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Research Article

Pre-Service Physics Teachers' Argumentation in a Model Rocketry Physics Experience*

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Abstract

This study investigates the quality of argumentation developed by a group of pre-service physics teachers' (PSPT) as an indicator of subject matter knowledge on model rocketry physics. The structure of arguments and scientific credibility model was used as a design framework in the study. The inquiry of model rocketry physics was employed in accordance with the model by two groups of participants through model rocketry design and development experience, as well argumentation sessions. The participants were 21 PSPTs from a public university in Turkey. Data were collected through video recordings of the argumentation sequences, which were then transcribed and analyzed using the structure of arguments and scientific credibility model. One of the major results was that PSPTs had a low quality of argumentation. Moreover, this study suggests that designing inquiry-oriented laboratory environments enriched with critical discussion would provide discourse opportunities that support argumentation. Also, PSPTs can be encouraged to support and promote argumentation in their future physics classrooms if they engage in argumentation-based inquiry-oriented laboratories.

Keywords

Pre-service physics teacher education • Argumentation • Argument quality • Subject matter knowledge • Model rocketry

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Scientific literacy, which was imparted to the literature by Paul Harder in the late 1950's (Laugksch, 2000), is an essential part of education not only for people making a career in science but also for all citizens in today's societies dominated by science and technology (McPhearson, Pollack, & Sable, 2008). In Turkey, the main purpose of the implemented physics curriculum since 2013 has been the development of students' scientific literacy (Millî Eğitim Bakanlığı [MEB, Ministry of Education], 2013). In this context, some of the sub-objectives of the physics curriculum are to produce scientific knowledge, to justify and evaluate claims based on evidentiary proof, and to share scientific knowledge. To achieve these goals, the new physics curriculum aims to develop students' scientific process skills through a relation between conceptual knowledge (knowledge of physics) and science technology in a social environment (MEB, 2013). However, teachers' beliefs, which are fundamental factors of thinking, motivation, intention and behavior (Bandura, 1977a, 1977b), are the key to the success of reforms (Cheung & Ng, 2000). Teachers are the ones who will transfer the newly prepared curriculum into the classroom (Anthony, 2008), and so if they do not believe in the curriculum they may be reluctant to implement it, may even modify it to fit their own ideas, or even interfere with it (Cheung & Ng, 2000; Czerniak & Lumpe, 1996). Therefore, teachers' pre-service training should also be modified according to the goals of the new curriculum reform.

In teachers' pre-service training, science educators are concerned with Schulman's teacher-knowledge model (1986), which is used as an organizational tool in the field of science teacher education. Schulman (1986, 1987) described teacher knowledge as content knowledge, general pedagogical knowledge, curricular knowledge, knowledge of learners, knowledge of educational contexts, and knowledge of the philosophical and historical aims of education. Researchers in science education have redefined and used Schulman's knowledge types in their works with a particular focus on content knowledge, pedagogical knowledge, pedagogical content knowledge, and contextual knowledge (Hill, Rowan, & Ball, 2005; Park & Oliver 2008).

Content knowledge, or subject matter knowledge (SMK), refers to a teacher's knowledge on a subject that s/he will teach and includes the concepts, ideas, principles, and structures of these knowledge elements. Shulman claimed that "the teacher need not only understand that something is so; the teacher must further understand why it is so." (1986, p. 9). Teachers should have an in-depth understanding of the subject in order to teach it well. Pedagogical content knowledge (PCK) is the knowledge that teachers use to transfer SMK to students. It includes understanding the ways of representing and formulating SMK so as to make it comprehensible for students, how to make learning specific topics easy or difficult for certain age groups of learners, and which preconceptions students bring with them to class (Zhou, 2015). Studies have shown that SMK and PCK affect quality of teaching and, thus, student learning

(Baumert et al., 2010; Hill et al., 2005; Kleickmann et al., 2015; Kleickmann et al., 2013). In the COACTIV project from Germany, PCK and SMK were found to be highly correlated (Baumert et al, 2010; Krauss et al., 2008). Because SMK is not sufficient by itself but a necessary condition of PCK (Even, 2011; Friedrichsen et al., 2009; Rozenszajn & Yarden, 2014), without it, PCK cannot be developed (Baumert et al., 2010; Depaepe et al., 2015; Friedrichsen et al., 2009). In this study SMK has been explored in detail.

