THE NATURE OF PRE-SERVICE SCIENCE TEACHERS' ARGUMENTATION IN INQUIRY-ORIENTED LABORATORY CONTEXT

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ABSTRACT

THE NATURE OF PRE-SERVICE SCIENCE TEACHERS' ARGUMENTATION IN INQUIRY-ORIENTED LABORATORY CONTEXT

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The purpose of this study is to explore pre-service science teachers' (PST) argumentation in the context of inquiry-oriented laboratory work. Specifically, this study investigated the kinds of argumentation schemes PSTs use as they perform inquiry-oriented laboratory tasks, and how argumentation schemes generated by PSTs vary by tasks as well as by experimentation and critical discussion sessions.

The participants in this study were 35 pre-service elementary teachers, who will teach middle school science from 6th through 8th grade students after graduation. In this study, participants were engaged in six inquiry-oriented laboratory tasks. The performance of laboratory tasks consisted of two stages. Through the experimentation stage, PSTs planned and developed their own hypotheses, carried out an experiment and collected data, and processed their data to verify their hypotheses. Through the critical discussion stage, one of the research groups presented their hypotheses, methods, and results orally to the other research groups. Each presentation was followed by a class discussion of weak and strong aspects of the experimentation.

The data of this study were collected through video- and audio-recording. The data were the transcribed from video- and audio-recordings of the PSTs' discourse during the performance of the laboratory tasks. For the analysis of PSTs' discourse pre-determined argumentation schemes by Walton (1996) were employed.

The results illustrated that PSTs applied varied premises rather than only observations or reliable sources, to ground their claims or to argue for a case or an action. The interpretation of the frequency data and the kind of the most frequent argumentation schemes can be seen as a positive indication that the inquiry-oriented laboratory tasks that were employed in this study are effective toward promoting presumptive reasoning discourse. Another result of this study, which is worthy of notice is the construction and evaluation of scientific knowledge claims that resulted in different number and kinds of arguments.

Results of this study suggest the following implications for improving science education. First, designing inquiry-oriented laboratory environments, which are enriched with critical discussion, provides discourse opportunities that can support argumentation. Second, both the number of arguments and the use of various scientific argumentation schemes can be enhanced by specific task structures. Third, "argumentation schemes for presumptive reasoning" is a promising analysis framework to reveal the argumentation patterns in scientific settings. Last, pre-service teachers can be encouraged to support and promote argumentation in their future science classrooms if they engage in argumentation integrated instructional strategies.

Keywords: Argumentation, Pre-service Science Teacher Education, Inquiry-oriented Laboratory.

ÖZ

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ ARAŞTIRMACI SORGULAMACI LABORATUAR ORTAMINDA YAPTIKLARI BİLİMSEL TARTIŞMANIN DOĞASI

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Bu çalışmanın amacı fen bilgisi öğretmen adaylarının araştırmacı-sorgulamacı laboratuvar ortamında yaptıkları bilimsel tartışmayı araştırmaktır. Özellikle, bu çalışmada, öğretmen adaylarının araştırmacı-sorgulamacı laboratuvar etkinliklerini gerçekleştirirken hangi tür bilimsel tartışma şemalarını kullandıkları ile bu şemaların yaptıkları etkinliğin niteliğine göre ve etkinliğin deney ve tartışma bölümlerine göre nasıl değiştiği araştırılmıştır.

Çalışmada yer alan katılımcılar, 35 fen bilgisi öğretmen adayıdır. Bu çalışmada, katılımcılar, araştırmacı-sorgulamacı yöntem ile hazırlanmış olan 6 adet laboratuvar etkinliği yapmışlardır. Her bir etkinlik deney ve tartışma olmak üzere iki bölümden oluşmaktadır. Deney bölümünde, öğretmen adayları varsayımlarını öne sürdüler, deney yaptılar, veri topladılar ve bu veriyi varsayımlarını desteklemek üzere kullandılar. Tartışma bölümü süresince ise, ilk olarak araştırma gruplarından biri varsayımlarını, yöntemlerini ve

sonuçlarını diğer gruplara sundu. Bu sunumun ardından deneyin güçlü ve zayıf yönleri üzerine bir tartışma yapılmıştır.

Çalışmaya ait veriler, fen bilgisi öğretmen adaylarının laboratuvar etkinliği süresince yaptıkları tartışmalarının deşifre edilmiş kamera ve ses kayıtlarından oluşturmaktadır. Verilerin analizi için daha önce Walton (1996) tarafından oluşturulan bilimsel tartışma şemaları kullanılmıştır.

Çalışmanın sonuçları, öğretmen adaylarının bir durum ya da eylem için yargıda bulunurken, gözlem ve güvenilir kaynaklardan başka çok çeşitli öncül nedenler gösterdiklerini ortaya koymuştur. Verilerin bilimsel tartışma şemalarının sıklığı ve çeşidi ile ilgili nicel analizi, bu çalışmada kullanılan araştırmacı-sorgulamacı laboratuvar etkinliklerinin varsayımsal akıl yürütmeyi desteklediğini göstermektedir. Bu çalışmanın dikkate değer bir başka sonucu da bilimsel bilginin oluşturulması ve değerlendirilmesi esnasında farklı sayı ve çeşitte bilimsel tartışma şemalarının ortaya çıkmasıdır.

Bu çalışmanın sonuçlarından fen eğitimi ve fen eğitimi araştırmaları ile ilgili şu çıkarımlarda bulunulabilir: Öncelikle, araştırmacı-sorgulamacı yöntemle düzenlenmiş ve tartışma bölümü ile desteklenen laboratuvar etkinlikleri, bilimsel tartışmaları destekleyen karşılıklı konuşma ortamlarına olanak sağlamaktadır. İkinci olarak, bilimsel tartışma sayısının ve farklı bilimsel tartışma şemalarının kullanılmasının belli etkinlik yapılarıyla desteklenebileceği söylenebilir. Üçüncü çıkarım, "varsayımsal akıl yürütme için bilimsel tartışma şemaları"nın, bilimsel ortamlarda yapılan bilimsel tartışmanın yapısını açığa çıkarmada başarılı bir analiz yapısı olduğudur. Son olarak, öğretmen adaylarının, gelecekteki fen sınıflarında bilimsel tartışma ortamları oluşturmaları için bilimsel tartışmanın ilişkilendirildiği öğretim yöntemleri ile desteklenebilecekleri söylenebilir.

Anahtar Kelimeler: Bilimsel tartışma, Fen bilgisi öğretmen eğitimi

To My Family

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LIST OF ABBREVIATIONS

PST	:	Pre-service Science Teacher
E	:	Experimentation
CD	:	Critical Discussion
TAP	:	Toulmin's Argumentation Pattern
NOS	:	Nature of Science

CHAPTER 1

INTRODUCTION

The learning of scientific knowledge includes what science tells us about people, events, objects, as well as abstract and theoretical concepts (Wells, 1999); for example, “things float since their density is less than the liquid which it is in” and “motion must end somewhere since there is friction force in the opposite direction of the motion”. Indeed we have been able to explain many things in our world and universe in the light of the scientific knowledge. However, science is not only a collection of facts but a process of investigating the physical world (Erduran, Simon, & Osborne, 2004; MoNE, 2006). The interpretation of scientific knowledge requires knowledge of these processes involved in developing that knowledge (Kolstø, & Mestad, 2005). Therefore, science education should give equal importance to the teaching of the practices and methods of science and its socially embedded nature through collaborative practical works as well as teaching the concepts of science (Driver, Newton, & Osborne, 2000).

This can be achieved, as Schwab (1962) suggests, when the teaching of science as inquiry becomes a priority in schools, and science is viewed itself as a process of inquiry (as cited in Bianchini & Colburn, 2000; Duschl & Osborne, 2002; Erduran, Osborne, & Simon, 2005). Scientific inquiry is conceived as an epistemological and social process through which students can construct, modify or justify knowledge claims (Duschl, 2007). Bybee (2004) indicated three meanings of inquiry in National Science Education Standards: a strategy for teaching science, a model for learning science, and content for science education. Inquiry as a teaching strategy for teaching science has two underlying goals (Bybee, 2004); one is to understand science as a way of knowing and explain the natural world, and second is to develop cognitive abilities and manipulative skills associated with scientific inquiry (p.5). These abilities and skills include identifying and asking scientific questions, proposing hypotheses, designing and conducting scientific investigations, constructing scientific explanations, and communicating and defending scientific arguments (Bybee, 2000, cited in Kipnis, & Hofstein, 2008). Kipnis, and Hofstein (2008) suggest that these abilities and skills associated with scientific inquiry are the central elements of inquiry-oriented laboratory work.

Inquiry-oriented laboratories provide a context where students experience authentic scientific inquiry (Hofstein, & Lunetta, 2004). In another study, it is indicated that a properly developed inquiry-oriented laboratory work enhances students' constructive learning, conceptual understanding, and understandings of nature of science (NOS) (Hofstein, & Lunetta, 2004). Inquiry-oriented laboratory work engages learners in a real scientific investigation with all components of science such as the language of science, the scientific reasoning, critical evaluation of data and evidences to construct or justify claims (Duschl, & Grandy, 2005; Erduran, Osborne, & Simon, 2005). The successful implementation of inquiry laboratories, however, is not an easy task (Kipnis, & Hofstein, 2008).

In the design of an inquiry-oriented laboratory, students should be given opportunities to choose materials, to interact with each other and to reflect on each other's ideas in order to initiate discussion among students and promote meaningful learning (Kipnis & Hofstein, 2008). That is, in an inquiry-oriented laboratory, there should be discourse on the alternative interpretations of the data collected as well as a focus on the purpose of the experiment, and the design to address the question (Driver, Newton, & Osborne, 2000). Osborne, Erduran, and Simon (2004) suggest that argumentation, a genre of discourse, should be an indispensable part of laboratory learning, since it not only engages learners with conceptual and epistemic goals of science education as inquiry, but also makes scientific thinking and reasoning visible for formative assessment practices.

Argumentation, as a general term, is an essential part of an interactive dialogue of two or more people reasoning together. Specifically for science, argumentation is an essential component in making scientific claims because in an argument one needs to introduce his/her idea as a consequence of evaluating alternatives and weighing evidences as scientists do. According to Kuhn (1993), argumentation is one of the discursive practices in scientific communities used to frame claims, weigh evidence, construct warrants, and discuss alternative explanations.

In education, there are two main definitions of argumentation stated by Driver, Newton, and Osborne (2000). The first definition is related to the rhetorical (Kuhn, 1992, cited in Driver, Newton, and Osborne, 2000) or didactic (Boulter, & Gilbert, 1995) interpretation of argumentation. This kind of argumentation is described as drawing reasons to support or oppose a proposition or an action (Driver, Newton, & Osborne, 2000). This rhetorical definition of argumentation has its limitations because it is one-sided and not always relies on evidences. Driver, Newton, and Osborne (2000) claim that this type of argumentation is not preferable if the aim of education is to seek evidence and reasons for the ideas students hold. The second definition of argumentation is related to dialogical interpretation of argumentation, which is described as the evaluation of different perspectives within an individual or within a social group to reach agreement on a claim or an action (Driver, Newton, & Osborne, 2000). This definition of argumentation involves consideration of plural accounts of a phenomenon to construct a view or to take an action. Jiménez-Aleixandre, and Erduran (2007) defined argumentation as **a discursive**

practice through which scientific knowledge claims are justified or evaluated based on empirical or theoretical evidence.

In recent years, argumentation has been receiving increasing attention in science education studies (e.g., Driver, Newton, & Osborne, 2000; Jiménez-Aleixandre, Rodríguez, & Duschl, 2000; Osborne, Erduran, & Simon, 2004). The studies imply that argumentation plays a vital role in science learning and it should be reinforced in science classrooms (Duschl & Osborne, 2002; Jiménez-Aleixandre, Rodríguez, & Duschl, 2000; Kelly, Druker, Chen, 1998), because students who are engaged in argumentation not only advance in the social construction of scientific knowledge but also learn the nature of scientific enterprise (Bell & Linn, 2000). Osborne (2005) emphasized that argumentation in science classrooms leads to significant gains in students' epistemological understanding about science in such a way that students do not only have conceptual understanding of scientific concepts but also develop an understanding of how scientific knowledge is constructed. Jimenez-Aleixandre, Rodriguez, and Duschl (2000) claimed that "argumentation is particularly relevant in science education since a goal of scientific inquiry is the generation and justification of knowledge claims, beliefs and actions taken to understand nature" (p. 75). However, a significant problem about argumentation in science classrooms is the need for a teacher to mediate the learning environment (Duschl, 2007; Erduran, Osborne, & Simon, 2005). Teachers should be educated so that they can not only create learning environments which are inquiry-oriented but also encourage students to take part in the construction of explanations and evaluation of evidences (Erduran, Osborne, & Simon, 2005).

In keeping the above mentioned reasoning, it seems worthwhile to investigate the argumentation practices of pre-service and in-service teachers in the context of inquiry-oriented science laboratory. As the context where scientific knowledge is justified with empirical data in rather short periods of time, laboratory serves a good ground for argumentation. Moreover, inquiry-oriented laboratories, especially the ones conducted through collaboration, are also expected to provide basis where critical discussion and evaluation of the knowledge claims are grounded on. Therefore, this study aims at revealing pre-service science teachers' argumentation when they justify and evaluate knowledge claims in an inquiry-oriented laboratory context.

1.1. Purpose of the Study

The purpose of this study is to explore pre-service science teachers' argumentation in the context of inquiry-oriented laboratory work.

Within the process of scientific inquiry, learners are engaged in the use of scientific language, the formulation of hypothesis, the planning of the collection of empirical data, and the use of data and evidence in justification of knowledge claims (Duschl, & Osborne, 2002; Erduran, Osborne, & Simon, 2005; NRC, 2000). This study focuses on argumentation as a particular component of scientific inquiry.

Here the aim is not to evaluate and judge the quality of arguments but first, to describe and second, to understand the argumentation schemes frequently used by Pre-service Science Teachers (PST) when they are engaged in scientific inquiry.

1.1.1. Research Questions

The study addressed the following research questions:

RQ1. What kind of argumentation schemes do PSTs use as they perform inquiry-oriented laboratory tasks?

RQ1 focused on the PSTs' argumentation schemes in the context of inquiry-oriented laboratory. The literature on argumentation asserted that broad array of argumentation schemes employed by students in response to scientific tasks (Duschl, 2007). For this research question, the most appropriate analysis framework developed by Walton (1996) was used to investigate PSTs' argumentation schemes. Investigation of this research question has a potential in providing a better and more comprehensive understanding for PSTs' argumentation in scientific contexts.

RQ2. How do the argumentation schemes generated by PSTs vary by tasks as well as by experimentation and critical discussion sessions?

RQ2 investigated the variation of PSTs' argumentation by tasks and by experimentation and critical discussion sessions. Scientific argumentation has been studied by several science educators with different inquiry contexts (e.g., Richmond & Striley, 1996; Kelly, Drucker, & Chen, 1998; Kim & Song, 2006). When the results of these studies investigated, there has not been any discussion about how argumentation varies by tasks as well as by experimental part and the critical discussion part in a task. Thus, with this study, argumentation literature was tried to be extended focusing on the variations of argumentation schemes by tasks and by the experimentation and the critical discussion.

1.2. Significance of the Study

Argumentation is an effective instructional approach and educational goal for science education (e.g., Grandy & Duschl, 2007; Osborne, Erduran, & Simon, 2004). However, it rarely takes place in science classrooms (cited in Grandy & Duschl, 2007; Osborne, Erduran, & Simon, 2004), because of the failure of teachers or curriculum in reflecting the aspects of argumentation found in professional scientific practice (Bricker & Bell, 2008) argued. Thus, if science teachers are trained in argumentation practices similar to professional scientists', argumentation will be more widely integrated into science classrooms.

To engage science teachers in argumentation practices similar to professional scientists', the role of laboratory has an enhanced importance because laboratory provides discourse opportunities around evidences and explanations in scientific context (Duschl & Grandy, 2005). Although there are a few researchers, who investigated argumentation in inquiry-oriented scientific contexts (e.g. Richmond, & Striley, 1996; Kelly, Drucker, & Chen, 1998; Kim, & Song, 2006), there is little known about the argumentation practiced in the laboratory context, especially for the science teachers who are expected to bring the argumentation practices into their science classrooms. To fill this gap, this study critically looks at the argumentation practices of pre-service science teachers during inquiry-oriented laboratory work.

Science educators have used modifications of established argumentation models such as Toulmin's argument pattern (e.g. Erduran, Simon, & Osborne, 2004), or have developed their own models such as evidence-based dialogue maps (e.g. Okada, & Shum, 2008) in order to categorize, analyze, and interpret argumentation. By contrast, the present research offers an analysis framework based on the categorization of arguments according to Walton's (1996) argumentation schemes by presumptive reasoning. The resulting schemes, in this study, will provide an understanding about the argumentation schemes frequently used by PSTs. The results will give an idea to the extent in which future science teachers engaged in scientific argumentation, and what schemes of argumentation they refer to when constructing their knowledge claims and evaluating other scientific claims.

In this study, pre-service science teachers were chosen as participants. There are two main reasons that need to be highlighted for studying with pre-service science teachers. One of them is the policy of elementary science education in Turkey. It is stated in curricula documents that students need to be educated so that they can make evidence-based judgments when confronted with scientific issues as a distinctive characteristic of a scientifically literate individual (MoNE, 2006, p. 5). Although it is stated in policies of science curriculum that argumentation is a part of the usual science teaching-learning process, it is especially difficult in classrooms where science teacher is an authority who tries to establish an agreement on scientific world-view with the students (Erduran, Osborne, & Simon, 2005). The second reason is stated in literature as the need to educate teachers who are identified to be the major barriers to integration of argumentation in school science (Driver, Newton, & Osborne, 2000). Pre-service teachers need to be educated so that they can scaffold argumentation in their future science classrooms as well as support students to engage in argumentation. However, there is little known about how teachers, in-service or pre-service, construct arguments in scientific issues (Newton, Driver, & Osborne, 1999; Zembal-Saul, Munford, Crawford, Friedrichsen, & Land, 2002). To sum up, PSTs were chosen because they are ideal candidates to teach the tasks in their future classrooms and to integrate argumentation into science curricula.

Therefore, the results obtained from this study could also provide an important groundwork for training PSTs to be adaptive to their future workplace where argumentation is an integral part of science learning. Moreover, the results should also be an introduction to the research which seeks for improving the argumentation practices of science teachers in scientific contexts. This study may also add to the effort to develop materials which enhances the argumentation in laboratory contexts since each laboratory task is designed to allow dialogical discourse around scientific concepts.

CHAPTER 2

REVIEW OF LITERATURE

This chapter includes the review of the literature relevant with argumentation, argumentation in science education, and argumentation in science teacher education.

2.1. Argumentation

In this part, three main argumentation theories are described. The first one is Aristotle’s argumentation. In Aristotle’s argumentation (Puvirajah, 2007), analytic, dialectic and rhetoric forms of argument are examined. The second argumentation theory is Toulmin’s (1958) argumentation. In Toulmin’s argumentation, the components of an argument and the relationships among them are identified. The last argumentation theory identified in this study is Walton’s (1996) argumentation for presumptive reasoning.

2.1.1. Aristotle’s Argumentation Theory

Aristotle proposed three forms of arguments, namely analytic, dialectic and rhetoric arguments (Puvirajah, 2007).

The analytic argument is associated with rationalistic paradigm. According to this paradigm, there is an absolute truth or reality that can be found by any trained individual sooner or later. The truth is objective and free of any subjective interpretation. Therefore, in analytical arguments, there is an assumption that when given identical problems, any trained individual can reach the same conclusion (Puvirajah, 2007). Mathematical proofs are examples of this kind of arguments.

The dialectical argument has its basis on Hegel's thesis, antithesis and synthesis triadic. In this form of argumentation, there is an exchange of ideas through a dialogue. According to Hegel, any thesis exists with its antithesis, and a dialogue on a thesis would result in the synthesis of new thesis. Dialectical argumentation mainly occurs in resolving disagreements through logical discussion (Puvirajah, 2007). In this form of argumentation, two opposing parties propose their claims (thesis and antithesis), and they negotiate until they arrive at a mutually agreed solution (synthesis).

The rhetoric form of argumentation occurs when the aim is to persuade the opponent to the validity of a claim. In this form of argumentation, parties use evidences, witnesses, and documentation as well as persuasion skills, such as emotions, to convince the opponents that their claim is logical and acceptable. Rhetorical arguments are common in courtrooms (Puvirajah, 2007).

Aristotle's argumentation forms provided a base for the consideration of argumentation in specific situations, such as judicial and parliamentary settings. However, it is especially difficult to always justify claims with universal truths, or to reach an agreement in every negotiation, or to convince the audiences to a particular view. On the other hand, individuals ground their claims in the context of experiences, social interactions, and inferences rather than universal principles in daily life.

2.1.2. Toulmin's Argumentation Theory

Toulmin (1958) believes that the type of justification is dependent on the context. For example, a claim in the context of theology may not be valid in the natural sciences (Puvirajah, 2007). Therefore, Toulmin asserts practical argument that can be applied in different fields.

Toulmin (1958), in his book of *The Uses of Argument*, analyzed many arguments to explain everyday argumentation and presented a model, which includes the elements of an argumentation and the relationships between them (Figure 2.1). The main components of this model are:

1. Data: Facts or evidences, which support the claim.
2. Claim: Conclusion put forward for general acceptance.
3. Warrants: Reasons (rules, principles etc.) proposed to justify the link between data and claim.
4. Backings: Basic assumptions or generalizations, which provide the justification for warrants.

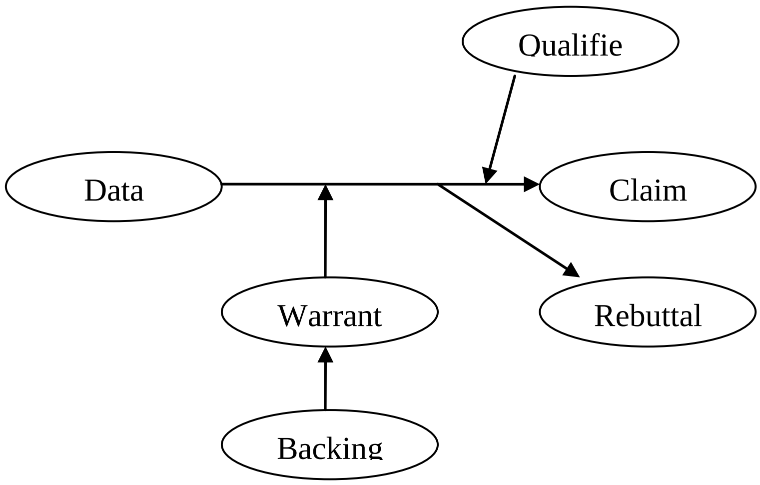
Driver, Newton, and Osborne (2000) formulated these main components of an argument in a sentence like: “because (data)…. since (warrant)…. on account of (backing)… therefore (claim)” (p.293).

In addition to the main components above, Toulmin (1958) identified two more components included in complex arguments:

2. Qualifiers: Phrases that show the conditions under which the claim is reliable, such as usually, strongly, generally.
3. Rebuttals: Circumstances under which the claim is refutable or undermined.

In Toulmin’s argumentation, claim is the base for all arguments. For a good argument, the claim must be justified by providing a warrant and a backing. However, Driver, Newton, and Osborne (2000) argue that Toulmin’s argumentation has mainly three limitations. These limitations are:

1. It only gives idea about the structure of the arguments, but does not evaluate their correctness.
2. It does not consider the dialogic structure of the argumentation, that is, no recognition is given to interactional aspects of the argumentation.
3. Toulmin's scheme is decontextualized, that is linguistic and situational contexts are not emphasized (Driver, Newton, & Osborne, 2000, p.294).



Source: Toulmin, S. (1958). *The uses of argument*. Cambridge: Cambridge University Press.
Figure 2.1 Toulmin's Argument Pattern (Toulmin, 1958).

2.1.3. Walton's Argumentation Schemes for Presumptive Reasoning

Walton (1996) pointed to argumentation is an essential part of an interactive dialogue of two or more people reasoning together. For Walton (1996) there may be arguments both in favor and against a claim, and the evaluation of arguments must be made considering the balance between them. He indicated that argumentation schemes, which are grounded on practical arguments that can occur in a dialogue, can be used to evaluate everyday argumentation.

Walton (1996) analyzed presumptive inference and applied this type of reasoning in argumentation schemes. For Walton (1996), presumptive reasoning is the reasoning "that is neither knowledge-based nor probability-based, but has the function of shifting a weight of presumption onto the other party in a dialogue". The presumptive reasoning is the basis of argumentation that commonly occurs in everyday dialogues (Walton, 1996). The presumptive reasoning does not need to be inductive or deductive, or does not need to be proved to be true. However, it needs to carry a weight of plausibility if an argument is to be accepted.

There are 25 argumentation schemes described and analyzed by Walton (1996). Each argumentation scheme is with its critical questions. Some of the argumentation schemes are fundamental, whereas others are composites made up from the fundamental ones. In the use of argumentation schemes, presumptive reasoning is essential to be evaluated and dialectical nature of the reasoning is necessary. In this way, one argumentation scheme can shift the weight of presumption to the other side of the dialogue and the opposing party can shift this weight back to the arguer by means of critical questions associated with that argumentation scheme (Walton, 1996).

2.2. Argumentation in Science Education

Argumentation in science education is conceived as a discursive practice through which scientific knowledge claims are justified or evaluated based on empirical or theoretical evidence (Jiménez-Aleixandre, & Erduran, 2007).

In this part, literature related to the place of argumentation in science education is reviewed in three sections. In the first section, the analyses of argumentation in science education are examined. Second section involves the research on supporting and promoting argumentation. In the third section, the research on teaching and learning argumentation is reviewed.

2.2.1. The Analyses of Argumentation in Science Education

The studies related to the assessment of argumentation mainly evaluate the quality or the characteristics of the argument. In this section, the approaches to the analyses of argumentation in science education literature are reviewed.

A comprehensive study about the assessment of the argumentation in science education was done by Sampson, and Clark (2008). The researchers reviewed the analytic frameworks used to assess the nature or the quality of the scientific arguments in terms of structure, justification, and content. Two domain-general analytic frameworks; Toulmin's argumentation pattern, and Schwarz, Neuman, Gil, and Ilya's argumentation analysis and four domain-specific analytic frameworks; Zohar and Nemet's argumentation framework, Kelly and Takao's argumentation, Lawson's hypothetico-deductive argumentation, and Sandoval's framework were examined in this review. The review evaluated the constraints and affordances of each framework used to examine the nature and quality of arguments generated by students in science education (Sampson, & Clark, 2008). There are several important results of this study. First, frameworks reviewed are tools created for specific purposes, so they are not fully interchangeable. Second, a given intervention is not enough to decide the quality of arguments generated by students, so researchers need specific details as well as assumptions of quality to interpret findings. Last, much research examines the very specific parts of students' argumentation, and there is a need for more holistic considerations (Sampson, & Clark, 2008).

