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Assessing Pre-Service Science Teachers' Understanding of Scientific Argumentation: What Do They Know About Argumentation After Four Years of College Science?

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ABSTRACT: The purpose of this study was to assess pre-service science teachers' understanding of science, scientific argumentation and the difference between scientific argumentation and scientific explanation. A total of 40 pre-service science teachers enrolled in a Turkish university completed a five-question questionnaire. The results showed that the majority of participants lacked an adequate understanding of science, scientific argumentation, the difference between scientific explanation and scientific argumentation. Implications of these findings for science teacher education, classroom instruction and assessment were elaborated.

KEY WORDS: Pre-service science teachers, argumentation, assessment.

INTRODUCTION

Current science education reform documents and science education research agree that students in K-12 classrooms need to be afforded rich opportunities to develop an adequate understanding of science and engage in scientific practices such as argumentation and modeling (National Research Council [NRC], 2000; 2013]. Argumentation, especially has received significant attention from science educators within the last 10 years across the globe (Berland & Reiser, 2008; Erduran & Jimenez-Aleixandre, 2008; McNeill & Krajcik, 2008; Sampson & Blanchard, 2012). One of the reasons why argumentation has received such significant attention is because it is believed that learning science through argumentation help students to develop an improved understanding of nature of science (Driver, Newton & Osborne, 2000; Kuhn, 1993) and conceptual understanding of core scientific ideas covered by formal curriculum (Duschl, Schweingruber, & Schouse, 2007; McNeill & Krajcik,

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2008; Songer & Wenk Gotwals, 2012). However, research on teachers' beliefs about and knowledge of argumentation show that most teachers hold naïve beliefs about scientific argumentation and lack pedagogical knowledge to teach science through argumentation (Sampson, 2009; Simon, Erduran & Osborne, 2006; Sampson & Blanchard, 2012). Most important, limited research on the connection between teachers' beliefs and practice show that teachers' knowledge and beliefs about scientific argumentation and explanation influences their pedagogical decisions regarding scientific explanations (Beyer & Davis, 2008; Forbes et al., 2013; McNeill, Lizotte, Krajcik, & Marx, 2006; McNeill, Pimentel & Strauss, 2013; McNeill & Krajcik, 2008; Minogue et al., 2010; Zangori, Forbes & Biggers, 2013). Given the importance of teachers' beliefs and knowledge in their pedagogical decisions (Nespor, 1987; Haney, Czerniak, & Lumpe, 1996; Tobin, Tippin, & Gallard, 1994; Zangori et al., 2013), we seek to explore pre-service science teachers' understanding of science, scientific argumentation and the difference between scientific argumentation and scientific explanation. Science educators have conducted research on in-service and pre-service science teachers' argumentation skills (Ozdem et al., 2013; Sampson, 2009); they have explored the impact of argumentation on pre-service teachers' conceptual understanding (Aydeniz et al., 2012; Kaya, 2012), and their pedagogical knowledge to teach science through argumentation (McNeill & Knight, 2013). However, studies exploring teachers' understanding of argumentation and explanation are lacking in science education literature. Exploring pre-service science teachers' understanding of scientific argumentation and explanation is important, because scholars agree that teaching science through argumentation requires science teachers who

a. understand the value of argumentation in the generation of scientific knowledge and learning of science (McNeill, Pimentel & Strauss, 2013),
b. the structure of scientific argumentation, elements of argumentative discourse, and value argumentation as an instructional practice to promote student learning of science in the classroom (Lizotte, McNeill, & Krajcik, 2004; McNeill, Lizotte, Krajcik, & Marx, 2006; Sampson, 2009; Simon et al., 2006).

Moreover, it has potential to affect the criteria that the teachers use to evaluate the quality of an argument.

Research Questions

The research question that guided our inquiry is: What do pre-service science teachers know about science, scientific argumentation and the difference between scientific argumentation and scientific explanation?

REVIEW OF RELEVANT LITERATURE

An increase in the number of argumentation related publications and conference presentations within the last 10 years implies that science educators have embraced the idea of teaching science through argumentation (Ozdem et al., 2013; Robertshaw & Campbell, 2013; Sampson & Blanchard, 2012). Argumentation has been defined in myriad ways in science education literature. Common to all definitions of argumentation is the notion of "reasoned discourse" and "justification of claims to knowledge through use of scientific evidence" (Driver, Newton, & Osborne, 2000). For instance, Sampson & Clark (2008) define argumentation as "a knowledge building and validating practice in which individuals attempt to establish or validate a conclusion, explanation, conjecture, or other claim on the basis of reasons (as stated in Sampson & Blanchard, 2012, p.1123). Duschl and Osborne (2002) on the other hand describe scientific argumentation as a practice that is used "to solve problems and advance knowledge" by scientific community (p. 41).