In the literature, teachers' SMK was initially assessed by true-or-false tests (Tatto et al., 2007; Yip et al., 1998, as cited in Abell, 2007), multiple-choice tests (Lawrenz, 1986, as cited in Abell, 2007; Akarsu, 2012; Bogdanovic, 2015; Demircioğlu & Uçar, 2015; Hill et al., 2005; Kulkarni & Tambade, 2013; Tatto, Schwille, & Senk, 2007), or diagnostic tests (Akarsu, 2011; Cheong, Johari, Said, & Treagust, 2015); and in recent years by open-ended questions (Baumert et al., 2010; Demirbağ & Günel, 2014; Taşoglu, Ateş, & Bakaç, 2015), number of courses taken by the students (Baumert et al., 2010), or visualization of mental models (Kurnaz & Ekşi, 2015). In the literature, however, no study is found where pre-service teachers have used their SMK dialectically in argumentation (Osborne, Erduran, & Simon, 2004) nor have the quality of arguments generated by pre-service teachers been associated with their SMK. Because scientific literacy is seen as a requirement for future citizens (Christensen, 2001; Roberts, 2007), PSPTs are required to be able to discuss socio-scientific issues (Sadler & Zeidler, 2005a); in other words, to be able to make informal reasoning activities (Means & Voss, 1996). Argumentation activities play an important role in developing informal reasoning skills (Means & Voss, 1996). In this sense, argumentation can be seen as one manifestation of informal reasoning (Sadler & Zeidler, 2005b). Ill-structured, debatable, complex, and open-ended problems related to the real world (Gee & Land, 2004) are used for informal reasoning (Kuhn, 1991) because informal reasoning processes are generally not invoked when information is readily accessible or when the problem is well-structured, familiar, and compatible with existing knowledge (Chase & Simon, 1973, as cited in Means & Voss, 1996; Larkin et al., 1980, as cited in Means & Voss, 1996). Because ill-structured problems do not have adequate information or parameters for easy solving (Gee & Land, 2004), students are encouraged to collaborate, share their thoughts, and discuss things with one another (Duschl, 2008; Gillies & Khan, 2008). Moreover, ill-structured problems related to the real world allow students to understand problems easily, and thus students can develop their reasoning skills through dialogue (Crawford, 1999; Hmelo-Silver, 2004; Mercer, Dawes, Wegerif, & Sams, 2004). Because ill-structured problems are related to the real world, they are authentic (Howard, McGee, Shin, & Shia, 2001). To make a problem authentic for students in a classroom, it must connect to students' previous experiences (Mayer, 1998).

In this study, due to the model rocket design and production activity being related to the real world, PSPTs could continue thinking reflectively for a long time, collaborating with each other and engaging in model rocket design and production before argumentation (Cholewinski, 2009; Herrington, Reeves, Oliver, & Woo, 2004). After the design and production of model rockets, PSPTs were asked to debate about which model rocket design would fly the highest. For the PSPTs, this problem was authentic and ill-structured.

Meanwhile, the teacher also has an important role in argumentation as they encourage PSPTs to clarify their thoughts, reasons, and knowledge, as well as share these with the other PSPTs. The teacher provides opportunities for PSPTs to make lengthier contributions where they can express their current understanding or articulate difficulties (Rojas-Drummond & Mercer, 2003). Moreover, the teacher should create a learning environment that supports PSPTs' learning and gives them enough time to participate in argumentation (Akkus, Gunel, & Hand, 2007). As much as the teacher creates a supportive learning environment, the PSPTs will be more encouraged to justify their claims and provide their own arguments; thus, they will be more active in argumentation (Erduran, Simon, & Osborne, 2004). In this way, PSPTs can reflectively think about their learning and have more opportunities to correct the mistakes in their learning (Hammer, 1996; Redish, 1994).