In his book, *The Uses of Argument*, Toulmin (1958) defined the constitutive elements of an argument and the relationships among them. The definition made by Toulmin (1958) introduced a significant contribution to the analysis of argumentation discourse in science classrooms (e.g. Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Zohar, & Nemet, 2002; Erduran, Simon, & Osborne, 2004). For example, Erduran, Simon, and Osborne (2004) collaborated with 12 middle-school science teachers to develop instructional activities in order to integrate argumentation into their science classes. The study resulted with two methodological approaches for tracing argumentation discourse in science classrooms by Toulmin's model. In the first methodology, they used audio-taped verbal conversations of 12 science classes of year 8 students. The focus was on a socio-scientific question related to funding of a new zoo. The lesson included a whole-class discussion about the pros and cons of zoos, within group discussions about whether a zoo should be built, and presentation of group discussions. In the first methodological approach, the distribution of Toulmin's argumentation pattern (TAP) in whole-class discussions were traced and analyzed for two years. TAP is a five level scale used for assessing the quality of argumentation. Level 1 argumentation consists of simple arguments structured by a claim versus a counter-claim or a claim versus a claim. Level 5 argumentation consists of complex arguments structured by a claim supported by one or more warrants and backings and extended with more than one rebuttal. Table 2.1. shows the analytical framework benefiting from Toulmin's argumentation definition. The first part of the study enabled researchers to use TAP for both qualitative and quantitative analyses of argumentation in large groups. Erduran, Simon, and Osborne (2004) reported that the qualitative analysis reveals particular patterns in the distribution of TAP clusters. For example, at the beginning of the study, clusters that included two or three components of argumentation, such as CD (claim-data) and CDW (claim-data-warrant) occurred more frequently, whereas, at the end of the year, clusters that included four and five components, such as CDWB (claim-data-warrant-backing) and CDWBR (claim-data-warrant-backing-rebuttal) occurred more frequently. TAP also enabled researchers to do quantitative analyses of classroom discourse in terms of the statistical comparison of TAP cluster frequencies (Erduran, Simon, & Osborne, 2004). In the second methodology, 6 teachers, who were effective in promoting argumentation in their classes, were selected to continue to the same research. The data were collected in several lessons of these teachers. Transcripts of group discussions were examined to trace rebuttals in student group discussions. The frequency of rebuttals in student group discussions permitted the comparison of performances among groups because rebuttals are an indicator of opposing, which is a higher order skill.

Toulmin’s argumentation model has been widely used as a methodological tool for analyzing argumentation in science education. Recently, Simon (2008) introduced two more projects that TAP was incorporated for promoting teaching and evaluation of argumentation. One of the projects was to use TAP in evaluation of the impact of professional development programme on teachers’ learning. In this programme, teachers were presented series of arguments and they were asked to identify the components of the argument using Toulmin’s definition of argument. Simon (2008) indicated that the use of Toulmin's definition as a methodological framework for analyzing argumentation can have an influence on classroom practice. The other project extended the application of Toulmin’s framework in the use of argumentation software. Software, Digalo, was used by a small group of students in argumentative activity based on a task or problem. The discourse was mapped as argumentation proceeds to represent structural elements of an argument. An argumentative map was constructed at the end with a structured argument, similar to Toulmin’s framework. Simon (2008) argued that applying TAP to these argumentative maps was more clear-cut because students have already identified argument components and lines of support or opposition. The adoption of TAP to the written argument and transcripts enabled researcher to assess the quality of argumentation in terms of the number of components and the complexity of arguments (Simon, 2008).

Table 2.1. Toulmin's Analytical framework used for assessing the quality of argumentation

Level 1:	Level 1 argumentation consists of arguments that are a simple claim versus a counter-claim or a claim versus claim.
Level 2:	Level 2 argumentation has arguments consisting of claims with data, warrants, or backings, but do not contain any rebuttals.
Level 3:	Level 3 argumentation has arguments with a series of claims or counter-claims with data, warrants, or backings with the occasional weak rebuttal.
Level 4:	Level 4 argumentation shows arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter-claims as well, but this is not necessary.
Level 5:	Level 5 argumentation displays an extended argument with more than one rebuttal.

Source: Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education, 88,* 915-933.

Another research tool to analyze the quality of students' argumentation was developed by Okada, and Shum (2008). In their reported pilot study, the researchers introduced evidence-based dialogue maps as a participatory action research tool to investigate students' argumentation. Evidence-based dialogue mapping was used in a software application. The participants were a science teacher-researcher, a knowledge mapping researcher and 20 students, 12 and 13 years old. The students were given a case and seven activities on a participatory action research cycle to complete by using the software. The purpose of instruction was stated to engage students in action learning by reflecting on their maps to improve their arguments as a spiral process. Two case studies were examined qualitatively to describe the role of Evidence-based Dialogue Maps in scientific reasoning. The first case was designed to help students to generate evidence-based claims, and teachers to analyze their arguments. The second case presented as a self assessment tool in students' argumentation. Students reflected on their arguments and got feedback from the teachers to improve their arguments. The results of the study showed that evidence-based dialogue mapping can be used to link knowledge to support the linearization of the task to visualize the reasoning sequence and to enable the arguers reflect on their thinking and reasoning in response to teacher feedback. Moreover, evidence-based dialogue was presented as a method to investigate the quality of argumentative essays (Okada, & Shum, 2008).

Walton (1999) offered another method of evaluating an argument critically in a purposive type of dialogues. Walton (1999) called the framework as the "new dialectic". Walton's framework was mainly about everyday arguments, and was based on presumptive reasoning. Presumptive reasoning is defined by Walton (1999) as an inference, and its conclusion is a guess or presumption, which is subject to withdrawal when new information comes in. In the new dialectic, argumentation is analyzed and evaluated in the context where dialogue occurs because Walton (1999) asserted that an argument that is appropriate and reasonable in a dialogue might be highly inappropriate, or *fallacious*, in another type of dialogue. Walton (1996), identified twenty-five argumentation schemes for presumptive reasoning. Argumentation in everyday discourse was identified and evaluated according to the argumentation schemes. Each argumentation scheme has its matching set of critical questions. To evaluate a given argument, the argumentation scheme and the matching critical questions are used in relation to a context of dialogue in which the argument occurred. The weight of evidence on both sides of the dialogue is important to decide where the weight of acceptability is shifted to reach a conclusion. Asking of the critical questions matched with that argumentation scheme can shift the weight of acceptance to the other side of the dialogue (Walton, 1996; Walton, 1999).

An example of the use of Walton's argumentation schemes for presumptive reasoning in science education is the study conducted by Duschl, and Ellenbogen (1999). Argumentation schemes for presumptive reasoning by Walton (1996) were used to analyze middle school science students' small group discourse during a science investigation project. Seventeen students were participated in the study and they were interviewed. The interviews, used for the analysis, were about constructing tangram figures activity, and on the evidence and the claims made in the science investigation project. For the analysis of argumentation generated by students, eight of the 25 argumentation schemes proposed by Walton were selected. The researchers reported that broad set argumentation schemes employed by students, such as argument from sign and argument from consequences (Duschl, & Ellenbogen, 1999). Duschl (2007) indicates that Walton's argumentation schemes revealed that individuals generated more argumentation that can be detected and identified by other frameworks. This is an important finding because it shows that the most of the authentic argumentative practices of students reflected and analyzed using Walton's argumentation schemes.

2.2.2. Research on Supporting and/or Promoting Argumentation in Science Education

There are a number of strategies used to support and/or promote argumentation in science classrooms. One of the strategies is to design and evaluate learning environments to support teaching and learning of argumentation in science classrooms. Osborne, Erduran, and Simon (2004), working with a group of 12 science teachers, and junior high school students conducted a research on learning environment to support argumentation in two phases. In the initial phase of the research, the researchers, in collaboration with 12 teachers, developed sets of materials and strategies to support argumentation in the classroom, and assessed teachers' development in argumentation. The teachers' application of materials and strategies in their classrooms were audio and video-recorded. Toulmin's argument pattern was used to evaluate the quality of argumentation in classrooms. Osborne, Erduran, and Simon (2004) reported that teachers showed significant development in the use of argumentation within a year. In the later phase of the research, six of the teachers were selected to teach nine lessons to the experimental group. The focuses of the lessons were socio-scientific or scientific topics, which allowed argumentation. In this phase of the study, students were traced in terms of their improvement in capabilities with argumentation. Toulmin's argument pattern was applied for evaluating the nature of the discourse and its quality. The results indicated an improvement in the quality of students' argumentation (Osborne, Erduran, & Simon, 2004).

The online or computer-based strategies were also employed to increase the use and the quality of argumentation in science classrooms. For example, Clark, and Sampson (2007) used a customized online discourse system to support students' dialectical and rhetorical argumentation in a study on understanding scientific inquiry. Through "personally-seeded discussions" in online interface, students were encouraged to build principles to describe data they have collected, and elicit, share, and contrast their opinions in scientific argumentation and inquiry. By using the software, students were grouped into discussion groups, involving multiple perspectives. Toulmin's argumentation pattern for analysis of the quality of argumentation, developed by Erduran, Osborne, and Simon (2004), was employed to explore the efficacy of this personally-seeded approach. The researchers reported 68% of the oppositional statements were higher level arguments, suggesting that personally-seeded discussions scaffold high structural levels of scientific argumentation (Clark, &

Sampson, 2007). In addition, personally-seeded discussions required minimal teacher training, and were found to scaffold significant levels of argumentation.

Lawson (2009) employed the inferences of abduction, retroduction, deduction, and induction as an instructional framework to improve student reasoning and argumentative skills. Abduction was the first strategy used to generate hypotheses based on observations. Retroduction, deduction, and induction were used as a reasoning strategy to form a pattern of If/then/Therefore structure. This structure was applied to test the hypotheses generated in the first step. Lawson (2009) presented three representative case histories (Galileo's discovery of Jupiter's moons, Rosemary and Peter Grants' research on Darwin's finches, and Marshall Nirenberg's Nobel Prize–winning research on genetic coding), which allowed reasoning and argumentation in an If/then/Therefore form. The examination of case histories showed that the framework enabled the researcher to differentiate among an argument's *declarative* components, such as observations, hypotheses, predictions, and conclusions, and its *procedural* components, such as abduction, retroduction, deduction, and induction (Lawson, 2009, p.23). Although the framework contributed the nature and the quality of argumentation, Lawson (2009) asserted that students more frequently need to be engaged in making observations to construct hypotheses, and testing them.

Using concept cartoons is another strategy to encourage students' argumentation among groups. Chin, and Teou (2009) investigated the use of concept cartoons to stimulate talk and argumentation among students in small groups. Two classes of primary 5 and 6 year students participated in the study. Four concept cartoons pertained to science topics, such as photosynthesis, heat transfer and heredity traits were used to present findings. Students in groups discussed the opposing ideas posed in the cartoons. After the group discussions, students were allowed to make group presentations to challenge each other's ideas. The audio recordings of group discussions were transcribed and discourse was analyzed using the frameworks of Mercer, Wegerif, and Dawes (1999), and Toulmin (1958). The results of the study showed that dialogic talk and argumentation made students' reasoning visible for formative assessment purposes.

2.2.3. Research on Teaching and Learning Argumentation in Science Education

In the discussion of why argumentation is in the science classroom, Jiménez-Aleixandre, and Erduran (2007) proposed five possible answers: (1) supporting cognitive and metacognitive processes in the learning of sciences, (2) enhancing the development of communicative skills and promoting critical thinking, (3) enabling scientific literacy and empowering students to talk and write in the language of science, (4) developing epistemology of students in the evaluation of knowledge claims, and making the enculturation of science possible, and (5) promoting scientific reasoning.

In the following, these functions of argumentation proposed by Jimenez-Aleixandre, and Erduran (2007) are extended.

First, argumentation supports cognitive and metacognitive processes in the learning of sciences. For example, von Aufschnaiter, Erduran, Osborne, and Simon (2008) investigated junior high school students' processes of argumentation and cognitive development in science and socioscientific lessons. They used video and audio records of small group and whole-class discussions to assess the quality and frequency of students' argumentation, and students' development and use of scientific knowledge. In the analysis of argumentation, Toulmin's (1958) argumentation pattern was used. Knowledge development was traced drawing on a schema for determining the content and level of abstraction of students' meaning-making. The researchers reported that student rely on their prior experiences and knowledge when engaging in argumentation, and students employ these knowledge and experiences at relatively high levels of abstraction. Moreover, the findings of the study revealed that if students were familiar to the content of the task, high quality of the arguments generated. The research put forth the importance of prior knowledge and experiences to engage in argumentation.

Second, argumentation enhances the development of communicative skills and promotes critical thinking. For example, in their research, Sampson, and Clark (2009) examined the impact of collaboration during scientific argumentation. They studied with 168 high school chemistry students, who were randomly assigned to either collaborative argumentation or individual argumentation. In the initial phase of the study, students were asked to complete a task that required them to engage in argumentation and justify their explanations for a discrepant event. Then, the effect of collaboration on individual learning was assessed using two follow-up tasks. First task was related to a mastery problem, and the second task was related to a conceptually similar transfer task. Students were required to generate written arguments that justify their explanations for the event in the tasks. The researchers reported that when performing initial task, collaboration did not have any effect on the quality of arguments generated by students. However, the students who worked in a group, when performing two follow-up tasks, produced significantly better arguments than the students who worked individually. Sampson, and Clark (2009) suggested that collaboration improved students' learning gains both from and about scientific argumentation when the task requires the consideration of plural explanations. They argued that collaborative argumentation is effective because it gives opportunities to share different viewpoints, and think about the problem or what counts as a good argument.

Third, argumentation enables scientific literacy and empowers students to talk and write in the language of science. Gott, and Duggan (2007) argued that being scientifically literate requires an understanding of evidence and its underlying ideas in order to understand public claims fully. They asserted that to comprehend a scientific issue in an informed way, one needs to consider the design, data collection and analysis required to support the claims made on that issue, that is called "looking back" in their words. Gott, and Duggan (2007) outlined three kinds of practical work, which are field investigations, diagnostic tasks, and simple laboratory tasks, and linked Toulmin's structure of argumentation with its elements to exemplify "looking back" in practical science in school. They believed that achieving scientific literacy would not be difficult if students learn to question the warrants, qualifiers and backings that lie behind the claims, and they relied on primary data to make it easier (Gott, & Duggan, 2007).

Fourth, argumentation develops epistemology of students in the evaluation of knowledge claims, and makes the enculturation of science possible. For example, Nussbaum, Sinatra, and Poliquin (2008) investigated the scientific arguments, in combination with constructivist epistemic beliefs to explore whether this combination would result with better learning of physics concepts. They studied with 88 college undergraduates, who in pairs discussed several physics problems related to gravity and air resistance in an online interface. Before the discussion activity, the treatment group was trained about the nature of scientific arguments. First, students were asked to complete a series of surveys online. The first survey was developed by Kuhn, Cheney, and Weinstock (2000) to classify individuals into three epistemic orientations: relativists, multiplists, or evaluativists. The argumentativeness scale, developed by Infante and Rancer (1982) was administered next to measure the tendency to argue with other people. Then, students were instructed to read the physics questions and were asked to discuss the problem online with their partner. The discussions were analyzed based on the reflection of four criteria of a scientific argument. First criterion was the identification of variables, second criterion was whether claims are supported by facts, third criterion was whether alternative theories are considered, last criterion was whether the argument accounts for all facts and searches for counterexamples. Finally, to examine learning gains in physics concepts, increase or decrease in misconceptions was observed. The researchers reported that students in the experimental group developed high quality arguments, and adopted the correct answer to one of the problems. Furthermore, in terms of epistemic beliefs, the results of the study revealed that epistemic beliefs played a role in students' argumentation. Specifically, evaluativists were found to raise more issues, whereas multiplists were less critical of arguments. The researchers concluded that the degree and nature of the argument are closely related with the epistemic position of the arguer (Nussbaum, Sinatra, & Poliquin, 2008).

Last, argumentation promotes scientific reasoning. For example, Dawson, and Venville (2009) conducted a research to explore Australian high-school students' argumentation and informal reasoning about biotechnology. Totally 30 students between 12 and 17 years old were participated in the research. In the semi-structured interviews, students were asked questions about their understanding and views of biotechnology, cloning, genetic testing for diseases, paternity and forensics, and the production and consumption of genetically modified food crops. The analytic framework to assess the quality of arguments was Toulmin's argumentation pattern. The researchers also investigated the informal reasoning patterns (rational, emotive, and intuitive) as frameworks. The results of the research revealed that most of the students did not use data or used only a simple data to justify their claims. In terms of the relationship between argumentation and the reasoning, the researchers stated that students, who use rational informal reasoning, engaged in more complex arguments (Dawson, & Venville, 2009).

Another study, which investigated the effects of argumentation on the students' reasoning and argumentation levels, was conducted by Eşkin (2008). The participants of the study were 52 tenth-grade students from two physics classrooms in a high school, in Turkey. Experimental group was treated by five argumentation integrated dynamic units. The study revealed that there is no clear correlation between argumentation process and change of the students' reasoning levels. However, the researcher stated that there was an interaction between the students' reasoning levels and argumentation levels. Moreover, it was indicated that conditions, in which students' reasoning and argumentation levels change were analogous, existed. Based on the findings, the researcher argued that the application of the argumentation within the classes have positive affects on the students' argumentation levels and partly on their reasoning levels (Eşkin, 2008).

In addition to the five function proposed by Jimenez-Aleixandre, and Erduran (2007), Driver, Newton, and Osborne (2000) addressed three emphases of argumentation in science education: argumentation for developing conceptual understanding, argumentation for increasing investigational capability, and argumentation for understanding scientific epistemology. They claimed that these emphases are of central importance to the decision-making in socio-scientific issues and so the development of scientific literacy (Driver, Newton, & Osborne, 2000)

The role of argumentation in developing conceptual understanding, for example, searched by Cross, Taasoobshirazi, Hendricks, and Hickey (2007). They investigated the relationship between learning gains, and engagement in scientific argumentation. Group discourse and individual learning during the implementation of software was observed. The software required 28 high school biology students engage in collaborative learning of biology concepts. Directions were given to help students engage effectively in the argumentation, and to encourage them to use complex forms of argumentation. Pre- and post-tests were administered to assess students’ learning. The researchers indicated that rather than the quantity of arguments, the type of argumentation used and the quality of the information in the claims were important in relation to learning gains. The argumentative structures, the quality of these structures, and the identities that students take on during collaborative group work were reported to be influential on student learning and achievement in science (Cross, Taasoobshirazi, Hendricks, & Hickey, 2007).

A comprehensive study about the effectiveness of argumentation on 10th grade students' understanding of concepts about gases, and the effectiveness of argumentation materials on students' understanding of nature of science was conducted by Yeşiloğlu (2007). A total of 54 students from two 10th grade classes in Turkey were selected in this study. The results indicated that students which were instructed through argumentation had higher achievement and conceptual change scores. The findings suggested that argumentation has a positive effect on 10th grade students' understandings of concepts about gases and their achievement to solve algorithmic problems about concepts and principles about gases (Yeşiloğlu, 2007).

Kelly, Druker, and Chen (1998) conducted a research to investigate the role of argumentation in increasing investigational capability. They examined the problem-solving process by focusing on students' arguments. The scientific task required students to apply their knowledge of electricity to solve a problem. The students worked on labs through the 'Electric Mysteries' performance assessment. The students were provided with batteries, bulbs and wires to construct electric circuits to determine the contents of the boxes. Data were collected through video-records of 10 pairs of students. The researchers applied a modified version of Toulmin's arguments to the students discourse. The analysis of students' arguments was done by focusing on the students' use of warrants. They found great variability in the students' argument patterns. However, the researchers stated that a large number of warranted arguments did not mean that students engaged more in argumentation or they possessed greater subject-matter knowledge. The researchers explained this condition that student should feel compelled to provide an explicit warrant, and it is not possible in procedural tasks.

Another study, which investigates argumentation skills during inquiry-based investigational practice, was conducted by Kim, and Song (2006). They examined the features of peer argumentation while middle school students' were performing open-ended inquiry tasks. Each group were asked to report their experiments for peer review, present their results, and critique in a way similar to conference presentations by scientists. The researchers reported that the critical peer discussion proceeded through the four stages: Focusing, Exchanging, Debating and Closing. They also found that a large percentage of evidence used in students' arguments was personal evidence and students used various cognitive and social strategies in the critical discussion. An important result of this study was that during argumentation, students showed improvement in their interpretation and methods of experiment process and this feedback made the inquiry circular. Finally, they constructed a model of argumentative scientific inquiry, which is used as a design framework in the present study.

The argumentation studies addressing the understanding of scientific epistemology were examined by Sandoval, and Millwood (2007). They defined scientific epistemology as a description of the nature of the scientific knowledge, involving the sources, and scientific warrants. Sandoval, and Millwood (2007) argued that students have to be in instructional contexts where they have to make explicit epistemic decisions in order to understand the scientific practice in a way scientists do. That is where students select data to collect, choose alternative interpretations of data, and decide one of the competing claims. Additionally, to make the epistemic decisions explicit, there should be strategies such as constructing and evaluating arguments (Sandoval, & Millwood, 2007). Similarly, Jimenez-Aleixandre, and Erduran (2007) claimed that argumentation, with the justification of claims through evidence, may support the development of scientific epistemology and understanding of the practices of the scientific community.

2.3. Argumentation in Science Teacher Education

In order to teach argumentation, teachers must know the argumentation strategies and be proficient in carrying-out evidence-based argumentative activities (Zohar, 2007). Moreover, they need to be prepared for any fallacies that may occur during the argumentation, and need to have pedagogical knowledge about teaching argumentation (Zohar, 2007). Therefore, teachers' training on argumentation is as much a concern in argumentation studies as students' training.

The early studies indicated that science classrooms were teacher-dominated, and did not allow much student discourse. For example, Newton (1999) asked that if argument is a central to science education, whether teachers give students opportunities to develop the skills of argumentation during their science lessons. He worked with secondary schools and used an observation schedule to determine the range of activities that take place in science lessons. Newton (1999) found that science lessons were carried with a heavy emphasis on question and answer interaction. He concluded that the teacher-dominant practices in science lessons did not involve activities that support discussion, argumentation or the social construction of knowledge. Newton (1999) asserted that limitations in teachers' pedagogical training related to classroom discourse, and the anxiety to complete the National Curriculum and its assessment system were the reasons for the inadequacy of the argumentation practices. Similar results were also reported by Yalçınoğlu (2007). In her PhD thesis study, Yalçınoğlu (2007) investigated high school biology teachers' epistemological criteria and their attention to reasoning and argumentation within their instructional practices. Data were collected through face-to-face interviews, classroom observations, and document collections. Teachers were asked to provide an argument about the validity of hypothetical conclusions drawn by the students based on two different scenarios related to evolution. TAP used to analyze argumentation. Yalçınoğlu (2007) reported that although elements of an argument were visible in the teaching practices, teachers did not explicitly introduce a well structured argument in their classrooms. As a result, students were not provided opportunities to practice high level of reasoning or improve their argumentation skills.

After Newton's (1999) statements about the inadequacy of teachers in promoting argumentation in their science classrooms and their persistence in traditional methods, research attempted to understand teachers' perceptions of argumentation and to develop their skills of argumentation. For example, Sadler (2006) investigated pre-service teachers' perceptions of and aptitudes related to argumentation during a science method course. The aim of the course was stated as to promote discourse and argumentation. Data were collected through instructor reflections, course documents, and student work. At the end of the course, participants reported argumentation as central to science, however most participants tended to view argumentation as a pedagogical strategy. Sadler (2006) proposed methods courses as one possible way of promoting argumentation in science education.

There has been an intensive research recently to train teachers in supporting and promoting argumentation in science classrooms. For example, Simon, Erduran, and Osborne (2006) focused on teaching argumentation in secondary science classrooms. They worked with 12 science teachers over a 1-year period to develop materials and strategies to support argumentation in their science lessons. The workshop series were conducted and were audio and video-recorded to identify where the teachers attempted to implement argumentation. TAP was used to assess the quality of argumentation in classrooms. Besides developing sets of materials and pedagogic strategies to facilitate argumentation in the classroom, the workshops with teachers also led to development in teachers' use of argumentation across the year. Simon, Erduran, and Osborne (2006) interpreted these results in such a way that to train science teachers to adapt and develop their practice of classroom discourse was possible, because teachers reported that the opportunity for students to reflect, discuss, and argue how evidence did or did not support a theoretical explanation was beneficial to students' engagement with scientific ideas.

Another attempt to advance teachers' skills in their pedagogy of argumentation was the use of portfolios in a continuing professional development programme (Simon, & Johnson, 2008). The researchers looked for portfolios to see the implications of a continuing professional development programme (CPD). The portfolios were involving evidence that demonstrated teachers' improvement in the teaching of argumentation, and their reflective analysis of practice. The CPD programme involved materials and strategies from King's College–Weizmann project on teachers' use of argumentation in science classrooms, and from the in-service training materials developed by other projects. Simon, and Johnson (2008) concluded that portfolios were useful in developing skills of reflection, self-evaluation and analysis, therefore contributed to an metacognitive development of teachers. However, they noted that the portfolios were the products of the processes involved in their development.

Acar (2008), in his PhD thesis study, investigated prospective science teachers' development of argumentation skills and conceptual knowledge in an undergraduate course where argumentation skills were incorporated to the science curriculum. A total of 125 pre-service science teachers were involved in an inquiry-based physics course. During the course, argumentation skills were assessed by the use of argumentation tests and the conceptual understanding of balancing and sinking and floating concepts were assessed by a conceptual test. Moreover, argumentation discourse of one small group of students was audio-taped during the course. Acar (2008) reported improvement in prospective science teachers' argumentation skills regarding balancing, sinking and floating concepts during the course. That is, pre-service teachers used counter-argument and rebuttal evidence and justification more frequently compared to the beginning of the course. The improvement in counter-argument and rebuttal evidence scores was reported to be content independent whereas improvement of counter-argument and rebuttal justification scores was content dependent. Another important result of the study related to argumentation skills was that argumentation gain scores were not related to initial conceptual knowledge level (Acar, 2008).

Zembal-Saul (2009) developed a framework for teaching science as argument in elementary schools. The researcher examined pre-service teachers' developing understandings and practices for teaching science as argument during the science method courses and synthesized the ways in which teacher education experiences mediated learning. The framework for teaching science as argument was used to engage students in argumentation practices within the content of investigation-based science learning. Sometimes, software was used to scaffold argumentation. Zembal-Saul (2009) indicated that the framework served as a powerful scaffold for pre-service teachers' developing thinking and practice.

To summarize, research show that argumentation in science classrooms has lead to significant gains in students' epistemological understanding about science in such a way that students do not only have conceptual understanding of scientific concepts but also develop an understanding of how scientific knowledge is constructed (Osborne, 2005). Therefore, a great deal of research has been devoted to the instructional strategies (e.g. Duschl, Ellenbogen, & Erduran, 1999; Kuhn & Reiser, 2006; Osborne, Erduran, & Simon, 2004) or the teaching materials, such as technology-enhanced learning tools (e.g. Bell & Linn, 2000; Clark & Sampson, 2005; Sandoval & Reiser, 2004) to integrate and support argumentation in the teaching of science. Moreover, much research interest has also been devoted to the analyses of students' and teachers' argumentation in socio-scientific (e.g. Kolstǿ, 2001; Sadler, 2004; Sadler & Zeidler, 2004) and scientific contexts (e.g. Erduran, Osborne, & Simon, 2005; Kelly et al., 1998). However, overview of the research indicates that there is an apparent deficiency on research that examine the nature of argumentation practices, that is how scientific are the arguments, and what premises are used in the argumentation, especially for pre-service and in-service teachers, during the construction and evaluation of scientific knowledge claims. In the argumentation for science topics, it is necessary to look at the reasoning criteria used by pre-service science teachers in the construction and evaluation of scientific claims. Therefore, the present study attempts to investigate pre-service science teachers' argumentation practices in scientific contexts while they are engaged in the construction and evaluation of scientific knowledge.

CHAPTER 3

METHOD

3.1. Introduction

The main focus of this study was to investigate PSTs' argumentation in an inquiry-oriented laboratory environment. In this study, issues related to different areas of science, such as physics, chemistry, and biology were used as scientific topics. While PSTs studying on scientific issues, they put a claim forward and tried to support it with experimental data. Then, they presented their results to their peers in order to evaluate the validity of their claims. Through these activities, PSTs engaged in many dialogical discourses that revealed their argumentation patterns.

The study first investigated PSTs' argumentation schemes in the context of inquiry-oriented laboratory; and second, explored the variation of argumentation schemes across experimentation and critical discussion sessions. The basic interpretive qualitative research approach was used in this study (Merriam, 2002). In this approach, the researcher tries to understand "how participants make meaning of a situation or phenomenon" (p.6), and the results are usually descriptive. Data are collected through interviews, observations, or document analysis. These data are inductively analyzed to identify the recurring patterns or common themes that cut across the data. A rich, descriptive account of the findings is presented and discussed, using references to the literature that framed the study in the first place. In this study, the researcher tried to understand how participants construct and evaluate scientific knowledge in inquiry-oriented laboratory. The results were descriptive in terms of the nature of arguments. Data were collected through observations. These data were analyzed to find out the recurring argumentation schemes that give an idea about the argumentation in a scientific context. In the results chapter, descriptive findings were presented and in the discussion chapter, they were discussed in the light of the literature.