Scientific argumentation can be viewed as "an *individual* activity" that takes place when the learner is engaged in reasoned discourse either through thinking or writing, or as "a "*social* activity taking place within a group" (Driver et al., 2000, p. 291). When it takes place within a group it has a dialectical character and calls for questioning and defense of knowledge through reasoned discourse and evidence (Sampson, Enderle, Grooms &Witte, 2013). While elaborating on the social aspect of argumentation Leita (2001) states:

> *The dialectical roles of proponent and opponent in argumentation are highly specific. The proponent is expected to advance a viewpoint and to defend it against counter-arguments and the critical questioning raised by the audience. The audience takes the role of opponent…for a dialogical exchange to turn into genuine argumentation, the participants must propound and justify their viewpoints while leaving room for these views to be examined in the light of the opposing claims and critical questions posed by the audience (p. 6).*

It follows that while written arguments can be described as evidence-based reasoned discourse, argumentation can be described as the process whereby two or more people are trying to challenge one person's claims to knowledge through questioning, while the proponent is trying to justify and defend his/her claim to knowledge through reasoned discourse. In spite of argumentation being a core scientific practice, we know little about teachers' understanding of argumentation. Exploring science teachers' understanding of argumentation during pre-service teacher education is critically important as it can give us the opportunity to address any weaknesses in their understanding of argumentative nature of science.

Another point of contention in argumentation studies is the difference between argumentation and explanation. While science educators have embraced the idea of teaching science through argumentation, the word argumentation and explanation has been interchangeably used in most studies (Osborne &Patterson, 2011). In fact, this confusion has already generated some discussion among science educators (e.g., see Berland & McNeill, 2012). Therefore, there is a conscious effort among science educators to use the two terms more carefully. Osborne and Patterson (2011) state, "if a field lacks clarity about the concept that it seeks to explore and promote as a feature of classroom practice, then it will fail to communicate its meaning and intent to the wider audience of curriculum developers, standards developers, and teachers."(p. 628). Drawing on work of Thagard (2008), Osborne and Paterson (2011) presents an argument for this differentiation. They argue that argument and explanation are "two discursive entities" (p. 629) in that while explanation "attempts to account for the given phenomenon" and serves as a mechanism to describe "how" and "why" the phenomenon occurs, an argument "examines the question of whether the explanation is valid…or whether it is better than competing accounts" (p. 629). "Within this view, the purpose of explanation construction in the science classroom is for students to make sense of how the world works by connecting the cause and effect of natural phenomena" (Zangori, Forbes & Biggers, 2013, pp. 991-992) through why and how questions.

While this discussion has been taking place among science education researchers, we know little about science teachers' understanding of scientific argumentation and explanation and the difference between the two. Given the importance placed on the role of argumentation in student learning across recent science education literature (Osborne, 2010) and most recent science education reform documents (Duschl et al., 2007; NRC, 2000; 2007; 2012) it is critical that science teachers develop a sophisticated understanding of science, scientific argumentation, scientific explanation and the difference between scientific argumentation from scientific explanation. Such understanding is crucial not only for the teachers to frame the purpose of their assessments but also for them to effectively "scaffold students' efforts to formulate evidence-based explanations." (Zangori et al., 2013, p. 994). Moreover, research shows that when teachers explicitly scaffold students' efforts to construct scientific explanations, they develop better conceptual understanding of scientific ideas promoted by school curriculum. (McNeill & Krajcik, 2008; Ruiz-Primo et al., 2010; Songer & Wenk Gotwals, 2012; Zangori et al., 2013).

In spite of the importance of science teachers' understanding of argumentation in their pedagogical decisions, we found only one study (Sampson, 2009) that looked at science teachers' conceptions of argumentation. Sampson (2009) conducted a study with 30 middle and high school science teachers in Florida and found that while teachers value argumentation as a way to improve the quality of student learning, they held naïve conceptions about scientific argumentation. He reported that most teachers ignore data in their scientific explanations. Furthermore, he found that their conceptions of quality scientific arguments are not in line with the conceptions accepted by science education research community. Sampson calls upon science education to invest efforts into exploring science teachers' conceptions of argumentation. We take upon his call and the identified gap in argumentation literature to explore pre-service science teachers' conceptions of scientific argumentation.

METHODOLOGY

Consistent with the aim of this study we used a mixed method case study approach in this study (Merriam, 2001). While we used an open-ended questionnaire to elicit participants' understandings, and content analyses in evaluating participants' responses, we used frequency statistics to report the results of our analyses. While asking open-ended questions provided the most meaningful data, and content analyses afforded the opportunity to develop more meaningful interpretation, frequency calculations allowed us to more effectively report the results of our analyses.