There is another important problem in physics teacher education in Turkey. In this country, physics departments are responsible for pre-service physics teachers' education in physics (SMK) in some universities, while the physics education department is responsible for their pedagogical knowledge and pedagogical content knowledge (Özoğlu, 2010). Physics departments offer ordinary university teaching with traditional structures that are unable to provide PSPTs with a good example of how physics should be taught in school (Yiğit & Akdeniz, 2004). Moreover, PSPTs are unable to feel like teacher candidates; this weakens their attitude towards the teaching profession (Baştürk, 2011; Baştürk, 2009; Saraç, 2006; Yiğit & Akdeniz, 2004). Even after PSPTs have completed their studies in the physics department, they fail to form a coherent picture of physics. PSPTs possess some relevant knowledge, but it is fragmented and unorganized. In traditionally taught physics departments, this unorganized and fragmented knowledge seems to be a common problem among PSPTs. They have a picture of physics that is a collection of facts, definitions, laws, and specific problem-solving strategies (Bagno, Eylon, & Ganiel, 2000; Mäntylä & Nousiainen, 2013). This may result from PSPTs not having enough time or opportunity during studies in the physics departments to reflect on "what they know" and "how they know what they know" (Mäntylä & Nousiainen, 2013; Mestre 2001). Another problem in the physics departments is the role of experiments and models in forming a coherent view of physics subject knowledge. Since the required importance is not given to experiments and models, PSPTs are unable to know "how they know what they know" or reflect their understanding into their teaching (Mäntylä & Nousiainen, 2013). The third and final challenge is that PSPTs need opportunities and resources to reflect or assess their knowledge and experience related to SMK in physics and physics education (Mäntylä & Nousiainen, 2013).

An argumentation-based model rocketry physics activity (an inquiry-oriented laboratory approach) has been designed and applied in this study to enable PSPTs to address these problems as a solution. Designing model rockets, producing them, and then debating the development process allows PSPTs to become more conscious of their current knowledge. The analytical quality of the arguments shows PSPTs "what they know," "how they know what they know," and "how well they know it."

In an inquiry-oriented laboratory, a small group of people (10-20) engage in an ongoing series of conversations about an agreed-upon problem or question; it is moderated by a facilitator. The facilitator acts as a coach in order to assure everyone has equal rights and opportunities to speak, neither trying to validate every opinion nor forcing the argumentation process to a predetermined end. Facilitators are careful not to advance their own ideas as having more weight because of their authoritative role in class. They try to have each member internalize the argumentation process, thus distributing it throughout the group. The process leads through a communal process of posing questions; exploring alternatives and hypotheses; asking for evidence, criteria, and reasons; connecting and distinguishing ideas; and drawing temporary conclusions (Kennedy & Kennedy, 2010).

This article presents and describes an example of an inquiry-oriented laboratory approach (argumentation-based model on a rocketry physics activity) to show how PSPTs can be supported so as to realize their SMK.

Purpose

This study looks at the argumentation practices of PSPTs during inquiry-oriented model rocketry lab work. The lab work in this study has two sessions: design and development of model rockets and argumentation sequences over critical discussions on model rocket flights. PSPTs' goal in the lab work is to make the best model rocket that will fly the highest. Before launching their model rockets, PSPTs are to perform critical discussions through argumentation. The study addresses the following research questions: (a) What quantity of arguments are developed by PSPTs during the lab work? (b) What is the quality of the arguments developed by PSPTs during the lab work? (c) How is the scientific credibility of arguments developed by PSPTs during the lab work? (d) What is the relationship between the quality and scientific credibility of arguments developed by PSPTs during the lab work?

The research questions aim to contribute to the existing literature of PSPT education by showing that PSPTs can become better aware of their SMK using argumentation-based inquiry-oriented lab work such as model rocketry in a physics lab.

Methodology

Research Design

The case study design (Yin, 2012) guided this research in order to investigate PSPTs' SMK by examining the quality of their arguments. The research draws on qualitative data to identify and explain the quality of PSPTs' arguments.

