentation may result increase in their production of arguments. Familiarity with the content, content and context of the argumentation, dynamism and characteristics of the interaction, and learners' characteristics are critical in influencing the interwine between knowledge and argumentation.

Limitations, Implications and Suggestions

The limitation of this study might be the number of participants for such a correlational study. Nevertheless, it should be kept in mind that analysis of knowledge and arguments of 13 participants in six different scientific argumentation sessions took quite long time. This limitation was tried to be eliminated by performing qualitative analysis in order to observe any relation.

Though this research indicates a relationship between content knowledge and argumentation, it also points out that learners sometimes may produce small number of arguments with high level knowledge. However, learners do not generate high quantity of arguments with low level of knowledge. Therefore, when instructors evaluate an argumentation and assess learners' knowledge, they may consider high number of arguments, which demonstrates high level knowledge. Moreover, this explanatory study illustrates that cognitive, affective and interactional factors together play a role in generating arguments. Instructors should be aware of these factors while they are preparing the environment for scientific argumentation to facilitate increase in learners' cognitive capacities. The contents and contexts of the six argumentation sessions in this study would be examples for instructors who want to embed argumentation in their teaching. The current study contributes to the science education literature toward a better understanding of the interplay between knowledge and scientific argumentation.

Future research would arrange the groups based on the interactional factors among the students and focus on how passiveness and competition change students' arguments and how the shifts in argumentative process make any difference in their learning.

Productive argumentation is a form of collaboration (Andriessen, 2006) and an argument should be evaluated on the basis of its collaborative value as a contribution to the conversation (Grice, 1975). Intense interaction between peers is one of the features essential to successful collaboration (John-Steiner, 2000). Thus, dialogue theory may also help in comprehending the relationship between argumentation and knowledge. According to this theory, an argument is a move made in a dialogue in which two parties are attempting to reason together (Walton, 2000). Dialogue theory suggests that in arguing to learn, learners are not primarily making an effort to convince each other; instead, they are engaged in cooperative explorations of a dialogical space of solutions (Andriessen, 2006). Further studies may combine theoretical framework of the current study with dialogue theory to be able to elucidate the role of collaborative interaction in the knowledge-argumentation association.

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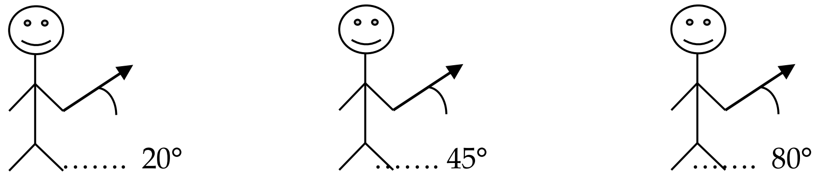
APPENDIX

SECOND WEEK ARGUMENTATION WORKSHEET

1. Three friends are trying to throw 3 separate stones to the farthest to a lake. Their throwing angles are presented in the drawings below.

Mary, George and Jack will throw 3 stones with different weights and throwing angles as specified in the sketch below to a lake. But beforehand, they begin to argue, so who do you think that the answer of the following questions will belong to?



200gr stone	**600gr stone**	1 **kg stone**
Mary's	**George's**	**Jack's**

Your opinion **Why (What makes you think this way?)**

a) The longest flight time ____________ ____________________

____

b) The longest range ____________ ____________________

____

c) The highest h_{max} ____________ ____________________

____

d) The shortest flight time ____________ ____________________

____

e) The shortest range ____________ ____________________

____

f) The shortest h_{max} ____________ ____________________

____

2. Have you changed your mind after the class discussion? Please specify to which direction and why?

3. Let's consider George's 45^o throw. If George did this throw on the Moon with the same initial velocity, what would you say about the throw's
 a) time of flight
 b) distance
 c) maximum height
when it is compared with the same throw on the Earth? Please explain with your reasons (please ignore the air resistance).

4. When these 3 friends did their throws with the same initial velocities on the Moon;
 a) time of flight
 b) distance
 c) maximum height
who would achieve the highest and the lowest values of the measurements above (ignore the air resistance)? Please explain with your reasons.

5. Have you changed your mind after the class discussion? Please specify to which direction and why?