Context and Participants

The participants were 40 pre-service elementary science teachers-seniors, chosen from an elementary teacher education program in Turkey. The sample was largely female; females (n = 29, 72.5%) and males (n=11, 27.5%). The mean age of the participants was 22.50 years (SD = 1.01). The participants were enrolled in an elective course entitled "experimental design and application in chemistry". The participants were selected through purposeful sampling. In our sample selection we wanted to work with pre-service teachers who had taken sufficient number of required content and pedagogy courses and experience with practicum in the local schools. Our survey of the participants prior to the intervention showed that participants had not been exposed to argumentation in an explicit manner in their teacher education program or in their learning experiences in K-12 settings. This ensured that there was no prior argumentation-based learning experience in formal schooling.

Data, Data Collection and Analyses

We collected data through an open-ended questionnaire that consisted of five questions (see Appendix A). The questions targeted participants' understanding of science, scientific argumentation, purpose of scientific argumentation, components of scientific argumentation and the difference between scientific argumentation and scientific explanation. After we received permission from the students for participation in the study, the participants were given 40 minutes to complete the questionnaire. After students completed the questionnaire, we collected their answers.

We used content analyses to evaluate participants' responses. Data analyses took place in several stages.

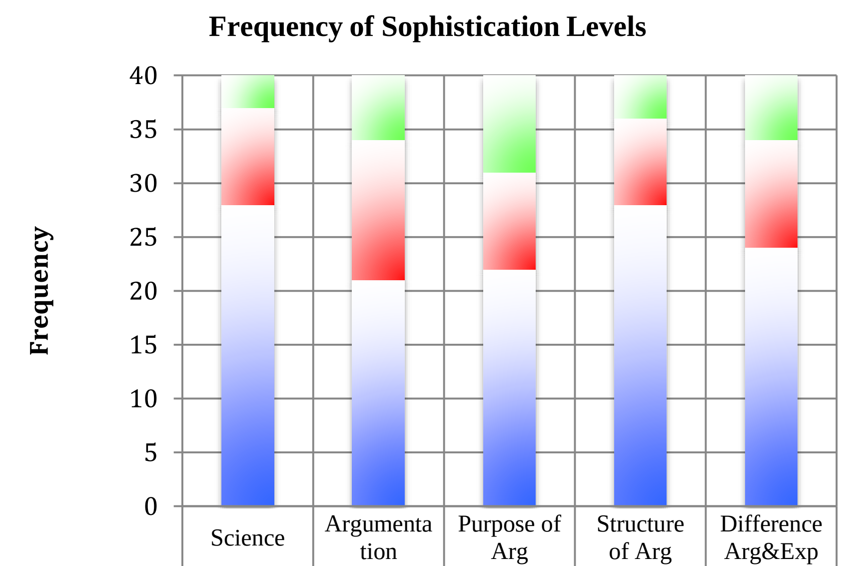
a. Each author independently read each answer for each question to become familiar with participants' responses.
b. Borrowing from the nature of studies (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2002), and by consulting argumentation studies in science education (e.g., Berland & McNeill, 2012; Erduran & Jimenez, 2008; Osborne & Patterson, 2011; Sampson, 2009) we developed a rubric to evaluate participants' responses and classify them into naïve, transitional and informed categories.
c. This rubric was applied to evaluate 10 participants' responses independently. After this initial evaluation we came together to discuss the rubric. We sought another colleague who also had done research in argumentation to provide feedback. We refined the rubric based on the discussion and the feedback we received from our colleague.
d. The refined rubric was used to independently evaluated participants' responses and categorized them as either being naïve, transitional or informed. After this process, we compared our evaluations/categorizations question by question for each participant and addressed any disagreements when occurred and came to consensus.
e. Frequencies were calculated for each sophistication level for each question and reported in a bar graph (Figure1). We also calculated the average scores (on a scale of 1-3, with 1 being naïve, 2 being transitional and 3 informed) for each question and reported it in a graph (Figure 2).

Establishing the Trustworthiness

The trustworthiness of qualitative research is often questioned because its validity and reliability cannot be established in the same way as the positivist studies do however; qualitative research has its own methods of establishing quality in scientific research (Miles & Huberman, 1995). Among others, these include: credibility, dependability and confirmability. Credibility is established by using established research methods, basing our analyses on articulation of the definitions of argumentation and explanation provided in the literature and by consulting "expert" opinion and debriefing between evaluators in data analyses. Dependability is addressed by providing detailed descriptions of data collection and analyses methods. Miles and Huberman (1995) consider that a key criterion for ensuring confirmability is the extent to which the researchers admit their own predispositions and provide detailed descriptions. We address this criterion by providing thick descriptions in the reporting of findings and by acknowledging our subjectivity in limitations section.

RESULTS

The results showed that pre-service science teachers held naïve views about science, scientific argumentation and various aspects of science scientific argumentation including the difference between argumentation and explanation. We summarized the statistics for science and each aspect of argumentation explored in Figure 1.