The rest of this chapter introduced the research design including the context of the study, laboratory tasks and data collection process, sampling, and data analysis.

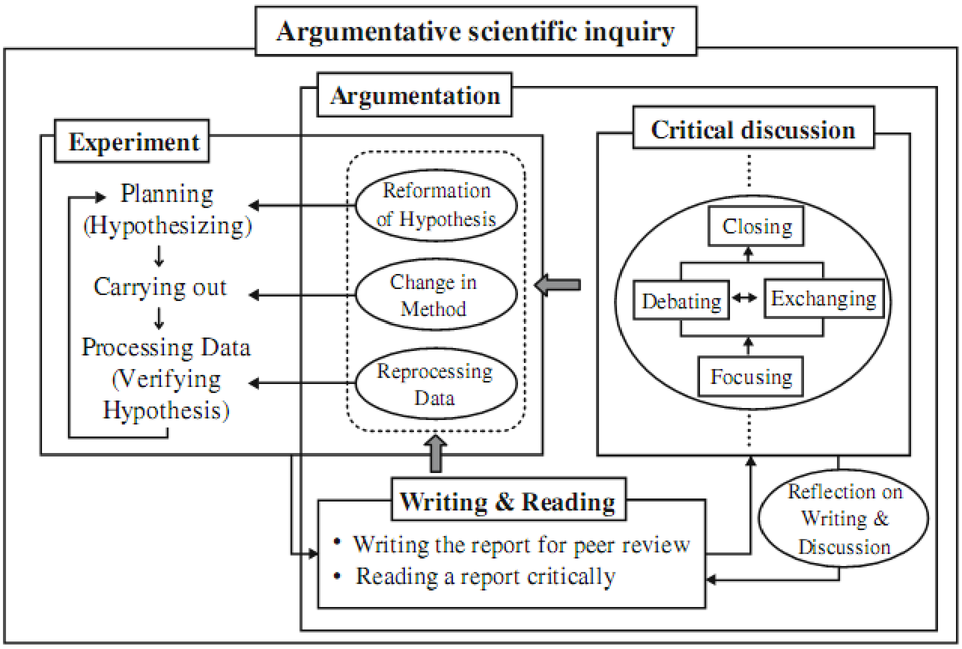
3.2. Research Design

3.2.1. The Design of the Study

The design of the study was influenced by both the study done by Kim and Song (2006), and the Imitating-Science project conducted by Kolstø and Mestad (2005).

Kim and Song (2006) conducted research groups to perform tasks related to scientific topics in order to examine the features of peer argumentation in middle school students' scientific inquiry. Groups of middle school students worked on a scientific question and they constructed scientific claims and evaluated these claims through peer argumentation. The resulting model of argumentative scientific inquiry (Figure 3.1.) was used to include an open debate on methods, interpretations, and conclusions in the design of this study.

In the Imitating-Science Project, Kolstø and Mestad (2005) let 9^{th} and 10^{th} grade science classes perform open-ended investigations in small research groups in order to stimulate students' learning of science as a process. In the project, research groups worked on the same research question related to a scientific issue to develop their own hypotheses. Research groups carried out their experiment and discussion of results made by students.



Source: Kim, H., & Song, J. (2006). The features of peer argumentation in middle school students' scientific inquiry. *Research in Science Education*, *36*(3), 211-233.

Figure 3.1. A model of argumentative scientific inquiry

Similarly in this study, the enquiry of scientific topics was employed by groups of pre-service science teachers (PSTs) through two stages. First, the groups worked on the same task according to the framework of experimentation offered by Kim and Song (2006). Through the experimentation stage, PSTs in groups planned and developed their own hypotheses, carried out an experiment, collected data, and processed their data to verify their hypotheses. Through the critical discussion stage, one of the PSTs groups presented their hypotheses, methods, and results orally to the other groups. Each presentation was followed by a class discussion of weak and strong aspects of the experimentation as offered by Kolstø and Mestad (2005).

3.2.2. The Context of the Study

The course serving as the subject of this investigation was Laboratory Applications in Science Education course. The course was given to the prospective elementary science teachers in their third year of undergraduate programme. It was a must course offered as part of the elementary science teacher education curriculum at a large public university. The focus of the course was concepts of science process skills, scientific inquiry, nature of science, and their applications to elementary science education laboratory. The purpose of this course was to study on the laboratory planning for science and nature of science instruction in the elementary school science. Upon the completion of this course, students were expected to develop necessary skills for application of science process skills, to understand the basic concepts related to nature of science, to understand laboratory instruction at various levels of cognitive and psychomotor domains, to develop designs for laboratory instruction, to understand the issues that make a well designed laboratory instrument.

The PSTs enrolled in the course were divided into two sections. In section 1, there were 17 PSTs and this section took the course on Mondays. In section 2, there were 18 PSTs and this section took the course on Wednesdays. In each section, PSTs worked in groups of four or five to complete each task. A research assistant was assigned to each group. The assistants were helpful in providing materials required for the experiment, collecting lab reports of the groups, and guiding group members through the steps of investigation. They were not allowed to give feedback about the validity or the reliability of the knowledge claims made by the group members but rather they directed PSTs to use the time efficiently, take part in discourse and perform the tasks in order.

The role of the researcher was being a facilitator. The researcher guided each group, when they required to go further but did not sure what to do next, by questions and/ or counter-arguments to promote argumentation among group members.

There were 10 laboratory applications in a semester. For the purpose of this study, six laboratory applications, which are inquiry-oriented, were selected. Each laboratory application included a task that was either an open-ended question, for example, “what is the relationship between the force applied to a spring and its elongation?”, or an enquiry, for example, “based-on your observations related to the black box, hypothesize and design a system that functions as the same way the black box does”. According to Gillies and Khan (2009), open-ended and discovery-based tasks are ill-structured since there is no certain answer to the problem. Through working on these tasks, students need to share ideas and information to resolve the problem, therefore, ill-structured group tasks encourages the student interactions and related achievement gains (Gillies & Khan, 2009). A week before each laboratory application, PSTs were informed about the nature of the task by a laboratory manual (Appendix A). The laboratory manual involved the aim of the laboratory task; descriptions of the required science process skills to complete the task; focus on the aspects of the nature of science (if available); the question or the enquiry of that week; and spaces to write hypotheses, data, results, and conclusions. Each laboratory application constituted two sessions: experimentation and critical discussion.

During experimentation, groups worked separately on the laboratory task of the week. Each week, one of the groups was selected as focus group during experimentation. Experimentation session involved hypothesizing, designing an experiment, conducting the experiment, collecting data, interpreting data, and drawing a conclusion. During experimentation, within-group discourse occurred. The researcher encouraged PSTs construct arguments by asking questions of “why/ what evidence did you have/ how did you arrive to this conclusion” or by proposing counter-arguments, for example, “the compounds, for example salt, are composed of two chemicals, like sodium and chlorine. This does not mean that salt is made up smaller particles, but it means that salt has two components”. PSTs were allowed to review their hypotheses, experiment design, or data interpretation as a result of discourse. At the end of the experimentation, all groups prepared their group reports. The focus group also prepared a 5 minute presentation to present their findings and claims to the rest of the class. Each experimentation session lasted about 80 minutes long.

During critical discussion, whole-class discourse occurred. At the beginning of the critical discussion, focus group presented their experimental results and claims in 5 minutes. After the presentation, other groups were allowed to ask questions, comment on the experimentation, or present their results. By this time, in most cases, a focus question arose against the claim(s) made by the focus group. In other cases, the researcher asked a focus question including either competing theories or misconception related to the science topic of the week. For example, in a task related to evolution theories, researcher forwarded two competing theories. One of the theories was related to the transmutation of species, and the other theory was about common descent. The researcher asked the groups which evidence they had to support their claims and which one was valid. In another task related to the floating-sinking-balancing concepts, the researcher focused on the misconception that is density is dependent on the volume or the mass of the matter when the temperature and the pressure are held constant. PSTs debated and exchanged their ideas for about 15 minutes. The discussion session sometimes ended with an agreement, sometimes diverging ideas emerged, and sometimes there was no closure because of the time limitation.

3.2.3. The Laboratory Tasks

In this study, participants were engaged in six inquiry-oriented laboratory tasks. With these tasks, participants' argumentation was explored because these tasks were suitable for investigation of scientific argumentation. The laboratory manual format was adapted from the book *Introductory Science Skills* by Gabel (1993). The book was designed to help the readers understand the scientific inquiry with emphases on science process skills, mathematical skills, and the use of theories and models (Gabel, 1993).

Six laboratory tasks were used in this study in order to answer the research questions. In the following, there are the descriptions of each task.

3.2.3.1. Task 1: Hooke's Law

The task dealt with the relationship between the force applied to a spring and its elongation. The researcher developed the task with her advisor. PSTs were asked to explore the relationship by means of experimenting. First, they hypothesized the relationship; second, they designed an experiment to test their hypotheses; and at last, they discussed their results with their peers.

3.2.3.2. Task 2: Black Box

This task was adapted from Lederman and Abd-El-Khalick's (2002) study by Özgelen, Hanuscin, and Yılmaz-Tüzün (2009). There are two main reasons to select a black box activity: First, the black box activities were developed to enrich classroom discourse and support scientific knowledge, which are highly important for scientific argumentation schemes to appear. Second, the black-box activities provide students with opportunity to conduct inquiries similar to the way scientists do and this open-ended nature makes black box activities genuinely different from usual laboratory experiences (Lederman, & Abd-El-

Khalick, 2002). In this black-box activity, first, PSTs made observation of a black-box; second, they hypothesized possible models to explain how the black-box works; third, they designed and tested their hypotheses; and finally, they compared their models, and discussed the implications.

3.2.3.3. Task 3: Candles

This task was adapted from the Pre-service Teacher Guide prepared by The Council of Higher Education in Turkey (2007). The aim of this task was to reinforce the concept of density by means of inquiry. Osborne, Erduran, and Simon (2004) argued that as a primary pedagogical strategy that will both initiate and support argumentation, teachers require to help their students consider alternative explanations of a phenomena. These multiple accounts could be a scientific theory and its alternative, such as a common misconception. Therefore, as a common misconception the concept of density and its relation to floating-sinking-balancing were selected. In the task, PSTs were asked to identify the reason for floating and sinking of candles in three different liquids. Then, they tried to find the density of one of the candles through experimenting. At the end, PSTs discussed the concept of density and its relationship with the mass and the volume of the matter.

3.2.3.4. Task 4: Particle Theory of Matter

The task dealt with the particle theory of matter and the law of conservation of mass. The researcher developed the task with her advisor. PSTs were asked to provide evidence first, for the theory that states "matter composed of particles", and second, for the law that states "the mass of a closed system will remain constant over time, regardless of the processes acting inside the system". The task was appropriate for the purpose of this study because it was mainly related with providing evidences, which is central to argumentation.

3.2.3.5. Task 5: Evolution Theories

This task was adapted by Özgelen, Hanuscin, and Yılmaz-Tüzün (2009) from the book *Teaching about Evolution and the Nature of Science* prepared by National Academy of Sciences (1998). The reason to select this task was that the task was aimed to develop abilities of scientific inquiry, which enable PSTs to

- formulate descriptions, explanations, predictions, and models using evidence,
- think critically and logically to make relationships between evidence and explanations, and
- recognize and analyze alternative explanations and predictions (NAS, 1998, p.81)

In the task, PSTs were asked to decide whether humans evolved from apes, or modern apes and humans have a common ancestor. The apes discussed in this task are the chimpanzee and the gorilla. PSTs were asked to hypothesize the morphological tree that shows the relationships between gorillas, chimpanzees, and humans. Similarly to the modern research techniques, which allow biologists to compare the DNA to make predictions about the relatedness of the organisms from which they took the DNA, PSTs used models of these techniques to test their hypotheses and determine which one is best supported by the data they develop. To develop data, they synthesized DNA strands by connecting paper clips in the proper sequence according to specifications given in their laboratory manuals. Next, they discussed how they used the data to determine the relationships between humans, apes, and other animals.

3.2.3.6. Task 6: The Structure of Light

The task dealt with the structure of light. The researcher developed the task with her advisor. The aim of this task was to provide PSTs with the opportunity to develop the ability of using evidences to construct scientific models and explanations. PSTs were provided one-evidence and two-experiments. The first experiment was related to the way the light follows. PSTs performed the first experiment and constructed a model of light, which shows that the light goes through a straight line. Then, photoelectric effect was given as evidence to the particle structure of light. PSTs used this piece of evidence to review the light models they constructed in the previous experiment. The last experiment was related to the interference of light waves. PSTs performed this experiment and they reviewed the light models they constructed to include the wave property of light. At the end, PSTs discussed how they used the data and the evidence to construct a light model, which shows both particle and wave properties, and travel through a straight line.

All tasks used in this study included inquiry-oriented laboratory experiments selected from a wide variety of scientific disciplines, including physics, chemistry, and biology. As a result, totally six tasks including experimentation and discussion sessions were used to investigate the research questions. These tasks were given in Appendix A.

3.2.4. Data Collection

3.2.4.1. Video-Records

All students participated in the laboratory were video-taped. Video-records included experimentation and the critical discussion sessions for the six tasks. During the experimentation sessions, one of the groups was selected to be the focus group for the clarity of the recording. During the critical discussion, all groups were recorded.

3.2.4.2. Audio-Records

All students participated in the laboratory and all sessions were audio-taped. During the experimentation sessions, one of the groups was selected to be the focus group for the clarity of the recording. During the critical discussion, all groups were recorded.

3.3. Participants

Several inquiry-oriented laboratory tasks were utilized in order to explore PSTs' argumentation in this study. The participants enrolled in Laboratory Applications in Science Education course, which is a must course involved in elementary science teacher education programme.

The participants in this study were pre-service elementary teachers. PSTs will teach middle school for 6^{th} through 8^{th} grade students after graduation. Totally, 35 pre-service elementary teachers from a large public university, in Ankara, Turkey participated in the study. Of the participants 10 were male, and 25 were female. While 33 participants' major was elementary science education, 2 participants' was elementary mathematics education. All PSTs were in their third year except one PST, who was in her senior year of the elementary science education program. Thus, they had completed several science courses like physics, chemistry, and biology. For example, they had a chapter related to static equilibrium and elasticity in their basic physics course; a chapter related to ray model of light, waves, interference in their optics and modern physics course; a chapter related to the structural and physical properties of matter in their general chemistry course; a chapter related to evolution and diversity in their general biology II course. Thus, it was assumed that PSTs had sufficient previous knowledge about the science topics included in this study. Assuming that their previous knowledge of these science topics was adequate level, their content knowledge was not investigated in this study.

The PSTs voluntarily participated in this study. Before the video recording, all participants were also asked whether they wanted to participate in this study or not. Moreover, background knowledge and the purpose of the study were given to the participants. As a result, all PSTs were willing to participate in this study.

3.4. Data Analysis

3.4.1. Analysis of the Research Questions

The researcher investigated PSTs' argumentation schemes when they performed inquiry-oriented laboratory tasks. The video-recordings were analyzed in order to explore the research questions. The participants' argumentation schemes were explored with the constant comparative method (Glaser & Strauss, 1967).

The data of this study were the transcribed video-recordings of the PSTs' discourse during the performance of the laboratory tasks. There were 9 (for tasks 1, 2, 3, and 5 on Monday and Wednesday, and for task 4 only on Wednesday) transcribed video-recordings of the focus groups during experimentation sessions, and there were 9 (for tasks 1, 2, 3, and 4 on Monday and Wednesday, and for task 5 only on Monday) transcribed video-recordings of the whole-class critical discussion.

The transcriptions of the first three tasks were analyzed by the researcher and a researcher in the field of science education who was experienced in analyzing qualitative data. The transcriptions of the remaining 3 tasks were analyzed by the researcher and reviewed by the mentioned science education researcher. In addition, another science education researcher reviewed these analyzed task transcriptions.

The researcher used pre-determined argumentation schemes by Walton (1996) for the analysis of PSTs discourse. There are two main rationales put forward by Duschl (2007) to use Walton's argumentation schemes for the analysis of discourse in science classrooms. The first one is that Walton framework meets the 5 criteria proposed by Sampson and Clark (2006) for examining the quality of scientific arguments. Sampson and Clark (2006) reviewed the most commonly used five frameworks benefited for the assessment of argument. They outlined five criteria as essential to develop a consensual view of quality of argumentation. These criteria are:

1. Examine the nature and quality of the knowledge claim
2. Examine how (or if) the claim is justified
3. Examine if a claim accounts for all available evidence
4. Examine how (or if) the argument attempts to discount alternatives
5. Examine how epistemological references are used to coordinate claims and evidence (Sampson, & Clark, 2006, pp. 659-660).

Duschl (2007) forwards that Walton's framework is a promising one because it is a more detailed framework which addresses the components of the other frameworks described by Sampson and Clark (2006). The second rationale is that Walton's framework is more appropriate for the analysis of dialectical argumentative exchanges, which occurs during collaborative small group science investigations (Duschl, 2007). Duschl (2007) states that Walton's presumptive reasoning reflects what occurs in science classrooms quite well because this kind of reasoning takes place in a dialogue when there is need to take an action and not all evidence is available in the context, but still there is responsibility of proving onto the other dialogue participants. Therefore, Walton's presumptive reasoning schemes fit adequately to the dialogical reasoning that takes place between group members when debating on taking a specific action or arguing for, or against when evaluating a particular claim (Duschl, 2007).

There are 25 argumentation schemes described and analyzed by Walton (1996). Appendix B presents the framework of the Walton's argumentation schemes used in the present study in order to assess argumentation of PSTs. A total of 19 of these argumentation schemes were basic, whereas 6 of them were composite made up from these basic schemes. During the analyses of the transcripts, all of these argumentation schemes were taken into consideration.

Before the analyses, the researchers read all transcribed video-recordings to explore and understand the content and to ensure the accuracy of researchers' understanding of the content. Then, the researcher and the science educator of this study analyzed transcripts, and determined the argumentation schemes in the discourses independently. For example, for a specific task, the researcher and the science educator reviewed all discourse among PSTs, and determined the argumentation schemes involved in dialogues without any contact. The unit analysis in the present study was the presumptive reasoning of an individual in a dialectical argumentative exchange. The presumptive reasoning occurs during a conversation that takes place between group members when a course of action must be taken or when evaluating a particular claim.

Then, the researcher and the science educator compared their schemes on these transcripts to reach a consensus on the argumentation schemes. Each transcript involved two experimentation sessions (Monday group and Wednesday group) and two critical discussion sessions (Monday group and Wednesday group) for a task. For the independently analyzed three transcripts, which corresponds to 50% of the total transcripts, the researchers agreed on all schemes except 2 schemes (argument from sign and argument from precedent) out of 25 schemes. That is, in these analyses, over 90% inter-rater reliability was ensured. For the rest of the transcripts, the researcher made analyses and her analyses were monitored by the science education researchers of this study.

For RQ1, the researcher investigated what kind of argumentation schemes PSTs use as they performed inquiry-oriented laboratory tasks. The researcher reported the kinds and the structures of argumentation schemes by presenting examples of argumentation schemes PSTs generated.

For RQ2, the researcher investigated how the argumentation schemes varied by tasks as well as by experimentation and critical discussion sessions. The researcher reported the variation of argumentation schemes by presenting frequency and percentages of participants' argumentation schemes regarding each task and each tasks' experimentation and critical discussion sessions.

3.5. Trustworthiness of the Study

The trustworthiness of qualitative studies was reflected by the extent the researcher persuades the readers of the study about the validity and the reliability of the findings (Yıldırım, & Şimşek, 2008). To provide trustworthiness of this qualitative study internal validity issues were considered by the researcher during the study.

3.5.1. Internal Validity

In the following, there are the strategies to confirm internal validity followed by the researcher for the present study. Merriam (1998) suggests six basic strategies to enhance internal validity. Three of them were considered to ensure the internal validity of this study: (1) long-term observation; (2) peer examination; and (3) researcher's biases.

3.5.1.1. Long-term Observation

Long-term observation refers to gathering data by repeated observations of a phenomenon over a period of time in order to increase the validity of the findings (Merriam, 1998). In this study, data were collected through the observation of PSTs during the inquiry-oriented laboratory works for six weeks. Therefore, this study ensured the long-term observations for internal validity.

3.5.1.2. Peer Examination

Peer examination is asking to researchers to comment on the findings of the study (Merriam, 1998). In this study, the transcripts for three tasks, which correspond to 50% of the total data, were independently analyzed by the researcher and other two science education researchers, who are informed about the analyzing framework. The rest of the transcripts, which corresponds to the remaining 50% of the total data, were analyzed by the researcher and peer-reviewed by the science education researchers. Therefore, this study ensured the peer-review for internal validity.

3.5.1.3. Researcher's Biases

To ensure the internal validity, the researcher should "clarify the assumptions, worldview, and theoretical orientation at the outset of the study" (Merriam, 1998). In this study, the researcher was the facilitator of the laboratory sessions. At the beginning of each laboratory task, the researcher reminded the purpose of this week's investigation briefly. During the laboratory work, the researcher's role was to monitor the progress of PSTs and to support their discourse. In supporting the discourse among group members and in whole class, the researcher did not direct or did not encourage PSTs to use certain kinds of argumentation schemes. The researcher only promoted discourse by means of asking questions and/ or proposing counter-arguments, when PSTs required to go further but did not sure what to do next. It is assumed that researcher did not made any effect on how PSTs generated arguments, and what premises they relied on to construct their claims.

3.6. Assumptions of the Study

For this study, the following assumptions were made:

1. There is no intervention of the researcher to promote certain kinds of argumentation schemes. The researcher's role in the laboratory clearly stated to ensure the internal validity of the study.

2. The participants' actions were not affected by the presence of the video-camera and audio-recorder in the laboratory environment. To ensure that the participants got used to the presence of the video-camera and the audio-recorder, the researcher made video- and audio-recording for two weeks prior to the study.

3. The participants had some prior knowledge about the scientific issues given in the laboratory tasks. They took the related science courses so they had a background in science and was able to argue scientifically on the issues.

3.7. Limitations of the Study

Limitations of this study are similar to those generally prevalent in qualitative research methods:

1. The number of participants was limited to 35 pre-service science teachers. Consequently, the small number of participants reduces the external validity of this study. Therefore, results of this study may only be generalized to individuals whose credentials and academic experiences are similar to those studied.

2. The data collected for the argumentation practices of PSTs during experimentation sessions were focused on a group of 4 or 5 pre-service teachers. Therefore, the results related to the argumentation of PSTs during experimentation stages apply only for the focus groups.

3. The researcher did not have a chance to ask the subjects to confirm the data of this study so another limitation of this study remains that the interpretation and representation of subjects' statements in the study were limited to the understanding of the researcher. To reduce the possibility of researcher's biases, the transcripts of the video-recordings were analyzed by two other science education researchers, who are experienced in the field. Consequently, the researcher recognizes that her interpretations of the findings and the understandings are limited by her understanding of the subjects' statements.

4. In this study, the data were collected through video- and audio-recordings of the participants' work during laboratory sessions. The data analysis was done through these video- and audio-recordings so another limitation of this study is that the data were only limited to those that could be clearly recorded. Therefore, the researcher may have missed some parts of the participants' discourse during video-and audio-recordings. To decrease the possibility of the missing parts in discourse, the researcher run two video-camera and two audio-recorders at the same time.

5. The laboratory sessions in this study were designed as inquiry-oriented by the researcher. Therefore, the results of this study may not apply to the laboratory settings that are designed differently even if all other conditions were exactly the same.

CHAPTER 4

RESULTS

In this chapter, results of the study are presented in two sections comprising of; quantitative results, and qualitative results. In the first part, in-depth qualitative descriptions of the argumentation schemes were carried out in order to illustrate what kind of argumentation schemes pre-service science teachers use as they perform inquiry-oriented laboratory tasks. In the second part, the number of arguments was compared by experimentation and critical discussion sessions and by tasks in order to illustrate how argumentation schemes vary as PSTs are engaged in experimentation and critical discussion sessions. As a quantitative indication of arguments generated, frequency counts were recorded.

4.1. The Nature of Argumentation Schemes Generated by Pre-service Science Teachers during Inquiry-oriented Laboratory Task Performance

This section focuses on the first research question, kinds of argumentation schemes PSTs use as they perform inquiry-oriented laboratory tasks. In this section, results as descriptions of the argumentation schemes generated by pre-service science teachers were presented in order to illustrate the kinds of argumentation and their structures. This section will give an idea about the nature of the arguments generated by PSTs during inquiry-oriented laboratory applications.

4.1.1. The Nature of Argumentation during Experimentation

During the experimentation sessions, PSTs in groups, working independently planned and developed their own hypotheses, defined variables, designed and carried out an experiment to test their hypotheses and collected and recorded data in a proper form (as a table or a graph), and processed their data to verify their hypotheses.

In this part, the nature of PSTs' argumentation during experimentation session was described.

PSTs generated 20 kinds of argumentation during experimentation sessions. The resulting argumentation schemes were presented in Appendix C by tasks starting from the most frequent argumentation scheme for each task. In the following, the most frequent argumentation schemes were described in detail for experimentation sessions.

Argument from sign: Argument from sign was described in a form of "observation x is taken as an evidence of event E". During experimentation sessions, argument from sign was generated for different purposes.

For example, in task 1, which was about the force applied to a spring and its elongation, PSTs constructed argument from sign for purposes of discussing if there was an exact linear relationship according to the graph or while they were trying to describe the relationship:

PST A: So we will say that there was a linear relationship
PST B: I did a measurement: 100 g did not cause any change.

In this example, the measurement was taken as an evidence of the event that was the lack of extension in the spring with small amount of masses. Here, the measurement is a kind of observation, which was used to refute the claim made by the opponent.

In task 2, which was about a black box, PSTs constructed argument from sign for purposes of testing the model they hypothesized or while they were discussing possible system models:

PST A: The system should be something circuitous
PST B: Because water came out a little time later not instantly

The observation was identified here as a sentence, which is *water came out a little time later, not instantly*. This observation was used as an evidence for supporting to the hypothesis, which was *the system should be something circuitous*.

In task 3, which was about the density concept, PSTs constructed argument from sign for purposes of determining the densities of the liquids:

PST A: Now we should define an interval for this one.
PST B: Once we know that is greater than this one, greater than 0.74
PST C: But it is smaller than the other one because it floats on it, isn't it?
PST A: It floated on both but was closer to one of them, was closer to C
PST B: Thus, should we say that it is between 0.74 and 0.917?

In this example, arguments were constructed based on the observations related to the floating of the objects on liquids. These observations resulted with a conclusive density interval for the object.

In task 4, which was about the particle theory of matter, PSTs constructed argument from sign for purposes of trying to find evidence to the particle theory of matter:

PST A: The balloon expanded, it shows that water evaporated

PST B: That means, the balloon expanded and if it expanded, some of the water came from the beaker.

The observation related to the expansion of the balloon was used as evidence of the claim *some water evaporated from the beaker*, which was an indication of the particle theory of matter.

In task 5, which was about the evolution theories, PSTs constructed argument from sign for purpose of testing their hypothesized morphological tree:

PST A: There are 17 matches between the gorilla and the common ancestor

PST B: 12 between chimpanzee and common ancestor

PST C: Thus gorilla and common ancestor are close to each other.

In this task, PSTs usually made the number of matches in the DNA sequences to construct their claims. As in this example, the number of matches between gorilla and the common ancestor, and the number of matches between chimpanzee and common ancestor were gathered through counting classified as observation. This observation was used to support the inference that was *the relationship between common ancestor and gorilla is stronger than the relationship between common ancestor and chimpanzee*.

In task 6, which was about the structure of light, PSTs constructed argument from sign for purposes of observing the way light follows:

PST A: It is reflected on a certain area

PST B: But is there only one light coming from the source? What type of source do we have, point source?

PST C: No, it only hits this part and it cannot pass through because we don't see through the other slit.