Participants and Settings

The participants of the study were 21 senior-class PSPTs, 10 of whom were female. All participants were physics education students who would graduate by the end of the school year from a large public university in Istanbul. Their ages ranged from 21 to 25. Because the participants of the research are required to know the basic concepts of physics related to model rocketry such as kinematics, dynamics, impulse, momentum, work, power, and energy, the non-probability sampling method has been used in this research (Patton, 1990); the participants were purposively selected, and they participated in this study voluntarily.

In this public university, the PSPTs took physics courses required for SMK from the faculty of pure sciences, and pedagogy courses for their PK and PCK from the faculty of education. They were taking the "Instructional Technologies and Material Design" course during this semester. This course mainly aims to inform PSPTs about their role and the reasons for instructional technology and material, as well as to educate them in designing and constructing instructional material in accordance with the course objectives. This study was conducted with participants who had already completed their physics courses but were still taking their pedagogy courses.

Instructional Context and Study Design

This study's data were collected in the "Instructional Technologies and Material Design" course. The argumentative and scientific inquiry model, developed by Kim and Song (2006), was used as a design framework in the study. According to the model, inquiry into model rocketry physics was employed by two groups of PSPTs during two sessions (experience and argumentation sessions). This study was implemented over an eight-week period. In the first four weeks (the experience session), the pre-service teachers designed and constructed model rocketry to make them fly as high as possible. Before flying them, they had to have critical discussions (argumentation). Qualitative ill-structured problems were used to group the students for an argumentation session in the fifth week (please see Appendix for the questions). Their debates were guided by the teacher for two weeks, two hours per week. These four hours of argumentation were recorded on three camcorders. During the argumentation sessions, two groups of PSPTs tried to convince the other about which model rocket would fly higher. In the final week, the PSPTs launched their model rockets.

All video recordings were transcribed verbatim. These transcribed arguments were analyzed as a case study. The quality of the arguments made by the pre-service teachers was examined. Because the PSPTs had completed all of their physics courses and had previous knowledge of physics subjects, the aim of instruction was to provide opportunities for them to become involved in the argumentation process and argue about model rocketry physics using their SMK in the process.

Data Collection

All PSPTs participating in the argumentation sessions were videotaped, from which the data were collected. Before the video sequences, PSPTs were divided into two groups according to their answers on the qualitative, ill-structured questions to induce them into debate. Four video sequences were based on four ill-structured questions. The PSPTs tried to persuade each other during the argumentation process. Because the study's aim was to examine the quality and credibility of the arguments developed by the PSPTs, the researchers did not focus on the groups or the PSPTs but rather on their arguments, their quality, and their scientific credibility. The PSPTs were divided into two groups in order to provide a debate environment.

Some information will be provided about how the questions were prepared. First, different diameter pipes for model rocket construction were available. Second, the constructed model rockets could have different mass. All model rockets used the same engines and were launched from the same launching pad. Lastly, air resistance would be neglected then included. As a result, four questions were created (see Appendix). In order to ensure validity and reliability, these four qualitative, ill-structured questions were examined and checked by two external physics experts who had majored in pure physics. They reported that the questions were suitable for PSPTs' content knowledge and had no substantial errors.

Data Analysis

Data analysis began with transcribing the video recordings. Analysis units in the present study were the PSPTs' statements that indicated a reasoning sequence provided when responding to another PSPT. The reasoning sequence here occurs during a conversation between PSPTs evaluating a particular claim. The PSPTs presented their propositions with a scientific explanation stating their claim. Using Puvirajah's (2007) structure of arguments and scientific credibility (SASC) model, we coded the arguments separately then analyzed their quality and scientific credibility. This model is shown in Figure 1. Puvirajah (2007) placed emphasis on not only the quality of an argument but also its scientific validity. For a good argument, both should be evaluated. In the SASC model, the structure of an argument is composed of a claim, evidence, and explanation (Figure 1). The PSPTs' arguments were categorized as arguments that supported a major claim (left side in Figure 1), or as the counter-arguments that opposed a major claim (right side in Figure 1).