	Science	Argumentation	Purpose of Arg	Structure of Arg	Difference Arg&Exp
Informed	3	6	9	4	6
Transitional	9	13	9	8	10
Naïve	28	21	22	28	24

Figure 1 **Sophistication level of participants' responses for each category.**

Participants' Views of Science

The first question focused on participants' understanding of science. For the science category, 70% of the participants expressed naïve views, 22.5% transitional views, and 7.5% informed views. Those who held naïve views (n=28) emphasized the role of objectivity, controlled experimentation and utility of scientific information for daily life. One such participant said: "Science refers to all of the carefully and objectively conducted investigations that produce generalizable conclusions. Most of the things that we use in our everyday lives that make living easier for us are products of science" when asked to define science. Another participant who was also categorized as holding a naïve view said:

> *Science is the field of study that tries to explain the living and non-living things, in a nutshell the field that tries to explain everything. It uses controlled experiments, observations and predictions as methods to develop products that help us live a comfortable life.*

Participants holding naïve views, while acknowledged the role of controlled experiments in the production of scientific knowledge, they did not elaborate on how scientists use the evidence that they gather from the experiments to develop theories. Not only did they fail to elaborate on the process of theory formation but they also ignored the subjectivity involved in the production of scientific knowledge.

In addition to those holding naïve views about science, 22.5% of the participants (n=9) held transitional views. These participants, while also emphasized the role of controlled scientific experimentation in science, defined the purpose of science as an attempt to understand nature. One such participant said, "Science is trying to understand nature by asking and pursuing answers to how and why questions by using verifiable observational and experimental data. It is a systematic and objective method of investigation that tries to generate theories." Another participant who was also categorized as holding transitional views said, "Science refers to the process whereby scientists are trying to develop new knowledge based on experimental/investigational data. The purpose of science is to understand nature by studying evidence and developing theories based on that evidence."

While the majority of participants held naïve views about science, 7.5% of the participants (n=3) held informed views about science. For instance, one such participant said:

> *Science is a field that develops theories based on observational/experimental/ investigational data. Science constantly improves and helps advance what we know about nature. It both helps advance the knowledge and improves the quality of our lives. The scientific knowledge is tentative; it responds to new evidence and can be modified based on new evidence. Scientists often benefit from what other scientists have produced earlier in developing their theories from the evidence they collect through controlled experiments.*

Another participant who was also categorized as having informed views about science said the following:

> *Science is a modern phenomenon that tries to develop theories based on observational and experimental data. However, they benefit from ideas conveyed in the literature to design new investigations. Science is very important for nations' advancements and economies; therefore, scientists' efforts produce new knowledge that can be used to develop new technologies. These efforts while produce new technologies; they also help us understand the natural and physical world better. Science tries to be as objective as it can be and it changes/evolves with time and as a result of new attempts to understand the nature with the aid of more advanced technologies.*

What separates these answers from the answers in other sophistication categories is that these participants explicitly stated the goals of science being theory development and understanding of nature through investigations. They also point out both the tentative nature of science and the theory-laden aspect of science. For instance, both answers acknowledge that scientists partly rely on existing knowledge to produce new knowledge.

Participants' Views of Argumentation

The second question measured participants' understanding of argumentation. For the argumentation, 52.5 % of the participants (n=21) held naïve views, 37.5% of participants (n=13) held transitional and 15% of participants (n=6) held informed views. Those holding naïve views about scientific argumentation defined the purpose of scientific argumentation as to reach a conclusion or to discover the truth. One such participant said, "It [argumentation] is the process whereby scientists express their opinions about a particular topic and talk about it. The purpose of these discussions is to better understand the nature and space." Another participant who was also categorized as holding naïve views said. "The process scientists use to discover the truth. It is in-depth discussion of ideas by scientists." While both of these examples defined argumentation, they failed to acknowledge the role of scientific evidence and the process of justification in the process of reaching a conclusion. While the first answer acknowledged that scientists discuss, there was no reference to scientific evidence or the process of scientists defending and justifying their answers. The participant framed the definition of argumentation as discussion rather than framing it through the language of critical discussion or reasoned discourse. This was a deficit understanding of scientific argumentation.

While the majority of the participants held naïve views 37.5% of participants (n=13) held transitional views about scientific argumentation. Those who held transitional views acknowledged the role of scientific evidence and discourse in scientific argumentation; they failed to effectively elaborate on the structure of argumentative discourse. One participant who were categorized as having a transitional level answer said:

> *Argumentation refers to the process of attempting to reach a conclusion by scientists about the correctness of an uncertain claim to knowledge. However, in doing so, they do not discuss ideas that cannot be justified through scientific evidence. Therefore, they only use experimental and observational data.*

Different from the answers that were categorized as being naïve, this transitional view acknowledges the role of scientific evidence and the process of justification. In addition, instead of defining argumentation as discussion, it defines it as justification. Another limitation is that the participants who fell under this category did not provide elaboration.