The claim in this example was that *light cannot pass through certain matters even if it follows a straight line*. PST C observed that there was no illumination of light across the other slit, and he showed this observation as evidence to his claim.

To sum-up, the nature of observation should be identified first in argument from sign. The observation might be gathered through looking for a pattern, or measurement, or counting. The important thing is that whether this observation is in support of an event. Therefore, there should also be an occurrence, which is inferred through the observation. This inference is classified as argument from sign.

Argument from correlation to cause: Argument from correlation to cause was described in a form of causal connection between two events, usually describing a positive correlation between them (Walton, 1996). In the following, there are examples of argument from correlation to cause, which were generated in the experimentation sessions.

In task 1, which was about the force applied to a spring and its elongation, PSTs constructed argument from correlation to cause for purposes of deciding on the control variable or while deciding on the manipulated variable:

PST A: Will we do that without considering the deformation of the spring?
PST B: I did not understand
PST A: The deformation of the spring, I mean, when we hang on masses, there will be an extension and it will stay like that.

In this example, there is a positive correlation between the events of deformation of the spring and the applied force by the masses. Here, this correlation took the form of the force applied to the spring causes the spring be deformed.

In task 2, which was about a black box, PSTs constructed argument from correlation to cause for purposes of discussing why much water came out from the box:

PST A: We can say there was water in it before the show. There was some water at first but there had to be a thing to push it out, so when we put water, it came through a path and pushed it.

In argument from correlation to cause, there should be two propositions that describe observable events. Here, in this example, PST A established a correlation between the event of adding some water into the box and the event of collecting water out of the box.

In task 3, which was about the density concept, PSTs constructed argument from correlation to cause for purposes of trying to identify the density of the candle or while trying to refute that floating or sinking depends on the mass of the object:

PST B: I mean, what if one of them has a greater mass
PST C: But in this case the height of it will change.

In this example, arguments were constructed based on the correlation that if a greater mass was used for the experiment, it would cause the height of the object to be greater.

In task 4, which was about the particle theory of matter, PSTs constructed argument from correlation to cause for purposes of trying to find evidence to the particle theory of matter:

PST A: The structure of matter does not change. Because the distance between particles increases, the density of matter decreases.

The observation about two events was correlated in this argument. They were (1) the increase in the distance between the particles, and (2) the decrease in the density of the matter. Although the correlation is not a positive one, the structure of the argument still infers a causal connection between two events.

In task 5, which was about the evolution theories, PSTs constructed argument from correlation to cause for purposes of trying to draw a conclusion:

PST A: Thus, we can say, for example, that the difference between chimpanzee and common ancestor might be because of the adaptation
PST B: As the time passing, to adapt to the environment, chimpanzee evolved and changed in some properties. After a while, human is evolved to adapt.

In this example, PST B described a correlation between the adaptation and the time passing. The correlation was not explicitly stated but PST B described this correlation in the form of "as the time passing". Therefore, it was also an example to argument from correlation to cause.

In task 6, which was about the structure of light, PSTs constructed argument from correlation to cause for purposes of observing the way light follows or while discussing why shadows are formed:

PST E: There were two different shadow tones.
PST F: They could be because they reset their wavelengths.

The claim in this example was that the reset in the wavelengths caused two different shadow tones.

To sum-up, in argument from correlation to cause, the first thing to look is the existence of two events and their causal connection. The causal connection might be in the form of a positive correlation or a negative one.

4.1.2. The Nature of Argumentation during Critical Discussion

During the critical discussion sessions, PSTs as a whole class, debated and exchanged their ideas. At the beginning of the critical discussion, focus group presented their experimental results and claims. After the presentation, other groups asked some questions, commented on the experiments, or presented their results. The resulting argumentation schemes were presented in Appendix D by tasks starting from the most frequent argumentation scheme for each task.

PSTs generated 18 kinds of argumentation during critical discussion sessions. In the following, the most frequent argumentation schemes were described in detail for critical discussion sessions.

Argument from correlation to cause: Argument from correlation to cause was described in a form of causal connection between two events, usually describing a positive correlation between them (Walton, 1996). In the following, there are examples of argument from correlation to cause, which were generated in the critical discussion sessions.

In task 1, which was about the force applied to a spring and its elongation, PSTs constructed argument from correlation to cause for purposes of discussing their conclusions:

PST A: Teacher we think we could write an equation.

PST B: Yes, we did. We think that there is a proportion between the applied forces and spring's elongation.

PST C: Yes it's directly proportional, and close to the constant. We think there is a constant because we used the same kind of spring.

In this example, there is a positive correlation, which is a direct proportion, between the events of elongation of the spring and the applied force by the masses. Here, this correlation took the form of the force applied to the spring causes the spring to extend.

In task 2, which was about a black box, PSTs constructed argument from correlation to cause for purposes of discussing the models constructed:

PST A: First, we made a hole at the bottom of a plastic bottle. Second, we put it with an angle and we poured water through this hole. Then the bottle fell off and we got much water than we added.

PST B: How did it fall off?

PST A: We put the bottle with an angle and we supported it with a hinge.

In argument from correlation to cause, there should be two propositions that describe observable events. Here, in this example, PST A established a correlation between the event of adding some water into the box and the event of falling of the bottle.

In task 3, which was about the density concept, PSTs constructed argument from correlation to cause for purposes of discussing whether floating depends on mass or while discussing whether the change of density is chemical or physical change:

PST A: But isn't it homogeneous?

PST B: Since we used the same candle as you said if we decrease the mass, density needs to be changed. Eventually it needs to float, doesn't it?

In this example, arguments were constructed based on the correlation that if the mass decreases, densities changes, and object starts to float. Although the correlation is not a positive one in this example, there is a causal connection between events.

In task 4, which was about the particle theory of matter, PSTs constructed argument from correlation to cause for purposes of discussing if the state of salt changes when it is in water or while discussing if dissolution is a chemical change:

PST A: No dear. We didn't change the structure of the compound.
PST B: When dissolving salt in water it decomposes into sodium and chlorine ions. To observe that we applied electricity and if the bulb lights on, the current flows.

The observation about two events was correlated in this argument. They were (1) the dissolving of salt in water into its components, and (2) the flow of electric current through the system. According to PST B, these two events were correlated.

In task 5, which was about the evolution theories, PSTs constructed argument from correlation to cause for purposes of discussing their hypotheses:

PST A: The lizards evolved from the organisms living in the past. Now, those organisms are not alive because they evolved. However, there can't be such a thing between gorilla and chimpanzee because gorilla and chimpanzee are still alive.

In this example, PST A described a correlation between the evolution and the extinction. The correlation was not explicitly stated but PST A described this correlation in the form of evolution causes some earlier creatures to extinct. Therefore, it was also an example to argument from correlation to cause.

In task 6, which was about the structure of light, PSTs constructed argument from correlation to cause for purposes of discussing why light has particles with energy:

PST A: The reason is the electron is ejected. We need energy to eject an electron and we said that this energy comes from particles with energy.

The claim in this example was that the *energy in the particles caused the electron to be ejected from the surface*.

To sum-up, argument from correlation to cause was generated in critical discussion sessions frequently. PSTs applied the causal connections between events to convince their peers to the validity of their claims.

Argument from sign: Argument from sign was described in a form of "observation x is taken as an evidence of event E". During critical discussion sessions, argument from sign was generated for different purposes.

For example, in task 1, which was about the force applied to a spring and its elongation, PSTs constructed argument from sign for purposes of discussing if there was an extension with small masses:

PST A: How do you know if you didn't see an extension?
PST B: We don't assume that there is a mm change in the spring. Because we took measurements individually in each case and take the average. But in this case none of us saw a change. So we said that it is related to the resistance of the spring.

In this example, the measurement was taken as an evidence of the event that was the lack of extension in the spring with small amount of masses. This structure was used to support the assumption related to the resistance of the spring.

In task 2, which was about a black box, PSTs constructed argument from sign for purposes of discussing why they think there was water before the show:

PST A: I want to say something else. We observed that there was no water flowing through when we add 300 ml water. When we exceed 300 ml, it started to flow. So we claimed that there is a threshold level of water.

The observation was identified here as a measurement, which is 300 ml of water. This observation was used as evidence in support to the hypothesis, which was *there is a threshold level of water*.

In task 3, which was about the density concept, PSTs constructed argument from sign for purposes of discussing if the mass can be constant as the volume is changing:

PST A: We chose the liquid A. When we put 1.27 g of candle into it, the candle floated. When we put 0.01 g of candle, it sank. It shows us that the floating is not related to the mass.

In this example, arguments were constructed based on the observations related to the floating of the objects on liquids. These observations resulted with a conclusion that *floating is not related to the mass*.

In task 4, which was about the particle theory of matter, PSTs constructed argument from sign for purposes of presenting their experimental results:

PST A: For example we thought the change of state. We took ice, we melted it. First we measured its volume before melting and we measured once more after it turned into water. According to our results, we compared the volumes that are the distance between particles; we said that the volume of the ice is larger.

The observation related to the volumes of ice blocks before and after melting was used as evidence of the claim, which is about *distance between the particles that form the ice blocks*, which was an indication of the particle theory of matter.

In task 5, which was about the evolution theories, PSTs constructed argument from sign for purposes of discussing the ladder theory or common ancestor theory:

PST A: We thought that the similarity shows which comes the next. For example, gorilla cannot come from human because there are 10 matches but there are 15 matches between chimpanzee and human. Therefore, we said that human evolved from chimpanzee.

In this task, PSTs usually applied to the number of matches in the DNA sequences to support their claims. As in this example, the number of matches between gorilla and human, and the number of matches between chimpanzee and human were gathered through counting classified as observation. This observation was used to support the inference that was the *evolution order is from chimpanzee to human and not from gorilla to human*.

In task 6, which was about the structure of light, PSTs constructed argument from sign for purposes of discussing the way light follows:

PST A: Yes, it follows a straight line. The light going through the hole causes a bright spot on the screen. The rest of the screen stays dark because light cannot go through if there is no hole.

The claim in this example was that light follows a straight line. PST A observed that there was no bright spot on the screen, and he showed this observation as evidence to his claim.

Argument from evidence to hypothesis: Argument from evidence to hypothesis was described in a form of "If a is true then b will be true".

For example, in task 1, which was about the force applied to a spring and its elongation, PSTs constructed argument from evidence to hypothesis for purposes of discussing whether there is a threshold of the spring to start to extend:

PST A: …we thought that the extension of the spring can be or cannot be observed in all situations. We did not think that there is a threshold.
PST B: We say that there is a resistance of the spring. Unless this resistance is surpassed, there won't be any extension.

In this example, the hypothesis was that *there will not be any extension.* The evidence can be seen in the sentence in a form of *unless this resistance is* surpassed.

In task 2, which was about a black box, PSTs constructed argument from evidence to hypothesis for purposes of discussing where the water pressure is effective:

PST A: It even flows through with a weak force.
PST B: To make this happen for example if we fill something with water in a system and we have a pipe.
PST C: Then if we fill the pipe with water, put that pipe on the base and stand the pipe to the same level I mean this level (shows where the water in the bottle is), all water will flow.

The hypothesis was that *all water will flow*. The evidence to this hypothesis was stated like *if we fill the pipe with water*.

In task 3, which was about the density concept, PSTs constructed argument from evidence to hypothesis for purposes of discussing if the mass can be constant as the volume is changing:

PST A: We make it heavier in weight by squeezing.
PST B: So you change the density.
PST C: But when the density changes as well the candle do.

In this example, arguments were constructed based on the evidence that if the density changes. This evidence resulted with a hypothesis that the candle will change.

In task 4, which was about the particle theory of matter, PSTs constructed argument from evidence to hypothesis for purposes of discussing how salt dissolves in water:

PST A: I don't think there are breaking up, but how anodes and cathodes go to different places in water.
PST B: Anodes and cathodes don't go anywhere.
PST C: If they were breaking up, when we evaporate the water, there won't be salt remaining.

The assumption related to the molecules and the possibility of them breaking up was used as evidence of the hypothesis that there won't be salt after the evaporation of water.

In task 5, which was about the evolution theories, PSTs constructed argument from evidence to hypothesis for purposes of discussing the ladder theory:

PST A: However, it is not valid for gorillas and chimpanzees because they are still alive.
PST B: If human evolved from gorilla, there won't be any gorilla now.

In this task, PST B used the evidence of human evolving from gorilla to hypothesize that there won't be any gorilla. This kind of argument from evidence to hypothesis is called as the falsification of a hypothesis (Walton, 1996).

Argument from evidence to hypothesis could not be located in Task 6.

In summary, according to Walton (1996), argument from evidence to hypothesis is a typical kind of argument in scientific reasoning. As in this study, it might be in the form of a verification of a hypothesis or a falsification of a hypothesis. In this study, both types of argument from evidence to hypothesis were located frequently in critical discussions.

4.2. The Variation of Argumentation Schemes Generated by Pre-service Science Teachers during Inquiry-oriented Laboratory Task Performance

This section focuses on the second research question, the variation of PSTs' argumentation by tasks and by experimentation and critical discussion sessions. In this section, results as the frequency of the argumentation schemes and their percentage were presented in overall as well as by tasks and by experimentation and critical discussion sessions in order to illustrate how argumentation schemes vary by tasks as PSTs are engaged in experimentation and critical discussion.

There were 25 argumentation schemes proposed by Walton (1996). Analyses of the laboratory discourses were carried by considering all argumentation schemes. As a result, a broad array of argumentation schemes was found to be employed by PSTs. Overall, 20 argumentation schemes were located in PSTs' discourses (Figure 4.1.). Five argumentation schemes, namely argument from position to know, ethotic argument, the causal slippery slope argument, the precedent slippery slope argument and the verbal slippery slope argument could not be located in discourses.

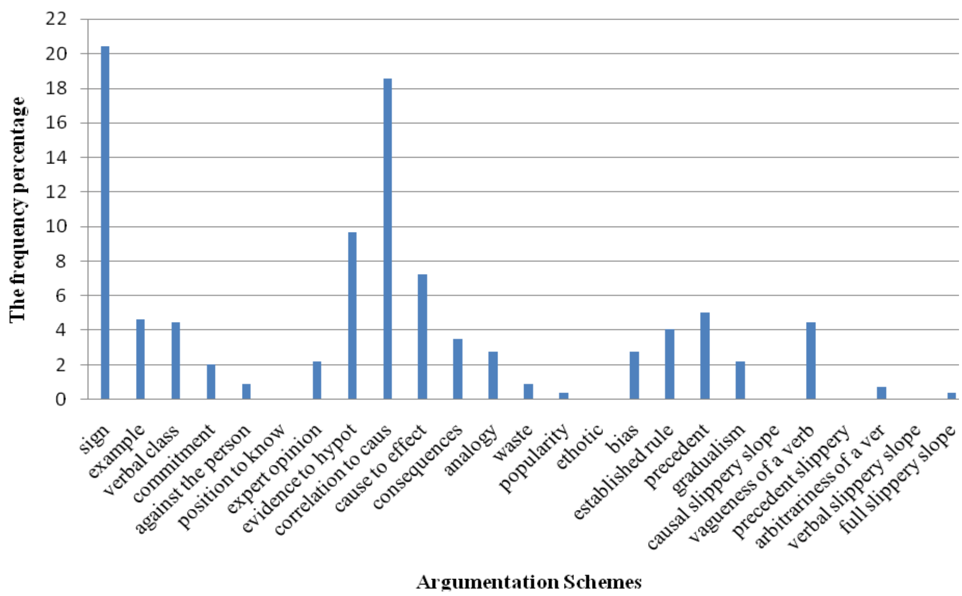


Figure 4.1. The percentage distribution of argumentation schemes.

The most frequently generated argumentation scheme was argument from sign with the percentage of 20.95. Argument from correlation to cause was the second in the rank with the percentage of 19.05. The resulted pattern indicate that PSTs engaged in dialogic argumentation where they reflected diverse presumptive reasoning patterns but the percentages of other argumentation schemes (Table 4.1.) were not particularly remarkable.

Table 4.1. The percentage of the argumentation schemes generated by PSTs as they perform inquiry-oriented laboratory tasks.

Argumentation Schemes	The percentage
Argument from sign	20.95
Argument from correlation to cause	19.05
Argument from evidence to a hypothesis	9.90
Argument from cause to effect	7.43
Argument from precedent	5.14
Argument from example	4.76
Argument from verbal classification	4.57
Argument from vagueness of a verbal classification	4.57
Argument from an established rule	4.19
Argument from consequences	3.62
Argument from analogy	2.86
Argument from bias	2.86
Argument from expert opinion	2.29
Argument from gradualism	2.29
Argument from commitment	2.10
Circumstantial argument against the person	0.95
Argument from waste	0.95
Argument from arbitrariness of a verbal classification	0.76
Argument from popularity	0.38
The full slippery slope argument	0.38
Argument from position to know	0.00
The causal slippery slope argument	0.00
Ethotic argument	0.00
The precedent slippery slope argument	0.00
The verbal slippery slope argument	0.00

Pre-service science teachers worked in small groups and conducted experiments throughout 6 inquiry-oriented laboratory tasks. The frequency of the argumentation schemes compared by tasks (Table 4.2.) indicates the variation in the kinds of argument in relation to the types of tasks.

Table 4.2. The percentage of the argumentation schemes by laboratory tasks.

Argumentation Scheme	**Task 1**	**Task 2**	**Task 3**	**Task 4**	**Task 5**	**Task 6**
Argument from sign	10	18	33	13	10	26
Argument from example	7	3	4	4	2	5
Argument from verbal classification	7	0	8	5	0	4
Argument from commitment	4	0	1	0	6	0
Circumstantargument against the person	3	0	1	0	1	0
Argument from position to know	0	0	0	0	0	0
Argument from expert opinion	3	0	2	4	3	0
Argument fro evidence to a hypothesis	11	16	10	7	5	3
Argument from correlation to cause	11	27	16	24	2	20
Argument from cause to effect	8	4	11	9	3	4
Argument from consequences	2	4	5	6	1	1
Argument from analogy	0	6	3	2	2	2
Argument from waste	0	2	3	0	0	0
Argument from popularity	1	0	0	1	0	0
Ethotic argument	0	0	0	0	0	0
Argument from bias	3	3	6	2	0	1
Argument from an established rule	3	4	9	4	0	2
Argument from precedent	9	6	2	5	0	5
Argument from gradualism	3	5	0	0	1	3
The causal slippery slope argument	0	0	0	0	0	0
Arg vagueness of a verbal classification	4	7	6	2	3	2
The precedent slippery slope argument	0	0	0	0	0	0
Arbitrariness of a verbal classification	1	2	0	1	0	0
The verbal slippery slope argument	0	0	0	0	0	0
The full slippery slope argument	0	2	0	0	0	0
Total	**90**	**109**	**120**	**89**	**39**	**78**

* Task 1. Hooke's Law, Task 2. Black Box, Task 3. Candle, Task 4. Particle Theory of Matter, Task 5. Evolution Theories, Task 6. The Structure of Light.

As can be seen from the frequencies of argumentation schemes, PSTs engaged in argumentation more frequently in Task 3: Candles, which was related to the concept of density. In three of the tasks, Task 1, Task 2, and Task 4, the most frequent argumentation scheme was argument from correlation to cause, by contrast, in Task 3, Task 5, and Task 6, the most frequent scheme was argument from sign. The schemes in terms of highest percentage ranks indicate similarities, but also there are differences in the order of percentages of the schemes between tasks. For example, argument from sign and argument from correlation to cause are the most frequently used kinds of arguments in all tasks, and composite argumentation schemes, such as argument from vagueness of a verbal classification and argument from arbitrariness of a verbal classification, are the low frequency schemes. However, the frequency order of other argumentation schemes differs between tasks.

Results illustrate that the number of kinds of arguments generated by PSTs are quite similar (Figure 4.2.). That is, there are 12 to 17 kinds of argumentation schemes located in each task.

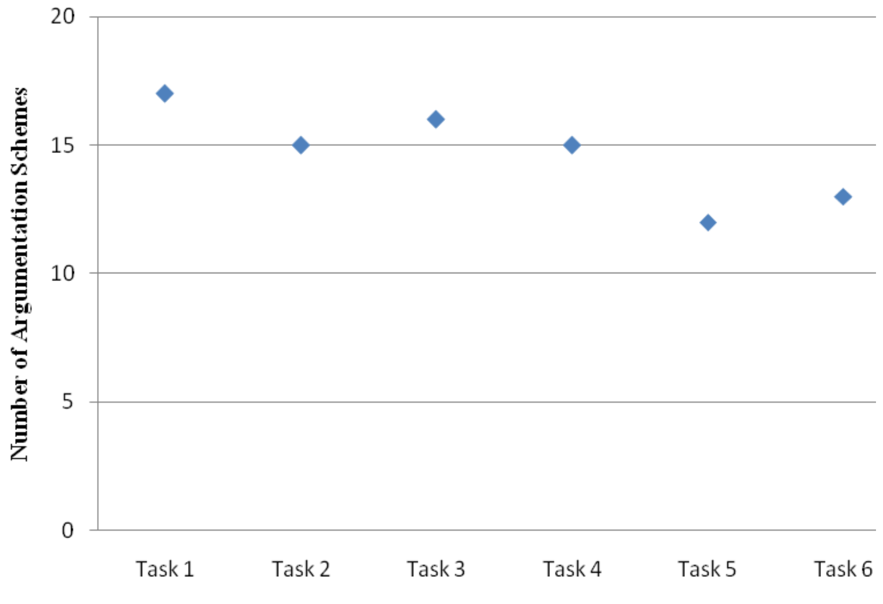


Figure 4.2. The number of the kinds of argumentation schemes generated in each task.

Each laboratory work consisted two sessions: experimentation and critical discussion. The frequency of the argumentation schemes and their percentage by experimentation (E) and critical discussion (CD) sessions were calculated (Table 4.3.).

As can be seen from the percentages in Table 4.3., in the experimentation sessions, PSTs generated mostly arguments from sign (24.84 %). Argument from correlation to cause is the second argumentation scheme (19.88 %) that was used frequently in experimentation sessions. In the critical discussion sessions, the most frequently generated kinds of arguments were argument from correlation to cause (17.73 %), argument from sign (14.78 %), and argument from evidence to a hypothesis (13.30 %).

Table 4.3. The frequency and percentage of the argumentation schemes by experimentation and critical discussion sessions

	Frequency		**Percentage**	
Argumentation Schemes	**E**	**CD**	**E**	**CD**
Argument from sign	80	30	24.84	14.78
Argument from example	18	7	5.59	3.45
Argument from verbal classification	17	7	5.28	3.45
Argument from commitment	4	7	1.24	3.45
Circumstantial argument against the person	2	3	0.62	1.48
Argument from expert opinion	3	9	0.93	4.43
Argument from evidence to a hypothesis	25	27	7.76	13.30
Argument from correlation to cause	64	36	19.88	17.73
Argument from cause to effect	23	16	7.14	7.88
Argument from consequences	8	11	2.48	5.42
Argument from analogy	7	8	2.17	3.94

Table 4.3. (continued)

Argument from waste	5	0	1.55	0.00
Argument from popularity	1	1	0.31	0.49
Argument from bias	5	10	1.55	4.93
Argument from an established rule	17	5	5.28	2.46
Argument from precedent	15	12	4.66	5.91
Argument from gradualism	9	3	2.80	1.48
Argument from vagueness of a verbal class.	16	8	4.97	3.94
Argument from arbitrariness of a verbal cla.	1	3	0.31	1.48
The full slippery slope argument	2	0	0.62	0.00
Total	**322**	**203**	**100.00**	**100.00**

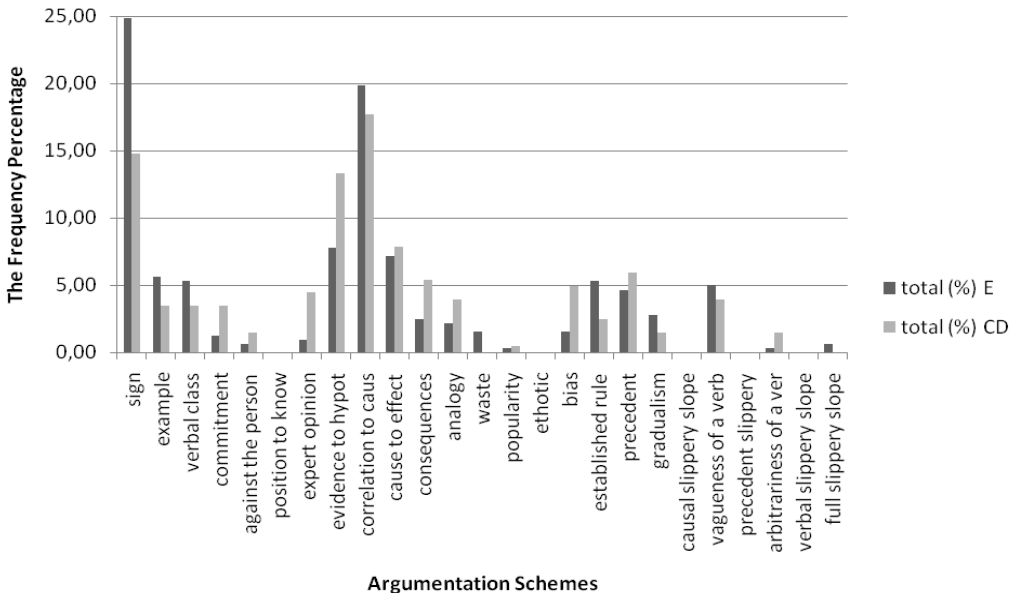


Figure 4.3. The percentage distribution of argumentation schemes by experimentation (E) and critical discussion (CD) sessions.

Figure 4.3. illustrates the distribution of argumentation schemes by experimentation and critical discussion sessions. As can be seen in Figure 4.3., there were kinds of arguments found in experimentation sessions but not in critical discussion sessions, such as, argument from waste and the full slippery slope argument.

Table 4.4. illustrates the argumentation schemes during experimentation and critical discussion sessions by tasks.

Table 4.4. The frequency and percentage of the argumentation schemes during experimentation and critical discussion sessions by tasks

Argumentation Schemes (Argument from…)	**Frequency**											
	Task 1		**Task 2**		**Task 3**		**Task 4**		**Task 5**		**Task 6**	
	E	**CD**	**E**	**CD**	**E**	**CD**	**E**	**CD**	**E**	**CD**	**E**	**CD**
sign	4	6	15	3	31	2	4	9	4	6	22	4
example	4	3	3	0	4	0	2	2	1	1	4	1
verbal classification	6	1	0	0	7	1	0	5	0	0	4	0
commitment	1	3	0	0	0	1	0	0	3	3	0	0
Circumstantial argument	1	2	0	0	1	0	0	0	0	1	0	0
expert opinion	2	1	0	0	1	1	0	4	0	3	0	0
evidence to a hypothesis	1	10	12	4	6	4	3	4	0	5	3	0
correlation to cause	8	3	20	7	6	10	11	13	1	1	18	2
cause to effect	6	2	2	2	6	5	5	4	1	2	3	1
consequences	0	2	2	2	3	2	2	4	0	1	1	0
analogy	0	0	4	2	0	3	1	1	0	2	2	0
waste	0	0	2	0	3	0	0	0	0	0	0	0
popularity	1	0	0	0	0	0	0	1	0	0	0	0
bias	1	2	0	3	3	3	0	2	0	0	1	0
an established rule	2	1	3	1	8	1	2	2	0	0	2	0
precedent	6	3	2	4	0	2	2	3	0	0	5	0
gradualism	1	2	5	0	0	0	0	0	0	1	3	0
vagueness -verbal class.	3	1	5	2	5	1	0	2	1	2	2	0
arbitrariness -verbal cla.	0	1	1	1	0	0	0	1	0	0	0	0
The full slippery slope	0	0	2	0	0	0	0	0	0	0	0	0
Total	47	43	78	31	84	36	32	57	11	28	70	8

As seen in the Table 4.4., there were similarities between tasks in terms of high frequency argumentation schemes both in experimentation and critical discussion sessions. On the other hand, the order of frequency for the remaining argumentation schemes was different between tasks for both experimentation and critical discussion sessions. For example, argument from verbal classification was located in the experimentation sessions for task 1, task 3, and task 6 whereas it could not be found in the experimentation sessions for task 2, task 4, and task 5. Similarly, argument from precedent was located in the experimentation sessions for task 1, task 2, task 4, and task 6, by contrast it could not be found in the experimentation sessions for task 3 and task 5. A likewise pattern was also emerged in critical discussion sessions. For example, argument from commitment was generated in the critical discussion sessions for task 1, task 3, and task 5, whereas it could not be located in the critical discussion sessions for task 2, task 4, and task 6. In the same way, argument from expert opinion was located in the critical discussion sessions for task 1, task 3, task 4, and task 5, but it could not be found in the critical discussion sessions for task 2 and task 6.