The results show that only a small number of participants (n=6, or 15%) held informed views about argumentation. Those holding informed views acknowledged the presence of: competing claims/hypotheses, the process of justification and defending claims and scientific evidence. We provide two examples of answers that fit into this category.

> *It [argumentation] is the process, whereby scientists holding different claims to knowledge come together to share, discuss and defend their ideas and hypotheses or theories. Einstein's response to Newton's theories is a form or scientific argumentation. Similarly, Einstein's and his colleagues' efforts to explain, justify and defend his claims based on the observations, experiments and investigations, is also a form of scientific argumentation [Participant 1].*

> *The process of attempting to reach a conclusion by different scientists about the correctness of an uncertain claim to knowledge. Scientists either establish the correctness of an idea or reject the idea. The idea is that you are trying to justify a claim to knowledge by drawing on objective scientific evidence. Scientific argumentation takes place between scientists working on the same topic and who have credibility in the field. The argumentation can take place over similar results or over different results by different scientists. [Participant 3].*

Across these answers, one can observe that the participants acknowledged the presence of competing claims, or a claim whose legitimacy has not been established scientific evidence, expert opinion, and made references to the process of defending and justifying claims.

Purpose of Argumentation

The third question measured participants' understanding of the purpose of argumentation. The results showed that the majority of the participants (i.e. pre-service science teachers) (55% or n=22) held naïve views, 22.5% or n=9 held transitional views and 22.5% or n=9 held informed views about the purpose of scientific argumentation. Those holding naïve views in this category failed to elaborate on the purpose of scientific argumentation. One such answer read, "Argumentation takes place in situations when an explanation does not satisfy people. People react to the situation by offering alternative explanations." Another answer read, "The purpose of scientific argumentation is to identify the best solution that will address human needs." Yet another one read, "the purpose is to make information more useful and to reach the truth."

While all of these answers are somewhat relevant to the purpose of scientific argumentation, they fail to capture the essence of the purpose of scientific argumentation, which is to justify claims to knowledge through scientific evidence and epistemic norms of science.

Those holding a transitional view emphasized the notion of persuading others, or each other, about the accuracy or weaknesses of a claim to knowledge, or emphasized the need to reach consensus about the validity of a claim. In addition, they acknowledged the role of scientific evidence in their responses.

We provide two examples of such responses below.

> *The purpose is to try to convince others of the benefits of a product, an idea over the other one. In doing so, scientists benefit from their experiences and what they know from the relevant literature. [Participant 1].*

> *A scientific argumentation takes place either when scientists experience disagreement over findings related to an idea or when they try to establish the benefits and detrimental effects of a product. Argumentation is sometimes undertaken when scientists brainstorm about the utility of a product for a specific purpose. [Participant 3].*

Those holding transitional views about the purpose of scientific argumentation, while defined the purpose of argumentation well they failed to acknowledge the role of scientific evidence. Yet the role of scientific evidence was implicitly conveyed. For instance, the first participant eludes to scientific evidence by saying "scientists benefit from their experiences and what they know from the relevant literature."

While only 22.5% or n=9 of the participants held informed views about the purpose of scientific argumentation, all of the answered captured the essence of scientific argumentation. One such exemplary statement read as:

Argumentation can be undertaken for multiple purposes: to support, to reject or to modify a theory via use of scientific evidence and method of justification. The purpose is to reach the most correct idea, to undo the validity of an existing idea, to identify the weaknesses and strengths of a hypothesis, or to strengthen the validity of a hypothesis or a theory.

Another answer that was characterized as being informed read:

Scientific argumentation is undertaken to support, to reject or to modify an explanation or a theory. Through argumentation, we can address the weaknesses of a scientific theory or law. The idea is that scientists will use the universal norms of science and critically interpret and evaluate scientific evidence to justify claims to knowledge in an effort to establish truth or to advance knowledge.

A close examination of these exemplary statements indicates that while they vary in their wordings, they both provide a comprehensive perspective on the purpose of scientific argumentation. That is to establish, to support, to refute or to improve the validity of a claim to knowledge, through the use of scientific evidence.

Views about the Structure of Scientific Argumentation

The results showed that the participants struggled the most with the elements of a scientific argument with 70% of the participants (n=28) holding naïve views, 20% (n=8) holding transitional views and 10% (n=4) holding informed views. Those holding naïve views, while made references (even implicitly) to the presence of two competing claims, failed to explicitly name the process of justification, warrants, scientific evidence and rebuttal in scientific argumentation. One answer that was categorized as being naïve read as, "Argumentation has to be *objectiv**e***, done by experts and every side should have equal opportunity to express their ideas. The two sides of argumentation needed to provide credible sources/evidence for their arguments." Another such statement read as, "A scientific argument must be objective. There needed to be sufficient evidence to back a claim. Each person needed to have equal opportunity and time to express their ideas."

While the majority of the participants hold naïve view about scientific argumentation, few participants (n=8) hold transitional views about elements of a scientific argumentation. We provide two exemplary statements that we categorize as being transitional below.

It consists of evidence collected through scientific experiments and experts who have credibility to speak about the topic on the table. More precisely, it must be scientific, done by experts and has to be objective and fair. Scientists use their knowledge to convince the other scientists. [Participant 1].

Argumentation consists of the topic to be discussed; the purpose of discussion, data collected through controlled and systematically conducted scientific experiments. Scientists produce scientific knowledge through systematic interpretation of scientific evidence so evidence is key to this process. [Participant 2].

Both of these statements while do not fully capture the scope of scientific argumentation, they emphasize the role of scientists, the purpose of argumentation and scientific evidence in the process.

While most of the participants hold naïve views, 10% of the participants (n=4) hold informed views about elements of a scientific argumentation. We provide two exemplary statements below to show how they differ from the naïve and informed views in terms of sophistication.

Scientific argumentation includes: the purpose of argumentation, experts who have credibility in the field, the topic to be discussed must be of significant importance in terms of science, the methods of argumentation, presence of alternative hypotheses, use of critical thinking and problem solving strategies, and scientific evidence. All of these collectively will contribute to the quality of an argumentation. [Participant 1].

The components of a scientific argumentation include: scientific evidence, scientists holding alternative hypotheses and proponents and opponents of these alternative hypotheses, and undecided audience. The purpose of scientific evidence is to help scientists back their claims to knowledge. They use scientific evidence to make interpretations and to develop theories. The main goal of scientists is to justify and defend their claim to knowledge. The goal of the audience is to become informed about alternative hypotheses, to look at things from alternative perspectives and to improve their literacy. [Participant 2].

A close examination of these statements indicates that while they both do not use the language of science education community (i.e., claim, evidence, warrant, qualifier, rebuttal), they capture most of the elements that are part of a scientific argumentation. For instance, they acknowledge presence of evidence, experts, alternative hypotheses, purpose, justification and audience.

The Difference between Scientific Argumentation and Scientific Explanation

Participants also struggle with separating scientific explanation and scientific argumentation from one another. In explaining the difference between the two, 60% express naïve views, 25% express transitional views and 15% express informed views. We provide two exemplary statements for views that fall under this category.

> *Yes, there is a difference between the two. While scientific argumentation is undertaken to address existing problems or to reach a conclusion, scientific explanation is communication of universally accepted truth. [Participant 1].*

> *Scientific explanation is necessary to communicate a new discovery to the audience. Scientific argumentation is undertaken to see if there are any new implications of the discovered data for the problem at hand. [Participant 2].*

While the majority of participants express a naïve view 25% of the participants (n=10) convey an understanding that is characterized as being transitional. Those who are placed in this sophistication category provide more specific language and elaboration. The following two examples show how transitional statements differ from the naïve statements reported earlier.

> *A scientific explanation can result in scientific argumentation. Scientific explanation is the communication of theories that have been justified through scientific methods and evidence… Scientific argumentation can take place about any topic. Experts or scientists do scientific argumentation. An idea, problem or concept is critically discussed from different perspectives. [Participant 1].*

> *Yes, there is a difference. Scientific explanation is the communication of an idea whose validity has been established through controlled scientific experiments and scientific evidence. While scientists use the scientific evidence and methods during scientific argumentation, the purpose here is to reach a conclusion by critiquing and comparing alternative ideas. [Participant 2].*

These statements highlight, or make an attempt to establish, the importance of critical discourse in scientific argumentation. Similarly, they provide more elaboration in their attempts to separate scientific explanations from scientific argumentation.

Only 15% of the participants (n=6) are able to show an informed understanding of the difference between scientific explanation and scientific argumentation. We share two exemplary answers that qualified to be in the informed category.

> *Yes, there is a difference between the two. Scientific argumentation takes place when there is more than one competing claim to knowledge (hypotheses, theories). Scientists use the related hypotheses, theories and evidence to establish the validity of the most compelling theory or idea. A scientific explanation is the type of knowledge whose validity has been established by all scientists using scientific evidence and methods. There is a consensus about this type of knowledge. In essence, in both cases we use scientific evidence and scientific methods to arrive at a conclusion. Scientific argumentation is used to refute the weaker explanations. [Participant 1].*

> *Yes, there is a difference between the two. A scientific argumentation is undertaken between different scientists defending different alterative explanations on the same topic. Scientific argumentation can be undertaken through writings or in person explanations using visuals etc. A scientific explanation is the process of scientists trying to explain a scientific idea, theory in detail to a specific audience. The purpose is to help the audience understand an established scientific fact. In scientific argumentation, scientists try to justify their position by using scientific evidence and reasoning. [Participant 2].*

The participants who expressed informed views while also explicitly stated the differences between scientific explanation and scientific argumentation, also provided an elaboration on the differences.