Results illustrate that the discourse of PSTs during inquiry-oriented laboratory covered a wide range of argumentation schemes. Totally 20 kinds of argumentation schemes were generated out of 25. This finding makes clear that PSTs applied varied premises rather than only observations or reliable sources, to ground their claims or to argue for a case or an action. Moreover, it is clear that there were differences in the kinds of arguments, the number of argument schemes, and the frequency of arguments generated between tasks in overall as well as in experimentation and critical sessions.

In this chapter, the argumentation schemes generated by pre-service science teachers in inquiry-oriented laboratory environment were analyzed qualitatively and quantitatively. Quantitative analysis indicated that PSTs engaged in discourse including wide variety of argumentation schemes. The kinds of arguments, the number of argument schemes, and the frequency of arguments generated were slightly different between tasks in overall as well as in experimentation and critical sessions. Qualitative results indicated that although the structure of argument differs between tasks and between experimentation and critical discussion sessions, PSTs can generate arguments during all stages of inquiry-oriented laboratory work, of constructing hypotheses, defining variables, designing an experiment, or drawing conclusions.

CHAPTER 5

DISCUSSION

This chapter presents a discussion in regard with the findings of this study based on the research questions and suggests implications for improving science education along with recommendations for future research.

5.1. Conclusions and Discussion

Argumentation is seen as an effective way of analysis and interpretation of discourse in science classrooms. It helps to understand how teachers and students engage in the construction and evaluation of scientific knowledge claims (Duschl, 2007, p.173). In a similar way, this study aims to explore how pre-service science teachers construct and evaluate scientific knowledge claims in inquiry-oriented laboratory work. For this purpose, participants performed inquiry-oriented laboratory tasks for six weeks. Each laboratory task consisted of two sections; the experimentation for constructing scientific knowledge claims and the critical discussion for evaluating the claims in the light of alternative ideas. In the analysis process, participants' argumentation processes were evaluated based on Walton's argumentation schemes for presumptive reasoning to describe the nature of arguments employed.

As PSTs perform inquiry-oriented laboratory tasks, the descriptions, the frequency and the percentage of the argumentation schemes were presented in overall as well as by tasks and by experimentation and critical discussion sessions in order to investigate the nature and the kinds of argumentation schemes they use. Results illustrated that there were 12 to 17 kinds of argumentation schemes located in each task. Totally, 20 kinds of argumentation schemes were generated out of 25. This finding makes it clear that PSTs applied varied premises rather than observations or reliable sources, to ground their claims or to argue for a case or an action. According to Duschl (2007), using varied kinds of argumentation schemes suggests that the broad array of presumptive reasoning schemes in such argumentative discourse "reflects a blending of analytical, dialectical, and rhetorical devices".

Although there were no categories available to collapse the argumentation schemes for statistical analysis, the higher frequency of some argumentation schemes in the whole data is noteworthy. For example, argument from sign, argument from correlation to cause, and argument from evidence to hypothesis schemes correspond to almost 50% of the whole argumentation occurred. This pattern is consistent with the results of the project SEPIA (Science Education through Portfolio Instruction and Assessment) by Duschl and his colleagues. In the project, they designed curricula to develop scientific reasoning (Duschl, 2007). They did their analysis with collapsed categories of 9 argumentation schemes by Walton (1996). The resulted pattern indicated that the intervention group employed higher frequency of inference schemes, and slightly higher frequency of request for information schemes. These were the argumentation categories that included the same frequently constructed argumentation schemes found in the present study, such as argument from sign, correlation to cause, and evidence to hypothesis. The interpretation of the frequency data and the kind of the most frequent argumentation schemes can be seen as a positive indication that the inquiry-oriented laboratory tasks employed in this study are effective toward promoting presumptive reasoning discourse. More specifically, the participants employed a diversity of schemes with reference to a variety of evidence and premises. This result supports the claims about the discourse in science classrooms that can be supported if the right context is provided (Lemke, 1990). In addition, data also support that when properly developed, inquiry-centered laboratories have the potential to enhance students to communicate and defend scientific arguments (Kipnis, & Hofstein, 2008).

Another remarkable result of this study was related to the kinds and the number of arguments by tasks. Results illustrated that some kinds of argumentation schemes were more frequently used in all tasks, whereas there were others specific for tasks. For example, argument from sign, argument from example, argument from evidence to hypothesis, argument from correlation to cause, argument from cause to effect, and argument from consequences were generated in all tasks. Therefore, these argumentation schemes can be interpreted as task-independent. It is quite possible that these argumentation schemes would appear in other scientific contexts, where participants have some background knowledge on the issue. On the other hand, there were other argumentation schemes that appeared specifically on one or more tasks, but could not be located in others. For example, it is quite interesting that argument from verbal classification was only located in tasks 1, 3, 4 and 6, whereas it could not be observed in tasks 2 and 5. Similarly, argument from expert opinion could not be located in tasks 2 and 6. In this study, there were inquiry-oriented tasks initiated by either an open-ended question or an enquiry, but in order to strongly argue about which argumentation schemes are specific to which tasks, the nature of the tasks should be specific enough and analyzed deeply. Therefore, this study supports the need to further examine which contexts are effective to support and promote argumentation in science classrooms (Duschl, & Osborne, 2002). However, at this instance, it is quite reasonable to argue that there were kinds of arguments that are task-dependent.

Another result of this study, which is worthy of notice is the construction and evaluation of scientific knowledge claims that resulted in different number and kinds of arguments. There were two stages in the design framework of this study: the experimentation stage to provide a context for the construction of scientific knowledge claims, and the critical discussion stage to provide an evaluation context where there is a ground to consider plural accounts or alternative views of the issue on investigation. In both stages, participants were found to be engaged in argumentation. However, the level of engagement differed for stages. For example, for six weeks, PSTs generated 322 arguments during experimentation, while they generated 203 arguments during critical discussion. The large number of arguments PSTs generated during both stages is important to indicate that argumentative scientific inquiry is an effective framework in supporting argumentation. Furthermore, it should be noted that although the number of arguments during the critical discussion seems remarkably smaller than during experimentation, the number is significant when the time allocated for each stage is taken into consideration. Given that each week, PSTs performed experiments on a task for 80 minutes, and discussed their findings only for 15 minutes, the number of arguments generated during critical discussion is more than expected compared to the number of arguments generated during experimentation stages. Therefore, it is clear that PSTs generated a noticeable number of arguments during critical discussions. Indeed, in the literature, it was argued that collaborative and interactive contexts brought together are recommended to support argumentation in science classrooms (Jiménez-Aleixandre, 2007). Hence, the argumentative scientific inquiry framework used in this study illustrates an example of such a context.

There were similarities between tasks in terms of high frequency argumentation schemes both in experimentation and critical discussion sessions. The similar argumentation schemes were those identified as task-independent argumentation schemes previously by the researcher. However, there are some patterns, which reveal the argumentation practices of PSTs. For example, there is a large gap in the use of some argumentation schemes between experimentation and critical discussion. PSTs generated a significantly larger percentage of argument from sign, and argument from an established rule while they were constructing scientific knowledge; whereas significantly larger percentage of argument from evidence to hypothesis, from expert opinion, from consequences, from analogy, and from bias while they were evaluating constructed scientific knowledge. This finding implies that PSTs based their arguments on a wider number of grounds during the evaluation of scientific knowledge stage than the number during the construction of scientific knowledge stage. This conclusion supports the role of critical discussion stage in providing an effective context where students are required to consider not singular explanations of phenomena but plural accounts (Duschl & Osborne, 2002).

About the nature of argumentation occurred among PSTs, the results are promising in terms of formative assessment practices because the revealed pattern elicits the grounds on which PSTs generate arguments. PSTs did not generate argumentation schemes such as causal slippery slope, precedent slippery slope, verbal slippery slope, which are categorized as composite types of arguments by Walton (1996). According to Walton (1996), composite types of argumentation schemes are more fallacious than basic schemes. The results of this study indicated that instead of using these fallacious argumentation schemes, PSTs' reasoning structures reflected argumentation schemes that more adequately fit to scientific investigations. More specifically, the most frequently seen argumentation schemes, namely argument from sign, correlation to cause, and evidence to hypothesis can be classified as scientific based on their structures described by Walton (1996) and the structures in this study. For example, Walton described argument from sign as an inference to the best explanation. He stated that argument from sign occurs as one-step inference where there is an empirical observation made, and this observation is interpreted as a sign in drawing of a presumptive conclusion. Similarly, in this study, students generated arguments from sign on the grounds that there was an empirical observation, a measurement, or a graph. The inferences based on these grounds were coded as argument from sign. Therefore, it can be argued that argument from sign is one example of schemes which fit easily into scientific argumentation. In a similar manner, argument from evidence to hypothesis can also be classified as scientific because Walton (1996) states that "this type of argumentation is typical of experimental verification or falsification of a hypothesis in scientific reasoning" (p.67). Therefore, it is not surprising that in this study argument from evidence to hypothesis was identified in high frequencies. Argument from correlation to cause, which is another high frequency argumentation scheme in this study, can be regarded as a scientific argumentation because according to Walton (1996) "whether there is a correlation between two events, and how frequent this correlation is, are questions of probability and inductive reasoning" (p.71). Inductive reasoning is used in science when scientists cannot test every incidence of an action, and find a reaction. Inductive reasoning based on the logic that if a situation holds in all observed cases, then the situation holds in all cases. Therefore, since argument from correlation to cause is an inductive type of argumentation, it can be seen as a scientific argumentation as well. To sum up, PSTs were found to construct scientific arguments in the context of inquiry-oriented laboratory. It can be concluded that in contrary to the research indicating that both pre-service and practicing teachers experience difficulty in constructing arguments (Zembal-Saul, 2009; Zohar, 2007), presumptive reasoning analysis in this study revealed that the framework of argumentative scientific inquiry appears to have assisted PSTs in constructing scientific arguments.

5.2. Implications of this Study

The implications of this study are: (1) that designing inquiry-oriented laboratory environments, which are enriched with critical discussion, provides discourse opportunities that can support argumentation; (2) that both the number of arguments and the use of various scientific argumentation schemes can be enhanced by specific task structures; (3) that argumentation schemes for presumptive reasoning is a promising analysis framework to reveal the argumentation patterns in scientific settings; (4) that pre-service teachers can be encouraged to support and promote argumentation in their future science classrooms if they engage in argumentation integrated instructional strategies.

First of all, in teaching science as inquiry and in teaching science in laboratory, importance should be placed on creating authentic experiences for students so that they learn science as an inquiry with the inclusion of critical discussion. Kuhn and Reiser (2006) have recently suggested that rather than only asking questions or creating contexts where students become only familiar to other ideas, science educators should also develop criteria for evaluating those ideas. The conclusions of this study support this suggestion. This research suggests that the design of inquiry-oriented laboratory environment should include discourse opportunities that support students' development of deeper understanding of scientific inquiry practices, such as constructing knowledge in the light of available data and evidences through collaboration and evaluating knowledge across alternative evidences and plural accounts.

Secondly, developing argumentation skills of students is an important goal for science educators because argumentation and related practices related to argumentation form integral components of scientific inquiry and science literacy (Puvirajah, 2007). However, the large number of arguments does not necessarily mean that the arguments are scientifically qualitative. Sampson (2007) asserts that "teachers can encourage students to engage in argumentation by designing tasks that require students to make sense of data, generate explanations, defend these explanations with appropriate evidence and reasoning, and to critique the explanations or arguments generated by others". The findings of this study support this assertion. This study suggests that since the nature of most argumentation generated is task-dependent in scientific contexts, the task structure should be given emphasis. In this study, tasks, which are initiated by open-ended questions or enquiry, were used to promote argumentation, and they were found to promote scientific argumentation among participants. Therefore, the use of ill-structured tasks can be suggested to support or promote argumentation in science laboratories.

Third, to know the nature of arguments is helpful for progressing scientific thinking and reasoning for formative assessment purposes (Osborne, Erduran & Simon, 2004). Duschl (2007) believes that Walton's presumptive reasoning schemes fits to discourse structures and reasoning sequences in scientific contexts. The analysis of this study supports Duschl in such a way that the use of Walton's framework reveals patterns in the argumentation of participants by eliciting the grounds on which the claims based on. By this analysis framework, researchers can understand the premises in the arguments and the criteria used to evaluate knowledge claims.

At last, this study showed that argumentation skills of the pre-service science teachers can be developed if argumentation skills are incorporated into the science curriculum in teacher education programs. If instructional strategies, which view teaching argumentation as a way to improve student scientific reasoning skills, are experienced by PSTs, then they should be better equipped with argumentation skills. Zohar (2007) indicated that teachers must be able to engage in high quality argumentation themselves before they can support students' successful argumentation. Therefore, the results from this study provided an important groundwork for training PSTs to be adaptive to their future workplace where argumentation is an integral part of science learning in laboratory.

5.3. Recommendations for Future Research

The results of this study suggest that use of Walton's argumentation schemes for presumptive reasoning to analyze the discourse in scientific contexts is a promising approach. This analyzing framework provides an opportunity to understand the kinds and the structure of argumentation that pre-service science teachers use when providing judgments about the validity of their claims related to the data they collected during laboratory investigations. Therefore, the use of Walton's argumentation schemes is recommended for the analysis of arguments in scientific contexts to understand the reasoning sequences and the premises underlying the claims for both teachers and students in scientific contexts.

In this study, the analysis of the discourse revealed that the nature of argumentation is closely related to the type of task. The inquiry-oriented tasks used in this study elicited a broad array of argumentation schemes. However, it is not only the type of task which facilitates the argumentation, but also further research should pay attention to (a) the dynamics of the group who perform the tasks in terms of social and cognitive strategies they use, and (b) the components of the tasks in terms of which parts of the task enhance the talk among group members.

Another direction for future research is to examine the challenges faced by pre-service and in-service teachers as they are engaged in argumentative practices in scientific contexts. The results of this study serve as an introduction to the research which seeks for improving the argumentation practices of science teachers in scientific contexts. However, there is still need to more research that investigates teacher adaptation to dialogue-based pedagogical strategies to science classrooms.

This study also adds to the effort to develop materials which enhances the argumentation in laboratory contexts since each laboratory task is designed to allow dialogical discourse around scientific concepts. Future work should also examine which factors influence the teachers in enacting inquiry-oriented curriculum materials. Furthermore, future work should need to continue to explore the pedagogical strategies as well as other supports required to change science classrooms to include greater focus on evidence, explanation, and argumentation.

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APPENDIX A

LABORATORY MANUALS

LAB 4: HOOKE'S LAW

Introduction:

In this lab you will be introduced to integrated science process skills.

4.1. Science Process Skills

Introduction

Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results (Carin, Bass, & Contant, 2005). Scientists make their discoveries by using their science process skills (Abruscato, 1995). SPS are classified in two different forms; Basic and Integrated SPS. Integrated SPS consists of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information (Brotherton & Preece, 1995). In this lab, we will concentrate on integrated science process skills.

4.1.1. Controlling Variables

Preliminary Information

In order to experiment in science, a scientist must control all the variables that will affect the outcome of the experiment. Before identifying the variables that must be controlled, the scientist first identifies the manipulated and responding variables. In order to test an inference or hypothesis, certain variables need to be manipulated or controlled.

Definition of the Types of Variables

1. ***The manipulated variable:*** Also known as the independent variable is the variable that is deliberately changed in an experiment.
2. ***The responding variable:*** Also called the dependent variable is the variable that changes as a result of the manipulation.
3. ***Controlled variables:*** They are the variables that remain constant through the experiment so as not to interfere with the results.

Be careful that *a controlled variable* doesn't change throughout the experiment, whereas *a manipulated variable* may change in a systematic way.

Let's imagine that you wish to test whether the length of the pendulum affects the number of swings. In order to set up this experiment, we must identify the variables. These are summarized in Table 1.

Table 1. Variables involved in determining whether the length of the pendulum affects the movement of the pendulum bob.

Variables		
Manipulated	**Responding**	**Controlled**
Length of pendulum (between 10-100 cm)	Movement of pendulum bob (number of swings)	Time (10 seconds) Mass (2 identical) Kind of string (kite cord) Position of object at start (180^0 with floor or parallel to the floor) Push given to object (none-only gravitational)

The manipulated variable can conveniently consist of string of different lengths. The responding variable is the movement of the pendulum. Controlled variables are the ones that might affect the outcome of the experiment so they kept constant for each try.

Review Question

Given the following situation, complete the following statements:

A student wishes to determine which kind of physical activity increases heartbeat the most. All the second grade children spend 15 minutes after lunch doing one of 4 activities (skipping, jumping, running, and hopping). Children's heartbeat/minute is measured before and after the exercise.

The manipulated variable is

………………………………………………………………………………………

The responding variable is

………………………………………………………………………………………

List four controlled variables

4.1.2. Defining Operationally

Preliminary Information

In science it is frequently necessary to define terms operationally. For example, if you wanted to see the effect of the amount of fertilizer on plant growth, you would have to define what you meant by plant growth as well as identify the appropriate units for "amount of fertilizer" and determine the kind of fertilizer you were using.

An operational definition states "what you do or what operation you perform" and "what you observe". For example, an operational definition of water might be: "water is a liquid that makes plants grow, quenches thirst and is necessary for life". In contrast a non-operational definition of water is that it is a compound composed of two atoms of hydrogen and one atom of oxygen. Both operational and non-operational definitions of terms are used in science because each serves a different purpose. If it is important to know how something operates, an operational definition is used.

When defining something operationally, list only things that are observed. For example, if you define a "metal", you might say that it is a shiny substance that is malleable and conducts heat and electricity. You would not mention that it is *not* colored or *not* an insulator.

Review Question

A teacher wished to find out how the size of an ice cube affects the time it takes for water to cool. Identify the variables and give two ways each could be defined operationally.

Manipulated Variable:	
Operational Definition 1:	
Operational Definition 2:	
Responding Variable:	
Operational Definition 1:	
Operational Definition 2:	

4.1.3. Formulating Hypothesis and Experimenting

Preliminary Information

Scientists make explanations of the natural phenomenon based on their observations and inferences that you will be familiar in the next lab session. When they wish to give a possible broader explanation- one that includes many inferences- it is called a hypothesis. For example, you may infer that bean plants grow better in light than in dark. You could infer this about corn, peas and radishes, too. You may hypothesize that all plants grow better in light than in dark. You would then test the hypothesis by growing a wide variety of plants in light and dark environments.

A hypothesis is also based on observations. Actually, it is based on a series of observations or occurrences of an event. It is a generalized explanation that includes all objects or events of the same class.

Hypotheses frequently refer to statements in which all cases have not been tested. If we experiment to find out whether the hypothesis (statement) is true, we need to test a variety of different cases. Each time we make a test on a particular case, and find out that the hypothesis holds, we say that the data *supports* the hypothesis. In order to *prove* the hypothesis, all possible cases must be tested. This is usually not possible to do. If we find an instance in which the data do not support the hypothesis, scientists modify the hypothesis.

Care must be taken to base hypothesis on what has been observed, rather than what you think should be observed.

Also be certain not to generalize in reverse. For example, you can say that “all tigers are cats” but you cannot say “all cats are tigers”.

Review Question

What hypothesis was the class testing in the following example?

A teacher decides to have her class determine how light affects the growth of plants. The teacher divides her class into four groups. One group exposes their plants to light 4 hours per day, the second group 6 hours per day, the third group 8 hours per day and the fourth group 10 hours per day. At the beginning and the end of two weeks, the students measure the height of their plants in centimeters.

4.1.4. Interpreting Data

Preliminary Information

Once scientists have made observations, they need to interpret the data. There are several ways of interpreting data. Many times the data are graphed in order to draw inferences more easily. If the observation is quantitative, it can be listed in an organized way in table form.

A graph is a common method of communicating numerical information obtained from an experiment. It is common practice to first organize the variables and results of the experiment in tabular form and then create a graph from the data table. Different types of graphs exist. The type that will be discussed here is line graphs.

4.1.4.1. Data Tables

Preliminary Information

Given below is a table of data for the pendulum experiment.

SWINGS OF PENDULUMS OF DIFFERENT LENGHTS

Movement of pendulum (# of swings)	Length of string (cm)
3	30
4	28
5	26
6	24
7	22
8	20
9	18
10	16

Note the following features of the data table

a. It has a title
b. Each variable is identified
c. The units for each variable are given
d. The numbers are organized in a logical order.

Graphing Rules

The general rules for making all graphs are the same. They are:

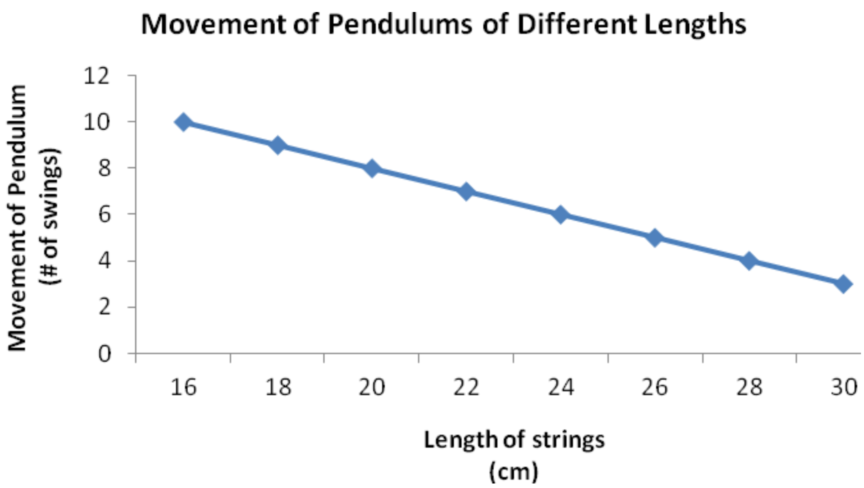
1. Choosing a title- a brief description including manipulated, responding and important controlled variables.
2. Selecting the proper axes for the variables
   a. Manipulated variable- placed on the horizontal axis (independent)
   b. Responding variable- placed on the vertical axis (dependent)
3. Labeling the axes- give variable tested
4. Showing the unit of the variable- place under or beside label
5. Choosing the scales for the axes:
   a. Both need not be the same
   b. Should be evenly divided
   c. Need not start at zero
   d. Should be selected so graph covers at least ¼ page

6. Plotting the data points- sometimes data need to be rounded
7. Drawing of the line.

4.1.4.2. Line Graphs

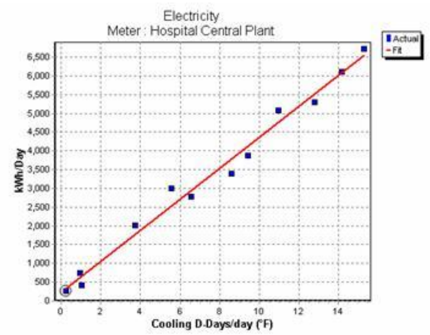
Preliminary Information

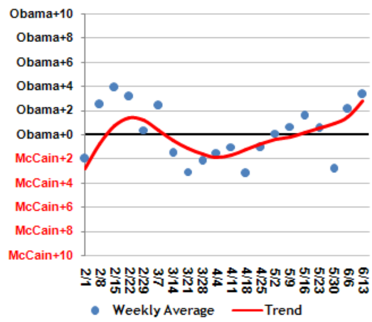
When both variables are continuous, a smooth line curve can be drawn through the data points. Continuous variables are those in which the variable can assume any value. For example, time is a continuous variable because we can break down seconds into tenths, hundreds etc. check to see that the following graph was drawn using the rules given in the section graphing rules.



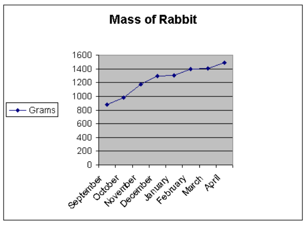
In drawing a smooth curve, you must try to draw the best-fit line. The best-fit line is one that best represents the data. All points are unlikely to fall on the line because of experimental errors made in doing the experiment. The best-fit line takes this into account and generally has the same number of data points above and below it.

The following are examples of best-fit, smooth curves:





When the data is discontinuous, a broken line is used instead of a smooth curve.



Review Question

Draw the best-fit line on the following graphs.

(Graphs will be given on a separate sheet of paper)

4.2.2. Hooke's Law

Preliminary Information

This laboratory experiment will provide you opportunity to use necessary basic and integrated SPS.

This laboratory presents a problem and lists materials available to you. Your task is to design a strategy for solving the problem. Please record all your answers on these sheets. You will have 30 minutes to plan and design an experiment to solve the problem.

Part-1. Planning- 30 minutes

Materials

Clamp	Metal rods
Springs	Weights
Meter stick	Ring-stand

Problem:

<u>Describe the relationship between the force applied to a spring and its elongation (stretch).</u>

Defining variables:

Defining operationally:

Formulating hypothesis:

Part-2. Carrying out- 40 minutes

Procedures:

Data table

Plot the graph

Do graphing on a separate sheet of a graph paper

Write an equation to show the relationship:

Equation :

Part 3- Evaluation (20 minutes)

1- Which kind of relationship exists between these variables?

____

2- Are these results support your hypothesis? Why?

____

____

____

____

3- Can you generalize your findings? Why?

____

____

____

4- Is there anything that you would like to add? (Recommendations, Experimental errors, comments on the application, etc.)

LAB 5: BLACK BOX

Introduction:

In this lab you will be introduced to basic science process skills, and learn that science is based on both observations and inferences.

5.1. Science Process Skills

Introduction

Making careful observations is among the most basic skills needed in the study of science. All science begins with observing. From the observations, inferences and predictions can be made. Experiments involve the collection of data which must be obtained by making observations. Once a scientist has made observations, he or she uses the observations to make inferences. An inference is an explanation or an observation of an event or phenomena that has taken place in the past. For example, let's imagine that you make the observation that the sun is setting later each day over a week's time. From this observation you can infer the time of the year is spring.

Teaching children to become discriminating observers is one of the major objectives of science instruction in the elementary school. In addition, making inferences and predictions is a frequent activity that children pursue in their study of science.

5.1.1. Observations

Preliminary Information

Making observations is a skill that begins very early in the life of a child and continues throughout adulthood. A piece of information that is obtained exclusively through one of the five senses (sight, hearing, touch, smell, and taste) can be considered an observation. For example, it can be observed that the paper on which this print occurs is white. The observation might be stated as "the paper is white". Children make observations at a very early age and use the information that they gain through their senses to make inferences such as in the recognition of their mother.

Observations form the basis of all science. Skills that you have introduced earlier n this course, such as classifying, predicting, formulating hypothesis are directly dependent on making precise observations. However, care must be taken to distinguish observations from inferences. To say for example, "the fish is dead" is to make an inference rather than an observation. One observes odor, floating on water lack of motion, etc. and concludes "deadness". Likewise, it is impossible to observe what objects are made of. Someone might conclude that the "eraser is rubber" after observing the signs or characteristics of rubber.

Types of Data

There are two different types of data; qualitative and quantitative.

1. *Qualitative data: i*s data gathered through observation in which no numbers are used (e.g., color, softness, texture). Most observations that you are used to making are of this type.
2. *Quantitative data:* is data gathered either through an observation in which numbers are used or by measurement in which there is a standardized unit (e.g., 3 leaves, 15 cm long). There are two types of quantitative data. Those that result from *counting* a number of objects (such as "the branch has 3 leaves"), and those that are obtained by *measuring* (such as "the branch is 15 cm long").

Sometimes there is little difference between what might be considered to be a qualitative and a quantitative data. What is difference in meaning between the following two statements?