Summary of Findings

The results collectively reveal several deficiencies in participants' understandings related to science, argumentation, purpose of argumentation, elements of a scientific argumentation, and the difference between scientific argumentation and scientific explanation. While participants score poorly on almost all categories, their understanding of science receives the lowest score. The second lowest scores are related to the elements of a scientific argumentation and the difference between a scientific argumentation and scientific explanation (Figure 2).

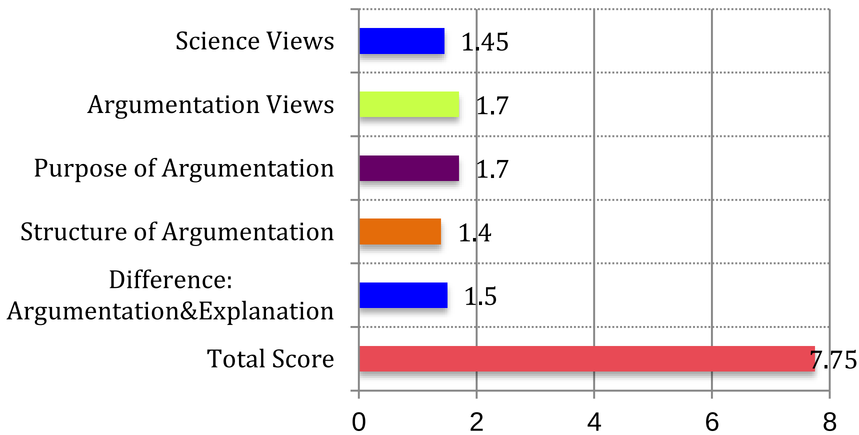


Figure 2 **Participants' performance across all questions on a scale of (0-3) + average total score. Maximum total score achievable is 15.**

DISCUSSION

With emerging evidence that document benefits of argumentation for students' learning of core scientific concepts, there has been an increasing push for inclusion of argumentation into school science curricula across the globe (Erduran & Jimenez, 2008; Larrain, 2014; Newton, Driver & Osborne, 1999; Osborne, Erduran &Simon, 2004; Sampson & Blanchard, 2012; Venville & Dawson, 2010). While there has been an increasing push for the inclusion of argumentation in science curricula, this type of "persuasive discourse" was not a characteristic of a typical science classroom (Berland & McNeill, 2010, p. 766). One of the reported reasons for the absence of scientific argumentation in science classrooms was teachers' limited understanding of scientific argumentation (Larrain, 2014; Ozdem et al., 2013; Sampson, 2009). In this study, we explored pre-service science teachers' understanding of science, scientific argumentation and the difference between scientific argumentation and scientific explanation.

The results showed, not surprisingly, that the majority of participants lacked an informed understanding of science, scientific argumentation, the purpose of scientific argumentation, components of a scientific argumentation and the difference between scientific argumentation and scientific explanation. This was a major concern because it showed that we were not able to help our students to develop a sophisticated understanding of the processes that led to the generation of established scientific knowledge in spite of 4 years of education in science. Pre-service science teachers' naïve understandings of science, scientific argumentation, purpose and structure of scientific argumentation as well as their limited understanding of the difference between scientific argumentation and scientific explanation had significant implications for classroom teaching and assessment as well (McNeill &Knight, 2013).

Hatano and Inagaki (1991) report that when students engage in argumentation, learners move between the acts of presenting their understanding of the phenomenon, evaluating and critiquing others' understandings of the same phenomenon, and modifying or refining their own understandings of the phenomenon based on their participation in argumentation. In order for students to successfully engage in this type of scientific argumentation, or to construct quality scientific arguments, they need to understand the purpose of argumentation, the structure of scientific arguments. It is unrealistic to expect students to have such understanding if their teachers lack such understanding (McNeill & Knight, 2013). For instance, we already know from the literature that students experience significant challenge in supporting their arguments with sufficient evidence (Sandoval & Millwood, 2005) or selecting appropriate data as evidence in support of their claims (McNeill & Krajcik, 2008). Research shows that when teachers scaffold students' efforts to construct scientific explanations in an effective manner, students develop a more robust understanding of scientific concepts under investigation (McNeill & Krajcik, 2008; Ruiz-Primo et al., 2010; Songer & Wenk Gotwals, 2012). If teachers themselves do not know the structure of a scientific argument and the role that evidence plays in forming an argument that can withstand criticism, they can be expected to have a hard time helping their students to form such arguments.