(1) The book is perpendicular to the table.

(2) The book is at a 90 degree angle to the table.

Both statements contain the same information, although by the definitions given, statement (1) is qualitative whereas statement (2) is quantitative.

Sometimes the same statement may contain both qualitative and quantitative information. Statement (3) below could be separated into two statements, one that is qualitative and one that is quantitative.

(3) The plant contains 5 white flowers.

5.1.2. Inferences

Preliminary Information

Scientists are interested in not only describing the world around them (observation) but in explaining why changes occur (inferences) and in forecasting future events (predictions). The thought processes used in making predictions are the foundation for experimentation. They start the process of testing the validity of drawing a conclusion about why something does or does not occur. In addition, these same thought processes help scientists create models and formulate theories to explain changes in the universe.

Inferences An inference is an explanation or interpretation of observations based on a particular event or situation. (If this is generalized to many situations, then the explanation or interpretation is called a hypothesis or general conclusion).

Imagine that the following observations were made: Bean plants are placed in a dark and a light place. The bean plants placed in the dark grow three inches per week; the ones placed in the light grow four inches per week.

The inference that would follow is: Bean plants grow better in the light than in the dark.

Now imagine that the following additional observations were made: The experiment is repeated with corn, zinnia, and spinach etc. plants; the same observations are made.

A more general conclusion might be formulated such as: Plants grow better in light than in the dark. If this statement was still tentative and you were testing it, it would be called a hypothesis.

Predictions A prediction is a forecast of future events based on observations.

Distinguishing between Observations and Inferences

Imagine that you observe a burning candle. The following are some examples of observations and inferences:

Observation	Inference
1. A white substance drops down the side of the candle.	1. Wax melts and drops down the side of the candle.
2. The liquid in the bowl is clear.	2. Melted wax accumulates in the bowl of the candle.
3. The candle gets shorter as time passes.	3. The wax is consumed in the burning process.

Notice that in these examples "wax" is considered an inference. Many observations are needed to identify what a substance is made of. We infer the composition of materials.

Alternate Inferences

Sometimes a series of observations are made, for which alternate inferences are possible. In the example that follows two inferences can be made from the observation.

Observation	**Inference 1**	**Inference 2**
A student is absent from class on Monday, Wednesday and Friday.	The student has dropped the course	The student is ill

Further observations are needed to determine which inference is correct.

5.2.1. Black Box

Preliminary Information

This laboratory experiment will provide you opportunity to understand that scientific knowledge includes observations and inferences; observations and inferences are different, and to use necessary basic and integrated SPS which you are familiar to.

Materials

None needed

Procedure

1. Carefully examine the Black Box model demonstrated by the instructor.
2. Make observations and make records of your observations (data)

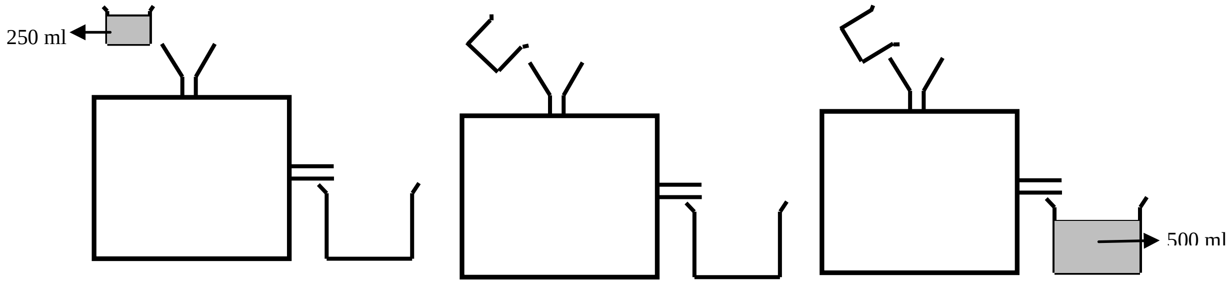


Figure　　Figure　　Figure

Data and Calculations

1. Record your observations (data).

2. What can you infer based on your observations about the system inside the black box? Please write all plausible inferences you can make.

3. Based on your observations and inferences suggest a model to explain step by step how the phenomenon (or demo) works.

Draw the model that you think explains how the black box runs.

4. Does your experimental design support your inference?

5. How certain are you about the model that you have drawn based on your observation and inferences?

LAB 6: CANDLE

Introduction:

In this lab you will practice science process skills and try to draw evidence-based conclusions and test them.

6.1. Science Process Skills

Introduction

Science process skills (SPS) are thinking skills that scientists use to construct knowledge, think on problems, and formulate the results (Carin, Bass, & Contant, 2005). Scientists make their discoveries by using their science process skills (Abruscato, 1995). SPS are classified in two different forms; Basic and Integrated SPS. Basic SPS consists of observing, inferring, measuring, communicating, classifying, and predicting. Integrated SPS consist of controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models, and presenting information (Brotherton & Preece, 1995).

6.1.1. Observations

Preliminary Information

A piece of information that is obtained exclusively through one of the five senses (sight, hearing, touch, smell, and taste) can be considered an observation. Observations form the basis of all science. Care must be taken to distinguish observations from inferences. To say for example, “the fish is dead” is to make an inference rather than an observation. One observes odor, floating on water lack of motion, etc. and concludes “deadness”. Likewise, it is impossible to observe what objects are made of. Someone might conclude that the “eraser is rubber” after observing the signs or characteristics of rubber.

6.1.2. Inferences

Preliminary Information

Scientists are interested in not only describing the world around them (observation) but in explaining why changes occur (inferences) and in forecasting future events (predictions). An inference is an explanation or interpretation of observations based on a particular event or situation. (If this is generalized to many situations, then the explanation or interpretation is called a hypothesis or general conclusion).

6.1.3. Measurement

Preliminary Information

Some of your observations will be quantitative. These make use of quantities or numbers. Measurements are called quantitative observations and are generally more useful than qualitative measurements.

6.1.4. Classifying

Preliminary Information

Classification is used widely in science as well as in everyday life. For example, if you think of the word "tree" you automatically include certain objects and exclude others. Being able to classify objects is a very useful skill to possess. It enables one to identify objects according to certain characteristics or attributes and to communicate those properties to another person quickly. For example, suppose I say to you "there are two types of animals we will study, domesticated and non-domesticated". Immediately certain animals come to your minds that have certain properties.

6.1.5. Predicting

Preliminary Information

Scientists are interested in not only describing the world around them (observation) but in explaining why changes occur (inferences) and in forecasting future events (predictions). The thought processes used in making predictions are the foundation for experimentation. A prediction is a forecast of future events based on observations.

6.1.6. Controlling Variables

Preliminary Information

In order to experiment in science, a scientist must control all the variables that will affect the outcome of the experiment. Be careful that *a controlled variable* doesn't change throughout the experiment, whereas *a manipulated variable* may change in a systematic way.

6.1.7. Defining Operationally

Preliminary Information

In science it is frequently necessary to define terms operationally. An operational definition states "what you do or what operation you perform" and "what you observe". For example, an operational definition of water might be: "water is a liquid that makes plants grow, quenches thirst and is necessary for life". If it is important to know how something operates, an operational definition is used.

6.1.8. Formulating Hypothesis and Experimenting

Preliminary Information

Scientists make explanations of the natural phenomenon based on their observations and inferences that you will be familiar in the next lab session. When they wish to give a possible broader explanation- one that includes many inferences- it is called a hypothesis. A hypothesis is also based on observations. Actually, it is based on a series of observations or occurrences of an event. It is a generalized explanation that includes all objects or events of the same class.

6.1.9. Interpreting Data

Preliminary Information

Once scientists have made observations, they need to interpret the data. There are several ways of interpreting data. Many times the data are graphed in order to draw inferences more easily. If the observation is quantitative, it can be listed in an organized way in table form. A graph is a common method of communicating numerical information obtained from an experiment.

6.2.1. Candle

Preliminary Information

This laboratory experiment will provide you opportunity to practice science process skills, draw evidence based conclusions and test your claims.

Materials

Write the materials that you will use in your investigation.

Cake candles in different colors, three kinds of liquids in bottles,…

Procedure

1. You have cake candles in different colors. Have at least 100 mL of each liquid in separate beakers. Put one candle into each liquid (try each color of liquid and each color of candle at least once), and observe what happens.

Write your ***observations*** to the space provided below.

2. Write your ***inferences*** related to your observations to the space provided below.

3. Choose one of your observations regarding only one color of a candle. Select the option(s) that you think support(s) your explanation about how the phenomenon works.

a. The mass of the candle is larger/smaller with respect to the liquids.

b. The volume of the candle is larger/smaller with respect to the liquids.

c. The temperature of the candle is cooler/warmer with respect to liquids.

d. The temperatures of the liquids are cooler/warmer with respect to the candle.

e. The density of the candle is larger/smaller with respect to the liquids.

f. The densities of the liquids are larger/smaller with respect to the liquids.

g. Other: …….

4. In this step you are expected to design a method to test your inference according to the choice you made in the previous step.

Write your procedure

Record your data (to the back of the page)

What is your conclusion(s)?

5. In this step, you are asked to give the (relative) density of the candle. Please design a method to calculate and/or measure the density of the candle you have selected. Do not forget to express the numbers in correct number of significant figures and in correct form of scientific notation when necessary.

Write your procedure

Record your data (to the back of the page)

What is your conclusion(s)?

LAB 7: PARTICLE THEORY OF MATTER

Introduction:

In this lab you will not only test a couple of theory and laws related to the particle structure of matter but also reconsider your conceptions of theory and law.

7.1. Theory and Law

Introduction

Theories and laws are very different kinds of knowledge. It is not the case that one simply becomes the other- no matter how much empirical evidence is amassed. Laws are generalizations, principals or patterns in nature and theories are the explanations of those generalizations.

For example, Newton described the relationship of mass and distance to gravitational attraction between objects. (This is the law of gravity) *At this point, there is no well-accepted theory of gravity. Interestingly, Newton addressed the distinction between law and theory with respect to gravity. Although he had discovered the law of gravity, ...in "Principia", Newton states "...I have not been able to discover the cause of those properties of gravity from phenomena, and I frame no hypothesis" "...it is enough that gravity does really exist, and act according to the laws which we have explained".*

McComas, W. F. (1998). *The principal elements of the nature of science: Dispelling the myths*. In Mccomas, W. F. (ed.) The nature of science in science education, 53-70, Kluwer Academic Publishers: Netherlands.

7.2. Modern atomic theory

Preliminary Information

In the early years of the 19th century, John Dalton developed his **atomic theory** in which he proposed that **each chemical element is composed of atoms of a single, unique type**. How precisely Dalton arrived at his theory is not entirely clear, but nonetheless *it allowed him to explain various new discoveries in chemistry* that he and his contemporaries made.

The first was **the law of conservation of mass**, formulated by Antoine Lavoisier in 1789, which states that **the total mass in a chemical reaction remains constant** (that is, the reactants have the same mass as the products). This law suggested to Dalton that matter is fundamentally indestructible.

The second was the **law of definite proportions**. First proven by the French chemist Joseph Louis Proust in 1799, this law states that **if a compound is broken down into its constituent elements, then the masses of the constituents will always have the same proportions, regardless of the quantity or source of the original substance**. Proust had synthesized copper carbonate through numerous methods and found that in each case the ingredients combined in the same proportions as they were produced when he broke down natural copper carbonate.

http://en.wikipedia.org/wiki/Atomic_theory

7.2.1. Particle theory of matter

The following is an activity to construct an argument related to the particle theory of matter which claims that each chemical element is composed of smaller particles called atoms. Work in groups of two to construct your argument.

Problem

Write at least three arguments, which serve as a good evidence to the claim that "Matter is made up of particles"?

a)....

b)....

c)....

Why do you think the above statement supports your argument?

Design an experiment to collect data to serve as an evidence to your claim.

Materials

Write the materials that you will use in your investigation.

Procedure

...

Write your ***observations/ data*** to the space provided below.

Write your ***inferences*** related to your observations to the space provided below.

7.2.2. The law of conservation of mass

The following is an activity to design an experiment which acts according to the law of conservation of mass which states that the total mass in a chemical reaction remains constant, that is, the reactants have the same mass as the products. Work in groups of four to construct your experiment.

Problem

Design an experiment to collect data to serve as an evidence to your claim.

Materials

Write the materials that you will use in your investigation.

(Available ones: vinegar, table salt, locked sandwich bag, electronic balance)

Procedure

...

Write your ***observations/ data*** to the space provided below.

Write your ***inferences*** related to your observations to the space provided below.

LAB 8: EVOLUTION THEORIES

Introduction:

In this lab you will have the opportunity to understand the theory-laden nature of scientific knowledge. That is, scientists' theoretical and disciplinary commitments influence their work. Meanwhile you will practice necessary basic and integrated science process skills.

8.1. Theory-laden nature of science

Introduction

... scientific knowledge is subjective and/or theory-laden. Scientists' theoretical commitments, beliefs, previous knowledge, training, experiences, and expectations actually influence their work. All these background factors… affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they make sense of, or interpret their observations. ... It is noteworthy that, contrary to the common belief, science rarely starts with neutral observations (Chalmers, 1982). Observations (and investigations) are motivated and guided by… questions or problems. These questions or problems, in turn, are derived from within certain theoretical perspectives.

Lederman, N. G. (2007). Nature of Science: Past, present and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp.831-881). Mahwah, NJ: Erlbaum.

8.2. Evolution Theory

Preliminary Information

In biology, **evolution** is change in the inherited traits of a population of organisms from one generation to the next. These changes are caused by a combination of three main processes: variation, reproduction, and selection. Genes that are passed on to an organism's offspring produce the inherited traits that are the basis of evolution.

Studies of the fossil record and the diversity of living organisms had convinced most scientists by the mid-nineteenth century that species changed over time.

However, the mechanism driving these changes remained unclear until the 1859 publication of Charles Darwin's *On the Origin of Species*, detailing the theory of evolution by natural selection.

Evolutionary ideas such as **common descent** and the **transmutation of species** have existed since at least the 6th century BC, when they were expounded by the Greek philosopher Anaximander.

Transmutation of species is a term to describe the altering of one species into another. It was one of the names commonly used for evolutionary ideas in pre-Darwinian times. Jean-Baptiste Lamarck proposed in his *Philosophie Zoologique* of 1809 a theory of the transmutation of species. Lamarck did not believe that all living things shared a common ancestor. Rather he believed that simple forms of life were created continuously by spontaneous generation. He also believed that an innate life force, which he sometimes described as a nervous fluid, drove **species to become more complex over time, advancing up a linear ladder of complexity that was related to the great chain of being.** Lamarck also recognized that species were adapted to their environment. He explained this observation by saying that the same nervous fluid driving increasing complexity, also caused the organs of an animal (or a plant) to change based on the use or disuse of that organ, just as muscles are affected by exercise. He argued that these changes would be inherited by the next generation and produce slow adaptation to the environment.

The second evolutionary idea is the one proposed by Charles Darwin. A group of organisms is said to have **common descent** if they have a common ancestor. In modern biology, **it is generally accepted that all living organisms on Earth are descended from a common ancestor** or ancestral gene pool. A theory of **universal common descent** based on evolutionary principles was proposed by Charles Darwin in his book *On the Origin of Species* (1859), and later in *The Descent of Man* (1871). All organisms on Earth are descended from a common ancestor or ancestral gene pool. Current species are a stage in the process of evolution, with their diversity the product of a long series of speciation and extinction events. More recently, evidence for common descent has come from the study of biochemical similarities between organisms. For example, all living cells use the same basic set of nucleotides and amino acids.

http://en.wikipedia.org/wiki/Common_descent

http://en.wikipedia.org/wiki/Evolution

http://en.wikipedia.org/wiki/Transmutation_of_species

8.2.1. Testing Evolution Theories

Modern research techniques allow biologists to compare the DNA that codes for certain proteins and to make predictions about the relatedness of the organisms from which they took the DNA. Students will use models of these techniques to test their hypotheses and determine which one is best supported by the data they develop.

This activity will give you the opportunity to observe differences and similarities in the characteristics of humans and apes. The apes discussed in this activity are the chimpanzee and the gorilla.

Problem

Find the morphological relationships between gorillas, chimpanzees, and humans.

Working in groups of four “synthesize” strands of DNA according to the following specifications:

(Each different color of paper clip represents one of the four bases of DNA.)

Materials

Four sets of black, white, green, and red paper clips, each set with 35 paper clips.

Black: adenine (A) Green: guanine (G) White: thymine (T) Red: cytosine (C)

Procedure

Each student will synthesize one strand of DNA. Thirty-five paper clips of each color should provide an ample assortment.

Group member 1: Synthesize a strand of DNA that has the following sequence:

A-G-G-C-A-T-A-A-A-C-C-A-A-C-C-G-A-T-T-A

Label this strand “human DNA”, this strand represents a small section of the gene that codes for human hemoglobin protein.

Group member 2: Synthesize a strand of DNA that has the following sequence:

A-G-G-C-C-C-C-T-T-C-C-A-A-C-C-G-A-T-T-A

Label this strand “chimpanzee DNA”, this strand represents a small section of the gene that codes for human hemoglobin protein.

Group member 3: Synthesize a strand of DNA that has the following sequence:

A-G-G-C-C-C-C-T-T-C-C-A-A-C-C-A-G-G-C-C

Label this strand “gorilla DNA”, this strand represents a small section of the gene that codes for human hemoglobin protein.

Group member 4: Synthesize a strand of DNA that has the following sequence:

A-G-G-C-C-G-G-C-T-C-C-A-A-C-C-A-G-G-C-C

Label this strand “common ancestor DNA”, this strand represents a small section of the gene that codes for human hemoglobin protein of a common ancestor of the gorilla, chimpanzee, and human.

Your research study should include;

1. State your group purpose

....

....

....

....

2. State your group hypothesis to explain how these organisms are related? (Three hypothesis or two hypothesis according to your theory)

....

....

....

....

....

....

....

....

3. Compare the human DNA to the chimpanzee DNA by matching the strands base by base (paper clip by paper clip). Count the number of bases that are not the same. Record the data in a table. Repeat the steps with the human DNA and the gorilla DNA.

Hybridization data for human DNA

Human DNA compared to:	**Number of matches**	**Unmatched bases**
Chimpanzee DNA		
Gorilla DNA		

How do the gorilla DNA and the chimpanzee DNA compare with the human DNA?

....

....

....

....

....

Data for common ancestor DNA

Common ancestor DNA compared to:	**Number of matches**	**Unmatched bases**
Human DNA		

Chimpanzee DNA		
Gorilla DNA		

What do these data suggest about the relationship between humans, gorillas, and chimpanzees?

....

....

....

....

....

4. Write your conclusion. Do the data support any of your hypotheses? Why or why not?

.... (continue to the back of the page)

LAB 9: THE STRUCTURE OF LIGHT

Introduction:

In this lab you will have the opportunity to understand the tentative nature of scientific knowledge. That is, scientific knowledge is never absolute or certain. All kinds of scientific knowledge, including “facts”, “theories” and “laws” are tentative and subject to change.

9.1. Tentativeness in science

Introduction

… Scientific knowledge is never absolute or certain. This knowledge, including “facts”, theories, and laws, is tentative and subject to change. Scientific claims change as new evidence, made possible through advances in theory and technology, is brought to bear on existing theories or laws, or as old evidence is reinterpreted in the light of new theoretical advances or shifts in the directions of established research programs. The construct of punctuated equilibrium was developed through an interpretation of the fossil record from a different perspective. Rather than taking a Darwinian view of gradual change, the lack of transitional species, among other observations, led to a reinterpretation of classic evolutionary theory. It should be emphasized that tentativeness in science not only arises from the fact that scientific knowledge is inferential, creative, and socially and culturally embedded. There are also compelling logical arguments that lend credence to the notion of tentativeness in science. Some have taken issue with the use of the word “tentative” to describe scientific knowledge. Descriptors such as “revisionary” or “subject to change” are preferred by those who feel “tentative” implies that the knowledge is flimsy and not well founded. Whatever word is used, the intended meaning is that the knowledge of science, no matter how much supported evidence exists, may change in the future for the reasons just discussed.

Lederman, N. G. (2007). Nature of Science: Past, present and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp.831-881). Mahwah, NJ: Erlbaum.

9.2. Theories about light

Preliminary Information

In this lab activity, you will perform some experiments and drive theories about the light based on your observations on the behavior of light.

9.2.1. Theory of Light-I

Materials

Three cardboards (1st one has three holes, 2nd one has two holes, and 3rd one has one hole), a flashlight, sticky rubber to hold the cardboards, a black card, and a black box.

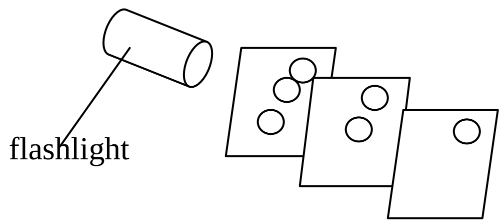
Procedure

1. Use your materials to construct the following experimental set-up into your black box.

Place your cardboards so that the one with three holes will be in the front, the one with two holes will be in the middle, and the one with a hole will be at the back.

There will be 5 cm between cardboards.

The cardboards will be placed so that the holes are in a straight line.



2. Light the flashlight in front of the cardboard with three holes and record your observations.

3. What can you infer based on your observations about the light?

4. Based on your observation and inferences suggest a model to explain the structure of light.

9.2.2. Theory of Light-II

Evidence

An experimental anomaly was the photoelectric effect, by which light striking metal surface ejected electrons from the surface, causing an electric current to flow across an applied voltage.

Review

1. Does this evidence support the light model you draw in the first part of the experiment? Report if they are consistent with your model, explain why you think they are consistent or not.

2. If the evidence does not support your model, modify your model to include this piece of evidence given.

9.2.3. Theory of Light-III

Materials

A cardboard with one slit, a cardboard with two slits, a flashlight, and a black box.

Procedure

1. Light your flashlight.

2. Place the cardboard with one slit in front of your flashlight.

3. Draw the pattern you observe on the side of the black box to the space provided below.

4. Remove the cardboard with one slit and place the cardboard with two slits in front of your flashlight.

5. Draw the pattern you observe on the side of the black box to the space provided below.

6. Do your observations support the light model you draw? Report if they are consistent with your model, explain why you think they are consistent or not.

7. If your observations do not support your model, modify your model to include your observations in this experiment.

8. What can you infer about the light based on your observations in three experiments?

9. Please explain why your model has been changed? What drove you to change your model?

APPENDIX B

ARGUMENTATION SCHEMES FOR PRESUMPTIVE REASONING BY WALTON

	Argumentation Scheme	Structure	Example
1	Argument from sign	Observation x is taken as evidence of event E	Here are some bear tracks in the snow Therefore, a bear passed this way.
2	Argument from example	If x has F then x will also have G	If it is a solid matter, it must have a certain mass and a volume.
3	Argument from verbal classification	a has a property F. For all x, if x has property F, then x can be classified as having property G. Therefore, a has property G.	Ross Perot is rich, on the grounds that anyone who has assets of more than 3 billion dollars can be classified as rich.
4	Argument from commitment	The proponent claims that the respondent is, or should be committed to some particular position.	Ed, you are a communist, aren't you? Well, then you should be on the side of the union in this recent labor dispute.
5	Circumstantial argument against the person	Where arguer's circumstances are claimed to be contrary to his or her argument.	There is strong evidence of a link between smoking and chronic lung disease. So you should not smoke. But you smoke yourself. So much for your argument against smoking.
6	Argument from position to know	When one party has reason to presume that another party has access to information that the first party does not have direct access	Suppose tourists ask shopkeeper the location since he has a position to know where.
7	Argument from expert opinion	This proposition is said to be to true by an expert	According to experts… According to reliable sources….
8	Argument from evidence to a hypothesis	If a is true then b will be true.	If Copernican system is correct, then venus will show phases. Venus shows phases. Therefore, the Copernican system is correct.

9	Argument from correlation to cause	A causal connection between two events	It was claimed that people who owned dogs showed evidence of having better than average qualities. The conclusion implied was that pet ownership is the cause of this improved social quality.
10	Argument from cause to effect	If one type of event occurs, then it is predicted the other would also occur.	When nations do not remain consistent in their policies, their prestige drops. We do not remain consistent in our policies. Therefore, our prestige is likely to drop.
11	Argument from consequences	This type of argumentation is used in a critical discussion where there is a divided opinion	There are bad consequences of the policy of mandatory retirement. Therefore, mandatory retirement is not a policy that we should have.
12	Argument from analogy	One case is said to be similar to another, in a certain respect.	Scientific research is similar to prospecting for gold. In the latter case, success is highly uncertain. The same can be said of scientific research.
13	Argument from waste	The speaker is striving to carry out a goal but suddenly begins to question whether continuing worthwhile. But then the speaker reasons all efforts will be wasted if I give up now, so I must continue.	Susan spent 5 years trying to finish her thesis. She intended to give up but then she thought I have put so much work into this. It would be a pity to give up now.
14	Argument from popularity	If a large majority accept A is true, then there exists a presumption in favor of A	Nearly everyone thinks that the lake is a good place to swim. Therefore Lake Cedar is probably a good place to swim in the summer.
15	Ethotic argument	If x is a person of good moral character, then what x contends should be accepted as plausible.	

16	Argument from bias	Negative type of argumentation. A respondent in a dialogue attacks a proponent's argument by claiming that the proponent is biased.	Unix is a major operating system Gates doesn't own. If NeXT program helps Unix become a standard, Gates may lose money and power.
17	Argument from an established rule	One participant in a dialogue is attempting to persuade another participant to carry out an action, and the other participant is resisting or questioning this persuasion	I don't think I will able to get my essay on Tuesday. Is it ok to hand it in the next week We all agreed that Tuesday is deadline. Sorry, that is the rule.
18	Argument from precedent	Citing a particular case to argue for changing an existing rule	I heard that you said someone to hand it on next week since she has another work to do. I have another work to do, too. So I should be able to hand it in next week, too.
19	Argument from gradualism	Series of small steps to persuade a respondent to accept a conclusion he or she would not accept in one big step.	A government needs to get an 18 % tax. However, the public would vote for in one single step, therefore the government adopts introducing 3 % each year.
20	The causal slippery slope argument	Warns a respondent that if he takes a first step, he will be caught up in a sequence of bad consequences	This is a step-by-step argument like gradualism but conclusion is "respondent do not take this step!"
21	Argument from vagueness of a verbal classification	Counter-argument to reply to an established rule or to verbal classification	Well the notion of poor return is too vague to be well defined what is a poor return?
22	The precedent slippery slope argument		The argument is that once you accept the religion, it will function as a precedent so that you will have to accept another and so on.

23	Argument from arbitrariness of a verbal classification	A rule or verbal classification is proposed by one participant in a dialogue is arbitrary or too arbitrary to support the argument on the other side in the dialogue.	The fetus should be considered a person through the third trimester You mean to say that the day before then the fetus is not a person. That is an arbitrary way of drawing a line.
24	The verbal slippery slope argument		
25	The full slippery slope argument	Once a first step is taken, it will lead by small steps (causal precedent or verbal type) to a sequence of further cases	

APPENDIX C

ARGUMENTATION ANALYSIS OF DISCOURSE DURING EXPERIMENT SESSION

Table C.1. Argumentation Schemes located in PSTs' discourse during experimentation session for Task 1. Hooke's Law

Argumentation Scheme	**Description**	**An Example Generated during Experimentation Session**
Argument from correlation to cause (with a frequency of 8)	A causal connection between two events	Example 1: (Monday group- while deciding on the control variable) PST A: Will we do that without considering the deformation of the spring? PST B: I did not understand PST A: The deformation of the spring, I mean, when we hang on masses, there will be an extension and it will stay like that. Example 2: (Wednesday group- while deciding on the manipulated variable) PST C: The amount of the manipulated variable is dependent on the force then.
Argument from verbal classification (with a frequency of 6)	a has a property F. For all x, if x has property F, then x can be classified as having property G. Therefore, a has property G.	Example 1: (Monday group-while deciding on the control variable) PST A: What should be the unchanging thing here? PST B: The original length of the spring, the starting length should be the same. PST A: We should call that as original distance or length Example 2: (Wednesday group- while deciding on the control variable) PST C: What about we say the spring constant at each part of the spring? PST D: No, we don't make it, it has already spring's property PST C: Whatever! PST D: No, we take the things that we can keep constant, let's say the starting point of the spring.
Argument from cause to effect (with a frequency of 6)	If one type of event occurs, then it is predicted the other would also occur.	Example 1: (Monday group- while discussing whether to ignore deformation of the spring) PST A: We should not ignore, I am serious PST B: I hanged on this and I won't measure only once, we will do the same thing twice or three times, which means if we do that, the spring will lose the first, I mean, the free length of it. Example 2: (Wednesday group- while discussing whether the starting point should be controlled) PST C: No, I don't think it is so necessary. I mean if the starting point changes, the point we hanged it on changes, would the elongation change?

Table C.1. (continued)

Argument from precedent (with a frequency of 6)	Citing a particular case to argue for changing an existing rule	Example 1: (Monday group- while discussing whether the spring always extends with hanged masses) PST A: So everybody agree that spring must extend when I apply a force PST B: Did you forget that there was a resistance of the spring? If you apply a very weak force, (it won't extend) Example 2: (Wednesday group- while trying to figure out a mathematical relationship) PST C: That is how we do in physics: if we take each interval as 5 cm, here we started at 2.5 but in mm. There were 1,2,3,4,5 (counts the number of intervals) so each one should be 10 cm, is that ok?
Argument from sign (with a frequency of 4)	Observation x is taken as evidence of event E	Example 1: (Monday group- while trying to find a relationship) PST A: So we will say that there was a linear relationship PST B: I did a measurement: 100 g did not cause any change. Example 2: (Wednesday group- while discussing if there was an exact linear relationship according to the graph) PST C: I said a mathematical relationship, I mean there is a linear relationship PST D: When we say it is directly proportional, I mean the magnitude of force is not necessarily the same but we mean that it increases as elongation increases, so not the square of it but it is just directly proportional.
Argumentation from example (with a frequency of 4)	If x has F then x will also have G	Example 1: (Monday group- while discussing whether to take deformation of the spring into account) PST A: You won't take it into consideration. It is like friction force, if so there is a loss of heat there and so on. Example 2: (Monday group- while discussing whether to take deformation of the spring into account) PST B: Of course, if you think so, it will extend more if we do the experiment in a desert.

Table C.1. (continued)

Argument from vagueness of a verbal classification (with a frequency of 3)	Counter-argument to reply to an established rule or to verbal classification	Example 1: (Monday group- while deciding on the manipulated variable) PST A: I think we can write force as manipulated variable, it should be force PST B: Actually, it is not a force we apply, but we should say different weights, it is reasonable. Example 2: (Monday group- while discussing where to start to measure the spring) Researcher: Please define what you mean by distance PST A: It is the place where the elongation stops beginning from the place where it rests when it is free. PST B: Hold on. The place where it is free does not differ. It is already the same for all.
Argument from expert opinion (with a frequency of 2)	This proposition is said to be to true by an expert	Example 1: (Monday group- while discussing where they can make a generalization of the results) PST A: Yes, for all springs until the weight exceeds the resistance of the spring. PST B: Resistance of what? PST A: Yes, if Hooke said like that, it must be true.
Argument from an established rule (with a frequency of 2)	One participant is attempting to persuade another participant to carry out an action, and the other participant is resisting or questioning this persuasion by citing a rule	Example 1: (Monday group- while trying to write down the relationship) PST A: Or we should say heavier the weight, longer the elongation. PST B: Here I would better look at the formula. Is it not like that f equals to k times x? So I would say which two are linear: x and f, aren't they? Example 2: (Monday group- whether to review the hypothesis in the light of the results) PST A: If we would use masses less than 100 g, say 50 g, there wouldn't be a change. Then we would say that we refute the hypothesis. But there is nothing wrong with the hypothesis; it is all about the resistance. We did not overcome that. PST B: Look, isn't it like when F is greater in the formula k times x. PST C: Elongation of the spring is longer PST B: The elongation increases.

Table C.1. (continued)

Argument from commitment (with a frequency of 1)	The respondent is committed to some particular position.	Example: (Wednesday group- while discussing if there are any controlled variable) PST A: But we cannot find anything as a control variable PST B: It is only weights, there is nothing else. There is force but it is impossible to keep the force constant.
Circumstantial argument against the person (with a frequency of 1)	Where arguer's circumstances are claimed to be contrary to his or her argument.	Example: (Wednesday group- while discussing whether to write the starting point can be a control variable) PST A: Yes, it would be, the place where we fix the spring PST B: But it may change PST C: No dear, it won't. We should fix the top of the spring so we can see the changes at the bottom.
Argument from evidence to a hypothesis (with a frequency of 1)	If a is true then b will be true.	Example: (Wednesday group- while discussing whether the length of the spring has an effect on the experiment) PST A: Which one should we use? PST B: It does not make difference because we will look at the elongation PST A: I think it differs PST C: But if the kind does not change, then won't it extend in the same way. The length of the spring is not our concern.
Argument from popularity (with a frequency of 1)	If a large majority accept A is true, then there exists a presumption in favor of A	Example: (Monday group- while discussing whether to write the force as a manipulated variable) PST A: I think we can write force as manipulated variable, it should be force. PST B: Yes, I think so PST C: I agree, ok, write force in a parenthesis
Argument from bias (with a frequency of 1)	Negative type. A respondent in a dialogue attacks by claiming that the proponent is biased.	Example: (Wednesday group- while discussing whether the length of the spring has an effect on the experiment) PST C: But if the kind does not change, then won't it extend in the same way. The length of the spring is not our concern. PST A: What do you mean by the same? How much does it extend? Our aim has already to identify how long it extends when we hang on how much mass?

Table C.1. (continued)

Argument from gradualism (with a frequency of 1)	Series of small steps to persuade a respondent to accept a conclusion	Example: (Wednesday group- while deciding on the manipulated variable) PST A: I cannot identify the manipulated PST B: It is force PST A: Is it force? Is it 10 N then? PST C: We should define what force is in this case. PST A: Yes but how we will define it? PST B: It is 10 N-force. PST A: Then measure it and we can write PST B: Ok, it is force. Before the experiment we should write it is force and 10 N. When we do the experiment we can write exact values. We have only force and elongation by the time.

Table C.2. Argumentation Schemes located in PSTs' discourse during experimentation session for Task 2. Black Box

Argumentation Scheme	**Description**	**An Example Generated during Experimentation Session**
Argument from correlation to cause (with a frequency of 20)	A causal connection between two events	Example 1: (Monday group- while discussing why much water came out from the box) PST A: We can say there was water in it before the show. There was some water at first but there had to be a thing to push it out, so when we put water, it came through a path and pushed it. Example 2: (Wednesday group- while discussing why much water came out from the box) PST B: (showing on the model he pictured) At first we had water at this level. It couldn't go through the other side because of the height. When the water pressure came here, because of the water pressure, it went through.
Argument from sign (with a frequency of 15)	Observation x is taken as evidence of event E	Example 1: (Monday group- while discussing possible system models) PST A: The system should be something circuitous PST B: Because water came out a little time later not instantly Example 2: (Wednesday group- while testing the model they hypothesized) PST C: (referring to the pipe) It must be tangled around. PST D: It should be at the bottom because all water inside the box came out.
Argument from evidence to a hypothesis (with a frequency of 12)	If a is true then b will be true.	Example 1: (Monday group- while testing the model they hypothesized) PST A: It is not something with a lid, friends. It is certainly something with a container but I don't know how to place that PST B: If it lies straight, the water inside will flow through when it is at this position. Example 2: (Wednesday group- while discussing why much water came out from the box) PST C: When we add water at this level, this part will be filled so there must be water at this level. Therefore this part will be full. I mean when the water flows, it will also move this part.

Table C.2. (continued)

Argument from gradualism (with a frequency of 5)	Series of small steps to persuade a respondent to accept a conclusion	Example 1: (Wednesday group- while discussing the model one of them hypothesized) PST A: … so it fell over when it reached maximum level of water, which is 450 ml PST B: You mean it is full with 250 ml, does it fall over after 250 ml? PST A: No 450 ml PST B: But there is something missing here. If it does not fall over after being full, there must be a mechanism to pull the water back. PST A: It is possible. There may be a spring. Example 2: (Wednesday group- while trying to explain the hypothesized model) PST C: Look at the end of the pipe. There should be something closed inside. Look, it came up to this point but it did not flow. PST D: It is normal PST C: What do you mean normal? PST D: Because of the pipe PST C: Because of the pipe or because there is a closed system there inside? I think there is a closed system.
Argument from vagueness of a verbal classification (with a frequency of 5)	Counter-argument to reply to an established rule or to verbal classification	Example 1: (Monday group- while arguing against a system with a lid) PST A: It is not a system with a lid because it does not explain why all of the water came out at once. Example 2: (Wednesday group- while testing the model they hypothesized) PST B: Did you mean that it will flow from this side when you fill the other side? PST C: Then if we add an amount, we should take that amount.
Argument from analogy (with a frequency of 4)	One case is said to be similar to another, in a certain respect.	Example 1: (Monday group- while testing the model they hypothesized) PST A: May I say something: is there a straight pipe in it? PST B: Yes but it doesn't need to be straight. PST A: Maybe there is a U –tube PST B: But there is a pipe at the bottom PST A: No, I mean, exactly the flusher system. Inside the flusher there is a U-tube like this. Example 2: (Wednesday group- while observing the black box) PST C: I think there is a closed system. The same logic like sucking fuel from the car with a pipe, it continues to flow.

Table C.2. (continued)

Argument from example (with a frequency of 3)	If x has F then x will also have G	Example: (Wednesday group- while observing the black box) PST A: Let me bring 250 ml, after 250, lets pour 50 ml more. PST B: Why? PST A: To see whether it starts to flow with 200 or 50? PST B: We already have added 200 ml. With this 200, it has been already 450 ml PST A: If we took 450 ml with additional 200 ml, will we have 300 ml with additional 50?
Argument from an established rule (with a frequency of 3)	One is trying to persuade another to carry out an action, and the other is resisting by citing a rule	Example: (Monday group- while testing the model they hypothesized) PST A: Look if we have the same amount of water PST B: But now, we cannot explain why water came out after a while but later all water came out. PST C: It is because it did not reach the threshold of the box.
Argument from cause to effect (with a frequency of 2)	If one type of event occurs, then it is predicted the other would also occur.	Example: (Monday group- while discussing the possible models) PST A: Actually there is water at the bottom but here there is a lid, I mean there are lids at both sides so when the pressure is enough it may come out at once. PST B: However, in this case, added water fills this part and not all water comes out.
Argument from consequences (with a frequency of 2)	In a critical discussion where there is a divided opinion	Example: (Monday group- while testing the model they hypothesized) PST A: It does not support your thesis… PST B: But if you add much water, it goes PST C: Do you know why: there was water in it in the first try.
Argument from waste (with a frequency of 2)	She suddenly questions whether continuing worthwhile. But she thinks that all efforts will be wasted if she gives up.	Example: (Wednesday group- when their findings did not support their hypothesis) PST A: Stop when it starts to flow PST B: We cannot know when it will start PST A: It will start when it is over PST C: Is it coming out? PST D: The system is broken down PST C: Didn't it come out at 350 PST A: Yes, it did PST D: It doesn't when the water is colored.

Table C.2. (continued)

Argument from precedent (with a frequency of 2)	Citing a particular case to argue for changing an existing rule	Example: (Wednesday group- while testing the model they hypothesized) PST A: There remains water here PST B: There must be water there PST C: Do you know where the problem is: we pour 350 and then we pour some more, which is to set this water in motion.
The full slippery slope argument (with a frequency of 2)	Once a first step is taken, it will lead by small steps (causal precedent or verbal type) to a sequence of further cases	Example: (Wednesday group- while testing the model they hypothesized) PST A: We need to adjust the height of this pipe PST B: How is it related with the height of the pipe? PST A: Because that water accumulated in that pipe PST B: The height of the pipe has already known PST A: Ok but all water came out from the pipe but the excess water did not.
Argument from arbitrariness of a verbal classification (with a frequency of 1)	A rule or verbal classification proposed is arbitrary or too arbitrary to support the argument	Example: (Monday group- while discussing the possible models) PST A: Thus, isn’t there something with a lid inside? PST B: There is not, I think, because when water reaches a level, it goes out on the other hand when it goes out there remains less water but it goes out, too.

Table C.3. Argumentation Schemes located in PSTs' discourse during experimentation session for Task 3. Candles

Argumentation Scheme	**Description**	**An Example Generated during Experimentation Session**
Argument from sign (with a frequency of 31)	Observation x is taken as evidence of event E	Example 1: (Monday group- while determining the densities of the liquids) PST A: Now we should define an interval for this one PST B: Once we know that is greater than this one, greater than 0.74 PST C: But it is smaller than the other one because it floats on it, isn't it? PST A: It floated on both but was closer to one of them, was closer to C PST B: Thus, should we say that it is between 0.74 and 0.917? Example 2: (Wednesday group- while determining the densities of the liquids) PST D: Did it sink more in this one? PST E: They were the same PST F: They seem the same looking from the outside PST D: Thus, C and B have almost the same density.
Argument from an established rule (with a frequency of 8)	One is trying to persuade another to carry out an action, and the other is resisting by citing a rule	Example 1: (Monday group- while trying to identify the density of the candle) PST A: Wait a minute it stays balanced PST B: No, it does not. It is not balanced; it does not stay where we left it. Example 2: (Wednesday group- while trying to refute that floating or sinking depends on the mass of the object) PST C: You increase the mass but keep the volume constant PST D: Do we try to keep the mass constant? PST F: No, try to keep the volume constant. PST D: The volume is constant and the mass is increasing, thus density is increasing. Density has to be changed.

Table C.3. (continued)

Argument from verbal classification (with a frequency of 7)	a has a property F. For all x, if x has property F, then x can be classified as having property G. Therefore, a has property G.	Example 1: (Monday group- while trying to identify the density of the candle) PST A: What is the density of C? 0.97 PST B: It floats on it, too. It is smaller than this one, too. PST A: Thus, x will be between 0.97 and 0.74 PST B: It should be around 0.80 Example 2: (Wednesday group- while trying to refute that floating or sinking depends on the mass of the object) PST C: I don't know if the volume is different PST D: Of course, it is. It turned to be sphere, the volume is less now.
Argument from evidence to a hypothesis (with a frequency of 6)	If a is true then b will be true.	Example 1: (Monday group- while trying to identify the density of the candle) PST A: If these two are too close to each other, mix to have another mixture PST B: The other one is also too close. In fact, these two are closer, I think. B and C will be too different, then. Example 2: (Wednesday group- while trying to refute that floating or sinking depends on the mass of the object) PST C: It would have sunk more, but it did not. Why? PST D: Because we do only small adjustments, I think we cannot change density so much. I think like this.
Argument from correlation to cause (with a frequency of 6)	A causal connection between two events	Example 1: (Wednesday group- while trying to identify the density of the candle) PST A: The volume depends on how much it increases the level of water. That is the volume of the candle. Example 2: (Wednesday group- while trying to refute that floating or sinking depends on the mass of the object) PST B: I mean, what if one of them has a greater mass PST C: But in this case the height of it will change.

Table C.3. (continued)

Argument from cause to effect (with a frequency of 6)	If one type of event occurs, then it is predicted the other would also occur.	Example 1: (Wednesday group- while discussing what the density depends on) PST A: What will happen when we heat the candle? PST B: Density PST A: Density will change? PST B: The candle will melt, too PST A: But no, density doesn't change because when m is reduced, V decreases, too. Example 2: (Wednesday group- while trying to find out the density of the candle) PST A: While the density increases, it has to go upward, hasn't it? Compared to A, doesn't it have to go up to the surface in B and C?
Argument from vagueness of a verbal classification (with a frequency of 5)	Counter-argument to reply to an established rule or to verbal classification	Example 1: (Monday group- while trying to identify the density of the candle) PST A: Which two do we mixed, B and C? PST B: Wait a minute, why did we mix those two? It has been already smaller than B and C. Example 2: (Wednesday group- while discussing about the liquids) PST C: It floats in B PST D: It is balanced PST C: B is water. Does it float on water? PST D: Not water PST E: I think, it sinks in water PST D: B is not water PST C: B is not water, then
Argument from example (with a frequency of 4)	If x has F then x will also have G	Example: (Wednesday group- while trying to observe the behavior of candles in liquids) PST A: First, I put the pink one. It floats. PST B: Ok, it will float on B, too but let's look the volume of the sunken part.
Argument from consequences (with a frequency of 3)	In a critical discussion where there is a divided opinion	Example: (Monday group- while trying to identify the density of the candle) PST A: Why did we choose B and not C? PST B: C is closer PST A: But we observed that it floats on C with a small part outside, and it floats on B with a big part outside. PST C: It does, but why did we take A and C but not A and B? Because the density of B is larger than the density of C. Therefore the interval becomes wider.

Table C.3. (continued)

Argument from waste (with a frequency of 3)	She suddenly questions whether continuing worthwhile. But she thinks that all efforts will be wasted if she gives up.	Example: (Wednesday group- while trying to refute that floating or sinking depends on the mass of the object) PST A: How successful are we, now? PST B: It is smaller PST C: It is smaller but it is still big. It doesn't become smaller, that is impossible. PST A: Yes, it cannot be squeezed more. PST C: I think, we would have squeezed this one less.
Argument from bias (with a frequency of 3)	Negative type. A respondent in a dialogue attacks by claiming that the proponent is biased.	Example: (Monday group- while discussing the possible procedures to identify the density of the candle) PST A: A cylindrical shape might be done PST B: If it is half sunken, they can calculate the volume, I think, but if it is not, they can't because they do not know the radius. PST C: For example, it cannot be perfect cylindrical.
Circumstantial argument against the person (with a frequency of 1)	Where arguer's circumstance is claimed to be contrary to his or her argument.	Example: (Wednesday group- while trying to refute that floating or sinking depends on the mass of the object) PST A: We can also say that in addition to this the amount of or the size of candle is not related with PST B: But to be able to say that, we need to use a smaller PST A: But I have already done PST B: Yes, you put a red one but PST A: I can do, you know.
Argument from expert opinion (with a frequency of 1)	This proposition is said to be to true by an expert	Example: (Wednesday group- while trying to refute that floating or sinking depends on the mass of the object) PST A: Both sank, there is nothing changed. PST B: According to the formula equation, the density would have been greater.

Table C.4. Argumentation Schemes located in PSTs' discourse during experimentation session for Task 4. Particle Theory of Matter

Argumentation Scheme	Description	An Example Generated during Experimentation Session
Argument from correlation to cause (with a frequency of 11)	A causal connection between two events	Example 1: (Monday group- while trying to find an evidence to the particle theory of matter) PST A: The structure of matter does not change. Because the distance between particles increases, the density of matter decreases. Example 2: (Wednesday group- while trying to find an evidence to the particle theory of matter) PST B: For example, in the evaporation process, water particles, since they have distances between, can evaporate and become invisible. Isn't this evidence that matter is made of particles without a need to condensation.
Argument from cause to effect (with a frequency of 5)	If one type of event occurs, then it is predicted the other would also occur.	Example 1: (Monday group- while trying to find an evidence to the particle theory of matter) PST A: We may say, for example, when we add salt to the water, if we think matter is not made of particles, it would remain as it is, but what happens is that it dissolves in water. Example 2: (Wednesday group- while discussing why evaporation is an evidence to the particle theory of matter) PST B: (If matter would not have been made of particles,) it would evaporate but it would evaporate as a whole at once, and it is impossible.
Argument from sign (with a frequency of 4)	Observation x is taken as evidence of event E	Example: (Monday group- while trying to find an evidence to the particle theory of matter) PST A: The balloon expanded, it shows that water evaporated PST B: That means, the balloon expanded and if it expanded, some of the water came from the beaker.
Argument from evidence to a hypothesis (with a frequency of 3)	If a is true then b will be true.	Example: (Monday group- while trying to identify the density of the candle) PST A: Let's see if the volume will increase. Look if the volume increases when it becomes liquid. PST B: Now, the water level will be less than 50 ml because some of the water has gone with the salt.

Table C.4. (continued)

Argument from example (with a frequency of 2)	If x has F then x will also have G	Example: (Wednesday group- while discussing why water molecules are evidence of the particle theory of matter) PST A: For example H_2O is a whole matter, a compound. When we compose it into H and O, we compose into atoms. Isn't this case an evidence of its particle property? I is composed of two particles, two different atoms.
Argument from consequences (with a frequency of 2)	In a critical discussion where there is a divided opinion	Example: (Wednesday group- while testing their hypothesis) PST A: Do you think you have changed the particle property of matter? PST B: It decomposes into particles; particles have gone to all sides. If the particles have gone although the mass is the same PST A: But doesn't the mass decrease? PST B: Now, it is a closed system. When it was this much, it covered this volume. It is the same water and the system is closed but it disperses, that means since it is made of things, it can disperse.
Argument from an established rule (with a frequency of 2)	One is trying to persuade another to carry out an action, and the other is resisting by citing a rule	Example: (Monday group- while discussing how dissolving process is an evidence of particle theory) PST A: It ionizes. Its solution… PST B: There must be a current for the electrical conduction.
Argument from precedent (with a frequency of 2)	Citing a particular case to argue for changing an existing rule	Example: (Monday group- while discussing how dissolving process is an evidence of particle theory) PST B: There must be a current for the electrical conduction. PST C: I can refute your case such that when we dissolve sugar in water, it dissolves like salt but it doesn't conduct electricity
Argument from analogy (with a frequency of 1)	One case is said to be similar to another, in a certain respect.	Example: (Monday group- while trying to find an evidence to the particle theory of matter) PST A: We can give an example of hot-air balloons. The air inside and outside of the balloon are the same air. When we heat the air inside, its density decreases. Since its density decrease, it becomes less dense than the air outside and the balloon flies.

Table C.5. Argumentation Schemes located in PSTs' discourse during experimentation session for Task 5. Evolution Theories

Argumentation Scheme	**Description**	**An Example Generated during Experimentation Session**
Argument from sign (with a frequency of 4)	Observation x is taken as evidence of event E	Example: (Wednesday group- while testing their hypothesized morphological tree) PST A: There are 17 matches between the gorilla and the common ancestor PST B: 12 between chimpanzee and common ancestor PST C: Thus gorilla and common ancestor are close to each other.
Argument from commitment (with a frequency of 3)	The respondent is committed to some particular position.	Example: (Wednesday group- while trying to propose an hypothesis) PST A: A step later from the gorilla can be chimpanzee, not apes so we can write gorilla at the top and chimpanzee under that. PST B: I think, since we are on the side of the common descent theory, we should say that human and chimpanzee have some common properties, too.
Argument from example (with a frequency of 1)	If x has F then x will also have G	Example: (Wednesday group- while trying to propose an hypothesis) PST A: I think chimpanzee is between because it has common things with both PST B: No, I think there should be gorilla and human under the branch of chimpanzee. If chimpanzee evolved to those two but there is something like gorilla and common ancestor also have lots of similarities.
Argument from correlation to cause (with a frequency of 1)	A causal connection between two events	Example: (Wednesday group- while trying to draw a conclusion) PST A: Thus, we can say, for example, that the difference between chimpanzee and common ancestor might be because of the adaptation PST B: As the time passing, to adapt to the environment, chimpanzee evolved and changed in some properties. After a while, human is evolved to adapt.

Table C.5. (continued)

Argument from cause to effect (with a frequency of 1)	If one type of event occurs, then it is predicted the other would also occur.	Example: (Wednesday group- while evaluating data) PST A: Firstly, chimpanzee and human are also similar so much PST B: Moreover, there is something. We said all evolved from common ancestor but for example, gorilla has more matching DNA than chimpanzee, and human has less than all. Therefore if their familiarity would be the same to the common ancestor, they would have similar number of matching bases.
Argument from vagueness of a verbal classification (with a frequency of 1)	Counter-argument to reply to an established rule or to verbal classification	Example: (Wednesday group- while evaluating data) PST A: In this case, gorilla evolved to human and chimpanzee PST B: No, it did not because the similarity between gorilla and human is not significant.

Table C.6. Argumentation Schemes located in PSTs' discourse during experimentation session for Task 6. The Structure of Light

Argumentation Scheme	**Description**	**An Example Generated during Experimentation Session**
Argument from sign (with a frequency of 22)	Observation x is taken as evidence of event E	Example 1: (Monday group- while observing the way light follows) PST A: It is reflected on a certain area PST B: But is there only one light coming from the source? What type of source do we have, point source? PST C: No, it only hits this part and it cannot pass through because we don't see through the other slit. Example 2: (Wednesday group- while observing the way light follows) PST D: This is my first observation: in the three holes cardboard everywhere is bright except three holes because the light goes through them.
Argument from correlation to cause (with a frequency of 18)	A causal connection between two events	Example 1: (Monday group- while observing the way light follows) PST A: It is not shadow, it is light coming PST B: That is the light itself PST C: That is the light coming from here PST D: Because the source sends the light dispersed like a point light source. Example 2: (Wednesday group- while discussing why shadows are formed) PST E: There were two different shadow tones. PST F: They could be because they reset their wavelengths.
Argument from precedent (with a frequency of 5)	Citing a particular case to argue for changing an existing rule	Example 1: (Monday group- while observing the way light follows) PST A: Yes, because the thing we saw was just that it follows a straight path. PST B: But if we could see the light between, could we say something related to the particle property? We didn't see the light between we just saw the reflection of it on the screen because of the setting. Example 2: (Wednesday group- while discussing particle property of the light) PST C: So you say there is photon. PST D: Do I need to prove whether there is photon or photon has energy? I can support that photon has energy because it explains the ETS (electron transport system) in the photosynthesis process.

Table C.6. (continued)

Argument from example (with a frequency of 4)	If x has F then x will also have G	Example: (Monday group- while discussing particle property of the light) Assistant: How do you know there are particles? PST A: Because there need to be something with energy, there must be a particle which can eject an electron from the surface.
Argument from verbal classification (with a frequency of 4)	For all x, if x has property F, then x can be classified as having property G.	Example: (Monday group- while observing the way light follows) PST A: Because the holes were closed PST B: It cannot pass through non transparent surfaces. It stays there.
Argument from evidence to a hypothesis (with a frequency of 3)	If a is true then b will be true.	Example: (Monday group- while discussing what if the light does not follow a straight line) PST A: There won't be a spot. Now there will be weird light beams. PST B: Or there will be larger shapes like a square.
Argument from cause to effect (with a frequency of 3)	If one type of event occurs, then it is predicted the other would also occur.	Example: (Monday group- while discussing the wave property of light) PST A: The light beams going through the same slit were observed in a different shape. PST B: If it follows a straight line through these slits we would see certain lines I mean the shape of slits but we did not see those. Instead we saw a pattern with dark and bright areas
Argument from gradualism (with a frequency of 3)	Series of small steps to persuade a respondent to accept a conclusion	Example: (Wednesday group- while discussing the evidence of photoelectric effect) PST A: Evidence is that it ejects electrons when it hits the surface. PST B: There is a current. PST C: There is a need of energy. PST B: We can say that there is energy in the light. PST D: We will say there are photons in the light.
Argument from analogy (with a frequency of 2)	One case is said to be similar to another, in a certain respect.	Example: (Wednesday group- while discussing the evidence of photoelectric effect) PST A: At last there is something let's say this is particle. PST B: Yes. For example when we are exposed to the sun we feel warm. We feel the heat energy.
Argument from an established rule (with a frequency of 2)	One is trying to persuade another to carry out an action, and the other is resisting by citing a rule	Example: (Monday group- while discussing the reflection of light) PST A: In this case we cannot mention about the reflection here. PST B: Doesn't the black surface absorb light? White reflects. PST C: Yes, black absorbs.