In addition, teachers' understanding of science and their understanding of the argumentative nature of science can impact their pedagogical decisions when it comes to framing student thinking, designing learning activities and assessment. For instance, one aspect of constructing scientific explanation is to establish connections between cause and effect that is how and why of the understanding. If teachers fail to provide such framing, "their explanations may be limited to what they have observed." (Zangori et al., 2013, p.992). So when student learning is not scaffolded effectively through teacher framing, students may be naturally forced to provide descriptions of their observations instead of providing explanations and arguments. This prevents students from engaging in and practicing with epistemologies of science, which in turn has significant implications for student learning. This implication is both for their understanding of the nature of science as well as their understanding of core scientific ideas (i.e. products of scientific argumentations).

Zangori et al (2013) maintain that, "To formulate scientific explanations for observed cause and effect, students must articulate a mechanism that describes "how" and/or "why" the phenomenon occurs. The "how" or "why" is what differentiates a description of an observed phenomenon and an explanation for it (Osborne & Patterson, 2011; Salmon, 1998; Trout, 2002)." (p. 993). It follows that if students are expected to develop an adequate understanding about how science works and develop adequate explanations for their observations of natural phenomena, they must understand the purpose of scientific explanations and arguments, the role of evidence in supporting and validating scientific explanations and arguments (Duschl et al., 2007; Osborne & Patterson, 2011; Zangori et al., 2013). If we expect students to achieve such conceptual clarity so they can effectively engage in scientific argumentation and develop quality scientific explanations, we need to bring teachers' conceptual understanding of argumentation and explanation under scrutiny.

Osborne, Simon, Christodoulou, Howell-Richardson, and Richardson (2013) state: "for teachers, professional learning is not just a case of developing a new skill but also one of developing a deeper understanding of the theoretical rational of any practice." (p. 338). It follows that without teachers with sophisticated understanding of argumentative nature of science, and those who have strong pedagogical knowledge of argumentation, students are unlikely to engage in such practices in science classrooms. In fact, a recent study, conducted by Ozdem et al. (2013), shows that pre-service teachers employ diverse schemes in constructing scientific arguments. For instance, while some participants use "argument from evidence to hypothesis" scheme, some use "argument from correlation to cause", and others use "argument from cause to effect" scheme (p. 2572). While the authors attribute this diversity to the nature of tasks and the composition of student groups, participants' conceptions of what makes a scientific argument may have also contributed to the reported diversity of schemes used to by pre-service science teachers. However, to our knowledge no studies have looked at the correlation between teachers' conceptual understanding of argumentation and the quality of arguments they construct.

Therefore, it is critical that the science teacher education community takes pre-service science teachers' understanding of scientific argumentation, purpose of scientific argumentation, elements of scientific arguments, and the difference between scientific argumentation and explanation seriously. This is critical because their understandings may influence how they engage in argument construction and critique. Unless we make a concerted effort to help pre-service science teachers to develop a sophisticated understanding of the argumentative nature of science, students are unlikely to engage in scientific argumentation and successfully develop scientific arguments and explanations in science classrooms (Beyer & Davis, 2008; Metz, 2009; McNeill, Pimentel & Strauss, 2013; Ozdem et al., 2013).

LIMITATIONS

As is the case with most educational studies, there were several limitations associated with this study.

1. As this study was within a teacher education program in Turkey, the results might be reflective of the curriculum studies in that particular institution.
2. While we collected data through open-ended questions and gave participants sufficient time to complete the questionnaire, we still might not have been able to capture participants' understandings. Following up the participants related to their responses through semi-structured interviews might provide more in-depth understandings and result in more valid responses. However, we did not have resources to conduct such a comprehensive study at this time. Researchers with sufficient resources could complement methods used in this study with follow-up interviews to capture and report a more accurate picture of pre-service or in-service science teachers' understanding of scientific argumentation.
3. While we did our best to categorize the participants' views into three distinct categories of sophistication (naïve, transitional, informed), based on what we knew from the literature about scientific argumentation, this classification was still subjective as it reflected our own understanding of scientific argumentation.

In spite of these limitations, we believe this study makes productive contributions to argumentation studies in science education.

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APPENDIX

Open-Ended Questionnaire: Beliefs about Argumentation

1. What is science? Please discuss your understanding of "what science is?" in as much detail as possible.
2. What is a scientific argumentation? Please elaborate on your definition of argumentation in as much detail as possible.
3. What is the purpose of scientific argumentation? Why do scientists engage in scientific argumentation? Please elaborate.
4. What are the core elements of a scientific argumentation? Explain the contribution of each element to scientific argumentation.
5. Do you think there a difference between scientific explanation and scientific argumentation? In either case, elaborate on the difference between "a scientific argumentation "and "a scientific explanation.