Table C.6. (continued)

Argument from vagueness of a verbal classification (with a frequency of 2)	Counter-argument to reply to an established rule or to verbal classification	Example: (Wednesday group- while discussing the evidence of photoelectric effect) PST A: We will say there are photons in the light. PST B: We cannot know that there are photons. There is something which goes through a straight line but it has energy.
Argument from consequences (with a frequency of 1)	In a critical discussion where there is a divided opinion	Example: (Wednesday group- while discussing the evidence of photoelectric effect) PST A: No my friend. We have nothing to do with the wave model. PST B: Because we cannot explain that it has energy because of something but not the movement.
Argument from bias (with a frequency of 1)	Negative type. A respondent in a dialogue attacks by claiming that the proponent is biased.	Example: (Wednesday group- while discussing the way light follows) (One of them drew straight line to represent the light and he put arrows on the lines) PST A: But doesn't it cause bias because if it goes like that, for example if the arrow on the last light line shows that this line goes in such a way, it cannot pass through and we cannot see that.

APPENDIX D

ARGUMENTATION ANALYSIS OF DISCOURSE DURING CRITICAL DISCUSSION SESSION

Table D.1. Argumentation Schemes located in PSTs' discourse during critical discussion session for Task 1. Hooke's Law

Argumentation Scheme	**Description**	**An Example Generated during Critical Discussion Session**
Argument from evidence to a hypothesis (with a frequency of 10)	If a is true then b will be true.	Example 1: (Monday- While discussing whether there is a threshold of the spring to start to extend) PST A: …we thought that the extension of the spring can be or cannot be observed in all situations. We did not think that there is a threshold. PST B: We say that there is a resistance of the spring. Unless this resistance is surpassed, there won't be any extension. Example 2: (Wednesday- while discussing whether there will be any extension with all masses) PST C: Based on these results, we concluded that the direction of elongation and the direction of the force applied will be the same. I mean, if the force is horizontal, the extension will be horizontal.
Argument from sign (with a frequency of 6)	Observation x is taken as evidence of event E	Example 1: (Monday- while discussing if there was an extension with small masses) PST A: How do you know if you didn't see an extension? PST B: We don't assume that there is a mm change in the spring. Because we took measurements individually in each case and take the average. But in this case none of us saw a change. So we said that its related to the resistance of the spring. Example 2: (Wednesday- while discussing if there was an extension with small masses) PST C: There is a threshold point of a spring. PST D: We saw the extension with 200 g but not with 100 g.
Argumentation from example (with a frequency of 3)	If x has F then x will also have G	Example: (Wednesday- while discussing whether the structure of spring is important in extension) (If a mass is hanged on a spring and it causes deformation…) PST A: In this case, you suppose there is a change in circumstances. PST B: For example the spring did not measure 100 g. So it won't measure 1 ton, either.

Table D.1. (continued)

Argument from commitment (with a frequency of 3)	The respondent is committed to some particular position.	Example: (Wednesday- while discussing if the formula can be an evidence to support) PST A: I think, it is my idea, if you look at from here for example what if k increases. We need to think about it. You change the spring. It depends on the spring.
Argument from correlation to cause (with a frequency of 3)	A causal connection between two events	Example: (Wednesday- while discussing their conclusions) PST A: Teacher we think we could write an equation. PST B: Yes, we did. We think that there is a proportion between the applied forces and spring's elongation. PST C: Yes it's directly proportional, and close to the constant. We think there is a constant because we used the same kind of spring.
Argument from precedent (with a frequency of 3)	Citing a particular case to argue for changing an existing rule	Example: (Monday- while discussing if their measurements were not accurate) PST A: No, they are not false. If we generalize, we think, there can be milimetric differences in measurements. The exact figures which show the elongation may be different but we saw what we want to see. PST B: In this case, yes, we generalize as long as we exceed the resistance of the spring.
Circumstantial argument against the person (with a frequency of 2)	Where arguer's circumstances are claimed to be contrary to his or her argument.	Example: (Wednesday- While discussing what to write to the horizontal axis of the graph) PST A: Mass does not affect this. The force which pulls down is the gravitational force. Therefore we have to write weight or force in Newton instead of mass. PST B: If we would write force, you were right. But we drew graph with mass because we considered mass.
Argument from cause to effect (with a frequency of 2)	If one type of event occurs, then it is predicted the other would also occur.	Example: (Wednesday- while discussing if there was an extension with small masses) PST A: We saw the extension with 200 g but not with 100 g. PST B: In this case, we can use a longer spring. If we use very long spring to measure 1 ton, it takes the spring away.

Table D.1. (continued)

Argument from consequences (with a frequency of 2)	In a critical discussion where there is a divided opinion	Example: (Monday- while discussing if there is a resistance of the spring) PST A: In our case, 100 g was not enough to overcome this resistance. PST B: We did not think it as resistance. Differently, we just thought that we should not hang on small masses so we can observe the elongation.
Argument from bias (with a frequency of 2)	Negative type. A respondent in a dialogue attacks by claiming that the proponent is biased.	Example: (Wednesday- while discussing why spring did not extend with small masses) PST A: We refuted our first hypothesis which states that there will be more elongation if we apply more force. PST B: But we applied 50 and we did not see any elongation. We applied 100 and we did not see, either. PST C: It might be because of the devices we used.
Argument from verbal classification (with a frequency of 1)	a has a property F. For all x, if x has property F, then x can be classified as having property G. Therefore, a has property G.	Example: (Monday- while discussing why spring did not extend with small masses) PST A: For the same would happen, for example, to ignore the resistance I mean, we all would have used the same spring, wouldn't we? All the springs we used would have been the same. PST B: We saw the extension with 100 g. But they did not see because the springs were different.
Argument from expert opinion (with a frequency of 1)	This proposition is said to be to true by an expert	Example: (Wednesday- while discussing if the formula can be an evidence to support) PST A: You change the spring. It depends on the spring. PST B: Assume there is the same spring. As long as the force increases, doesn't the elongation increase? This is a mathematical equation, my friend.
Argument from an established rule (with a frequency of 1)	One tries to persuade another participant to an action, and the other questions this persuasion	Example: (Wednesday- while discussing if there is a resistance of the spring) PST A: There have to be a threshold of the spring and it doesn't extend unless you overcome the threshold. PST B: If you would use more flexible spring, can't you see elongation with 100 g? If there is, you will observe.

Table D.1. (continued)

Argument from vagueness of a verbal classification (with a frequency of 1)	Counter-argument to reply to an established rule or to verbal classification	Example: (Monday- while discussing if there is a resistance of the spring) PST A: We say that spring starts to extend as long as we exceed its resistance. PST B: There is a situation like that the resistance of the spring is not the same always. In our case, 100 g was not enough to overcome this resistance.
Argument from arbitrariness of a verbal classification (with a frequency of 1)	A rule or verbal classification proposed is arbitrary or too arbitrary to support the argument	Example: (Monday- while discussing if there is a resistance of the spring) PST A: We used 100 g and as a result we would either say that we refuted our hypothesis or that we should review our hypothesis. We should consider what we observe. PST B: But you, I mean, why you used resistance is because you did not see anything observable. That's why you thought it is resistance.

Table D.2. Argumentation Schemes located in PSTs' discourse during critical discussion session for Task 2. Black Box

Argumentation Scheme	**Description**	**An Example Generated during Critical Discussion Session**
Argument from correlation to cause (with a frequency of 7)	A causal connection between two events	Example 1: (Monday- while discussing the models constructed) PST A: First, we made a hole at the bottom of a plastic bottle. Second, we put it with an angle and we poured water through this hole. Then the bottle fell off and we got much water than we added. PST B: How did it fall off? PST A: We put the bottle with an angle and we supported it with a hinge. Example 2: (Wednesday- while discussing the models constructed) PST C: When we fill it with some amount of water there is only atmospheric pressure here. But when it comes to this level. PST D: For example if we say H here, there is water pressure of this much H at this level and also there is an atmospheric pressure effective here. In addition, there is an atmospheric pressure coming from opposite side. These atmospheric pressures cancel each other and there remains only water pressure so water goes through this side.
Argument from evidence to a hypothesis (with a frequency of 4)	If a is true then b will be true.	Example: (Wednesday- while discussing where the water pressure is effective) PST A: It even flows through with a weak force. PST B: To make this happen for example if we fill something with water in a system and we have a pipe. PST C: Then if we fill the pipe with water, put that pipe on the base and stand the pipe to the same level I mean this level (shows where the water in the bottle is), all water will flow.
Argument from precedent (with a frequency of 4)	Citing a particular case to argue for changing an existing rule	Example: (Monday- while discussing the role of the u tube) PST A: There is an effect of this u tube. For example, if we would placed a pipe up to this level, we can have as much as we add but this u tube takes much water then this pipe.

Table D.2. (continued)

Argument from sign (with a frequency of 3)	Observation x is taken as evidence of event E	Example: (Monday- while discussing why they think there was water before the show) PST A: I want to say something else. We observed that there was no water flowing through when we add 300 ml water. When we exceed 300 ml, it started to flow. So we claimed that there is a threshold level of water.
Argument from bias (with a frequency of 3)	Negative type. A respondent in a dialogue attacks by claiming that the proponent is biased.	Example: (Monday- while discussing why one of the groups used hot water) PST A: Okay but the thing we are discussing here is not how many times the system works. It is how the system works. PST B: I don't think it is wrong but we didn't use hot water when we are experimenting. Did you infer that at the beginning the teacher used hot water?
Argument from cause to effect (with a frequency of 2)	If one type of event occurs, then it is predicted the other would also occur.	Example: (Monday- while discussing how a system with a falling bottle works) PST A: Even after it loses its balance, this force continues but if you fill more water, the magnitude of the force increases. PST B: I think that system would fall off soon if it is going to fall. It would not fall after 10 or 20 seconds because we always add the same amount of water. The amount of water doesn't increase or decrease.
Argument from consequences (with a frequency of 2)	In a critical discussion where there is a divided opinion	Example: (Monday- while discussing how a system with a falling bottle works) PST A: The amount of water doesn't increase or decrease. PST B: I don't understand this relationship because she says that the force is always the same. On the other hand, I say that the force is the same but after the system loses water, it doesn't matter how much water you add; it falls anyhow.
Argument from analogy (with a frequency of 2)	One case is said to be similar to another, in a certain respect.	Example: (Monday- while discussing the models constructed) PST A: We thought the threshold level of water is here because we saw nothing up to this level. PST B: It is like a pump. For example, you suck water from a pipe until you have some water and when you leave it you can't stop it flowing.

Table D.2. (continued)

Argument from vagueness of a verbal classification (with a frequency of 2)	Counter-argument to reply to an established rule or to verbal classification	Example: (Wednesday- while discussing whether the system depends on pressure) PST A: We use the pressure to start adhesion. We use it only to start the flow, the rest of it was adhesion. PST B: Actually your system depends on adhesion too, does not depend on pressure. PST C: We got the same amount of water when there is only pressure.
Argument from an established rule (with a frequency of 1)	One is trying to persuade another to carry out an action, and the other is resisting by citing a rule	Example: (Wednesday- while discussing the role of pressure in the systems) PST A: Don't we think the equation as one sided because the equation works only when the atmospheric pressure is equal but it doesn't need to be equal to gas pressure to repel all water. PST B: But there needs to be the gas pressure equal to the atmospheric pressure. Then there won't be any exchange of molecules.
Argument from arbitrariness of a verbal classification (with a frequency of 1)	A rule or verbal classification proposed is arbitrary or too arbitrary to support the argument	Example: (Wednesday- while discussing the role of u tube) PST A: I want to ask that unless you use this u tube in an upright position, will you get the same result. PST B: No, it doesn't. Because the water accumulates in it.

Table D.3. Argumentation Schemes located in PSTs' discourse during critical discussion session for Task 3. Candles

Argumentation Scheme	Description	An Example Generated during Critical Discussion Session
Argument from correlation to cause (with a frequency of 10)	A causal connection between two events	Example 1: (Monday- while discussing whether floating depends on mass) PST A: But isn't it homogeneous? PST B: Since we used the same candle as you said if we decrease the mass, density needs to be changed. Eventually it needs to float, doesn't it? Example 2: (Wednesday- while discussing whether the change of density is chemical or physical change) PST C: I say it is chemical. PST D: Because density can change only by temperature. For example, when the circumstances are changed as well the density or pressure.
Argument from cause to effect (with a frequency of 5)	If one type of event occurs, then it is predicted the other would also occur.	Example 1: (Monday- while discussing if the mass can be constant as the volume is changing) PST A: If its inside is empty, it is possible. PST B: If it is the same matter and its volume is the same, the mass would be the same. If the matters are different inside, the volumes and the masses would be different. Example 2: (Wednesday- while discussing if the mass can be constant as the volume is changing) PST C: For example if you look at the sizes of the control, I mean, there are temperature and pressure. If we keep them constant, we cannot obtain anything but if we change them, we do. PST D: As we observed, there is no change in the temperature but there might be pressure because spaces between molecules disappear.
Argument from evidence to a hypothesis (with a frequency of 4)	If a is true then b will be true.	Example: (Monday- while discussing if the mass can be constant as the volume is changing) PST A: We make it heavier in weight by squeezing. PST B: So you change the density. PST C: But when the density changes as well the candle do.
Argument from analogy (with a frequency of 3)	One case is said to be similar to another, in a certain respect.	Example: (Monday- while discussing if they can make any matter float) PST A: Or if I make it wider. PST B: You can float a plate on water but if you take a piece of porcelain it won't float.

Table D.3. (continued)

Argument from bias (with a frequency of 3)	A respondent in a dialogue attacks by claiming that the proponent is biased.	Example: (Monday- while discussing if the mass can be constant as the volume is changing) PST A: They have different masses. PST B: They have the same volume. PST C: It isn't possible but you propose that you squeezed it.
Argument from sign (with a frequency of 2)	Observation x is taken as evidence of event E	Example: (Monday- while discussing if the mass can be constant as the volume is changing) PST A: We chose the liquid A. When we put 1.27 g of candle into, it floated. When we put 0.01 g of candle, it sank. It shows us that the floating is not related to the mass.
Argument from consequences (with a frequency of 2)	In a critical discussion where there is a divided opinion	Example: (Monday- while discussing what the density depends on) PST A: It isn't a controlled experiment as the pressure changes. Pressure must be constant. PST B: The change in volume does not affect the density. The density is constant under standard conditions.
Argument from precedent (with a frequency of 2)	Citing a particular case to argue for changing an existing rule	Example: (Wednesday- while discussing the effect of temperature on density) PST A: There is an effect of pressure too but it is still a physical property. PST B: If it would be a chemical property, does it matter to change the temperature? For example the density of water is different at 20 C and 50 C temperature but its chemical properties are the same.
Argument from verbal classification (with a frequency of 1)	a has a property F. For all x, if x has property F, then x can be classified as having property G. Therefore, a has property G.	Example: (Monday- while discussing the effect of water temperature on floating) PST A: But there is something like that when we put in the liquid A and then take it out from the refrigerator, the candle floated on it. PST B: We did the same thing for the others. Another thing that we tested was that the candle was sinking in liquid A at first. When we heat the liquid A, we thought it would have floated but it didn't because the liquid's density decreases.

Table D.3. (continued)

Argument from commitment (with a frequency of 1)	The respondent is committed to some particular position.	Example: (Monday- while discussing if the mass can be constant as the volume is changing) PST A: There cannot be the same candle with the same volume but different mass. PST B: Why not? PST A: Because probably we cannot keep the volume constant. Only we can keep the mass constant.
Argument from expert opinion (with a frequency of 1)	This proposition is said to be to true by an expert	Example: (Wednesday- while discussing if the mass can be constant as the volume is changing) PST A: We squeezed. That is we could apply pressure. PST B: I mean if you look at the formula (d = m/v) it should change.
Argument from an established rule (with a frequency of 1)	One is trying to persuade another to carry out an action, and the other is resisting by citing a rule	Example: (Monday- while discussing if the mass can be constant as the volume is changing) PST A: We cannot do that in liquids it is very difficult but it can be done with the gases. PST B: You say we can do that in gases. However in gases we change the pressure.
Argument from vagueness of a verbal classification (with a frequency of 1)	Counter-argument to reply to an established rule or to verbal classification	Example: (Monday- while discussing if the mass can be constant as the volume is changing) Researcher: I asked a different question. Is it possible to have the same matter with the same volume but a different mass? PST A: It is not possible. Because in this case it won't be the same matter.

Table D.4. Argumentation Schemes located in PSTs' discourse during critical discussion session for Task 4. Particle Theory of Matter and the Law of Conservation of Mass.

Argumentation Scheme	**Description**	**An Example Generated during Critical Discussion Session**
Argument from correlation to cause (with a frequency of 13)	A causal connection between two events	Example 1: (Monday- while discussing if the state of salt change when it is in water) PST A: No dear. We didn't change the structure of the compound. PST B: When dissolve salt in water it decomposes into sodium and chlorine ions. To observe that we applied electricity and if the bulb lights on, the current flows. Example 2: (Wednesday- while discussing if dissolution is a chemical change) PST C: Can water molecules apply pressure to the spaces between NaCl? I mean do they separate because of water? Can we say that sodium chloride applies pressure to the water molecules and it separates them so water molecules go away from each other?
Argument from sign (with a frequency of 9)	Observation x is taken as evidence of event E	Example 1: (Monday- while presenting their experimental results) PST A: For example we thought the change of state. We took ice, we melted it. First we measured its volume before melting and we measured once more after it turned to water. According to our results, we compared the volumes that are the distance between particles, we said that the volume of the ice is larger. Example 2: (Wednesday- while presenting their experimental results) PST B: We took iron dust and a magnet. At first our magnet attracted iron. Then we took metal dust. They were too small and they were still attracted by the magnet. We could have divided it smaller particles but anyway we saw that matters are made of particles.

Table D.4. (continued)

Argument from verbal classification (with a frequency of 5)	a has a property F. For all x, if x has property F, then x can be classified as having property G. Therefore, a has property G.	Example 1: (Monday-while discussing whether there is a need for a chemical reaction) PST A: Sodium and chlorine need to enter a chemical reaction. PST B: But for example we don't have a chemical decomposition. There is only a dissolving process and similarly if we evaporate water we can obtain sodium chloride which means there is a physical process here. Example 2: (Wednesday- while discussing whether there is a need for a chemical reaction) PST C: We decompose a molecule into its components. PST D: It's chemical reaction absolutely. PST E: Because when sodium and chlorine come together, they form a different matter which means they don't carry their own properties.
Argument from expert opinion (with a frequency of 4)	This proposition is said to be to true by an expert	Example: (Wednesday- while discussing whether there is a need for a chemical reaction) PST A: But don't we learn that when sodium chloride dissolves, it decomposes into its ions and sugar dissolves into its molecules. I mean sugar stays as $C_6H_{12}O_6$ but sodium chloride dissolves as Na and Cl. … PST B: But there is something we learnt that chemical reactions are not reversible.
Argument from evidence to a hypothesis (with a frequency of 4)	If a is true then b will be true.	Example: (Monday- while discussing how salt dissolves in water) PST A: I don't think there are breaking up. But how anodes and cathodes go to different places in water. PST B: Anodes and cathodes don't go anywhere. PST C: If they were breaking up, when we evaporate the water, there won't be salt remaining.
Argument from cause to effect (with a frequency of 4)	If one type of event occurs, then it is predicted the other would also occur.	Example: (Wednesday- while discussing how the evaporation of water supports the particle theory of matter) PST A: If it was a whole matter and not made of particles, it would evaporate at once. However if I keep some of the water in the bottle and some of them evaporates it means it is not a whole matter but it has particles.

Table D.4. (continued)

Argument from consequences (with a frequency of 4)	In a critical discussion where there is a divided opinion	Example: (Wednesday- while discussing the electrolysis) PST A: We could condense that gas and have water back. PST B: If it would separate to H and O, we would expect not to have it back. However we want it to be water back.
Argument from precedent (with a frequency of 3)	Citing a particular case to argue for changing an existing rule	Example: (Monday- while discussing the electrolysis) PST A: How does it become liquid? PST B: Salt cannot conduct electricity in a solid state. PST C: Nobody see table salt conduct electricity.
Argument from example (with a frequency of 2)	If x has F then x will also have G	Example: (Monday- while discussing electrical conductivity) PST A: For example, sound conduction is seen in solids and it is less in liquids and the least in gases. There wouldn't be any conduction if they are not made of particles. Therefore we can support another thing that solids have more particles than liquids and gases.
Argument from bias (with a frequency of 2)	Negative type. A respondent in a dialogue attacks by claiming that the proponent is biased.	Example: (Wednesday- while discussing whether there is a need for a chemical reaction) PST A: It is not something like composing into its components but it is more like separating into small pieces. PST B: Maybe there was not enough activation energy so there was not explosion. PST C: Maybe there were H and O but they didn't react.
Argument from an established rule (with a frequency of 2)	One is trying to persuade another to carry out an action, and the other is resisting by citing a rule	Example: (Wednesday- while discussing electrical conductivity) PST A: Then how does it conduct electricity? PST B: But water itself conducts electricity. PST A: Pure water doesn't conduct electricity. PST C: But it was not pure water. It was tap water. PST A: There are not ions in it.
Argument from vagueness of a verbal classification (with a frequency of 2)	Counter-argument to reply to an established rule or to verbal classification	Example: (Wednesday- while discussing whether there is a need for a chemical reaction) PST A: But the chemical reactions are not reversible. PST B: There is nothing like chemical reactions are not reversible. It is not acceptable because there are reverse reactions.

Table D.4. (continued)

Argument from analogy (with a frequency of 1)	One case is said to be similar to another, in a certain respect.	Example: (Monday- while discussing if dissolution is a chemical change) PST A: (If it were a chemical reaction) We would have sodium and chlorine PST B: There was an experiment in physics class. For example there was a copper and a compound and that copper pieces were covering that compound. They were dissolving like ions. Therefore, here salt should dissolve to sodium and chlorine.
Argument from popularity (with a frequency of 1)	If a large majority accept A is true, then there exists a presumption in favor of A	Example: (Wednesday- while discussing whether there is a need for a chemical reaction) PST A: Maybe there were H and O but they didn't react. PST B: There is no need to activation energy for H and O come together. We all know that when they come together, they explode.
Argument from arbitrariness of a verbal classification (with a frequency of 1)	A verbal classification proposed is too arbitrary to support the argument	Example: (Wednesday- while discussing the ionization of salt is reversible) PST A: Are we sure that the evaporated water is only the water? I mean do we evaporate water extricating sodium and chlorine? Is it the same water we have at first?

Table D.5. Argumentation Schemes located in PSTs' discourse during critical discussion session for Task 5. Evolution Theories

Argumentation Scheme	**Description**	**An Example Generated during Critical Discussion Session**
Argument from sign (with a frequency of 6)	Observation x is taken as evidence of event E	Example 1: (Monday- while discussing the ladder theory) PST A: We thought that the similarity shows which comes the next. For example, gorilla cannot come from human because there are 10 matches but there are 15 matches between chimpanzee and human. Therefore, we said that human evolved from chimpanzee. Example 2: (Wednesday- while discussing common ancestor theory) PST A: We decided that human is more evolved than gorilla because when we looked at the number of matches between common ancestor and human, we saw 10 matches. That is there are less matches than gorilla. Gorilla and common ancestor have 17 matches. Therefore gorilla is closer to the common ancestor.
Argument from evidence to a hypothesis (with a frequency of 5)	If a is true then b will be true.	Example 1: (Monday- while discussing the ladder theory) PST A: We thought that if two of them have more number of matches, one evolved from the other. Example 2: (Wednesday- while discussing the ladder theory) PST A: However, it is not valid for gorillas and chimpanzees because they are still alive. PST B: If human evolved from gorilla, there won't be any gorilla now.
Argument from commitment (with a frequency of 3)	The respondent is committed to some particular position.	Example: (Monday- while comparing the theories) PST A: Do you mean that there is no common ancestor? If there is no common ancestor, how did you explain? PST B: Initially, we put the common ancestor at first. When we looked at the DNA sequences we thought that there can be a common ancestor but because we started with ladder theory, we removed common ancestor.
Argument from expert opinion (with a frequency of 3)	This proposition is said to be to true by an expert	Example: (Wednesday- while explaining the common ancestor theory) PST A: How do you explain the evolution? I mean how did they evolve? PST B: According to Darwin, the evolution occurs through adaptation.

Table D.5. (continued)

Argument from cause to effect (with a frequency of 2)	If one type of event occurs, then it is predicted the other would also occur.	Example: (Wednesday- while discussing the common ancestor theory) PST A: We don't say that each has different characteristics but eventually because they evolved, because they evolved as different species, they are different organisms. PST B: We mean that the reason of being different is the process of evolution.
Argument from analogy (with a frequency of 2)	One case is said to be similar to another, in a certain respect.	Example: (Monday- while discussing their hypotheses) PST A: When we looked at DNA sequences, we saw that it is not like one evolves from another. To support this we used tree model. According to the tree model, the root of the tree is the common ancestor and branches of the tree are gorilla, chimpanzee and human.
Argument from vagueness of a verbal classification (with a frequency of 2)	Counter-argument to reply to an established rule or to verbal classification	Example: (Monday- while discussing their hypotheses) PST A: As a result, it is a process. In this process the closest one to the common ancestor is gorilla. PST B: Do you say something like, I don't understand, whether you claim that common first evolved to gorilla, then chimpanzee, and at last human? Is there any transmutation?
Argument from example (with a frequency of 1)	If x has F then x will also have G	Example: (Wednesday- while discussing their hypotheses) PST A: In our first hypotheses, we drew a common ancestor and we said that human is a different species. We thought that there is another species, and chimpanzee and gorilla would be under this species. But we counted the number of matches and we decided it is impossible.
Circumstantial argument against the person (with a frequency of 1)	Where arguer's circumstance is claimed to be contrary to his or her argument.	Example: (Monday- while discussing their hypotheses) PST A: She said that chimpanzee evolved but if we look at the DNA sequences, I mean we compared and it was not like that. The first hypothesis is rejected.
Argument from correlation to cause (with a frequency of 1)	A causal connection between two events	Example: (Wednesday- while discussing their hypotheses) PST A: The lizards evolved from the organisms living in the past. Now, those organisms are not alive because they evolved. However, there can't be such a thing between gorilla and chimpanzee because gorilla and chimpanzee are still alive.

Table D.5. (continued)

Argument from consequences (with a frequency of 1)	In a critical discussion where there is a divided opinion	Example: (Monday- while discussing their hypotheses) PST A: There is no transmutation. It is a process. PST B: Is there a transformation from gorilla to chimpanzee? PST A: No, if it would be, we couldn't do it as branches. Here the root is the common ancestor but there is a process.
Argument from gradualism (with a frequency of 1)	Series of small steps to persuade a respondent to accept a conclusion	Example: (Monday- while discussing their hypotheses) PST A: You said there is a process. PST B: Yes, it is a process. It is not something happen suddenly. PST A: Is it only a process of time? Is there any effect of environment? PST B: Yes, it is time. PST C: It illustrates how close to the common ancestor. PST A: It is a different condition. It is not process then. It is relativeness.

Table D.6. Argumentation Schemes located in PSTs' discourse during critical discussion session for Task 6. The Structure of Light

Argumentation Scheme	**Description**	**An Example Generated during Critical Discussion Session**
Argument from sign (with a frequency of 4)	Observation x is taken as evidence of event E	Example: (Monday- while discussing the way light follows) PST A: Yes, it follows a straight line. The light going through the hole causes a bright spot on the screen. The rest of the screen stays dark because light cannot go through if there is no hole.
Argument from correlation to cause (with a frequency of 2)	A causal connection between two events	Example: (Monday- while discussing why light has particles with energy) PST A: The reason is the electron is ejected. We need energy to eject an electron and we said that this energy comes from particles with energy.
Argument from example (with a frequency of 1)	If x has F then x will also have G	Example: (Monday- while discussing the wave property of light) PST A: How did you understand it is wave? PST B: If it is not wave, if it is only a particle going through a straight line, there will be smooth rectangular shape on the screen but we didn't see that.
Argument from cause to effect (with a frequency of 1)	If one type of event occurs, then it is predicted the other would also occur.	Example: (Monday- while discussing the way light follows) PST A: If it doesn't follow a straight line. PST B: We wouldn't see clear cut shapes, we would see scattered shapes. PST C: We wouldn't see the shape of the hole, either. PST B: There wouldn't be shadow.