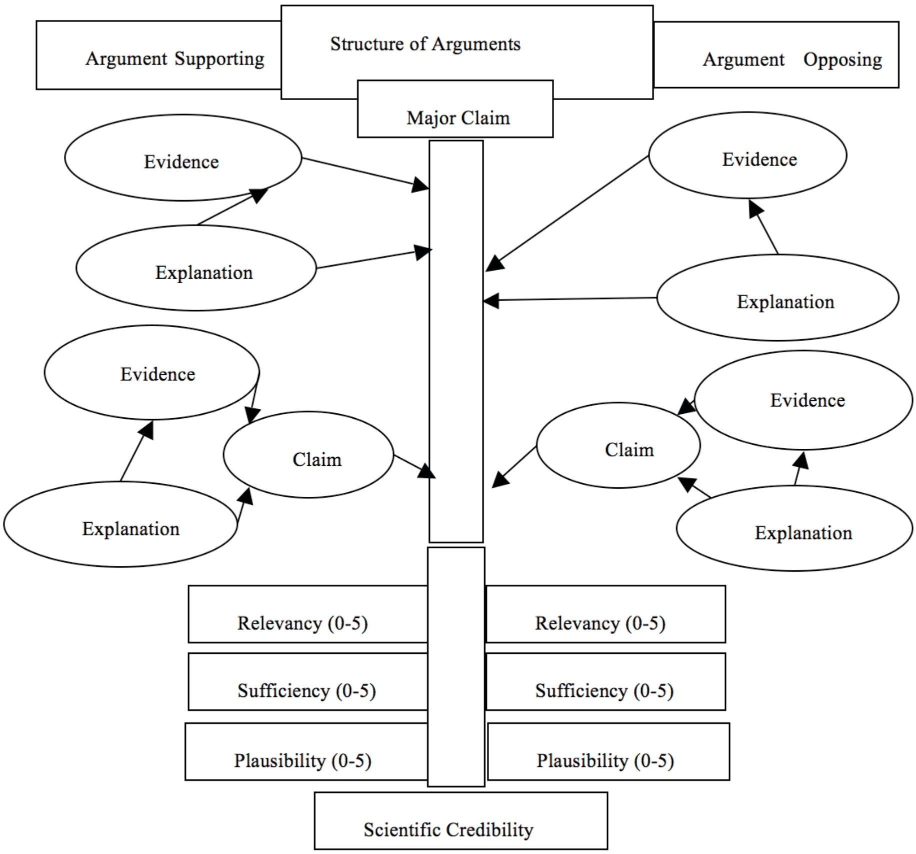

Figure 1. Structure of arguments and scientific credibility model.

In the SASC model, the quality of the argument structure is evaluated by analyzing the types of evidence and explanations used for the claim (Figure 2). There are three types of evidence: experiential (data comes from the speaker's experiences), referential (data is referred to from a source other than personal experience, i.e., textbook), and provisional (data is unrelated to the claim). The six types of explanations use explicit scientific theory, established scientific authority, perceived authority, one's own or a peer's work, unreliable testimonials; or nothing at all (no explanation is offered). These six types are further grouped together based on the nature and convincing strength of the explanation. Explanations using explicit scientific theory and established scientific authority have the highest convincing strength, while explanations with unreliable testimony or having no explanation have the least convincing strength. Explanations using perceived authority or peers'/self work fall in between these two groups. Puvirajah (2007) categorized the quality of argument structure into three levels: insufficient to basic, basic to proficient, and proficient to advanced.

	Evidence		Explanation		Quality of Structure of Argument
1	Experiential	A	Explicit Science Theory Established Science Authority	I	Proficient to Advanced
2	Referential	B	Perceived Authority Work of Peers/Self	II	Basic to Proficient
3	Provisional	C	Unreliable Testimonials No Explanations	III	Insufficient to Basic

Figure 2. The types of evidence for, explanations of, and quality of arguments defined in the SASC model.

Using the SASC model, the quality of arguments was first evaluated by determining the type of evidence and explanation used in the argument and then referencing Figure 3, which shows the possible evidence-explanation combinations and the resulting argument quality. For example, if an argument uses referential evidence (Evidence Type 2), and then provides an explanation using material from class notes (Explanation Type B), then the quality of the structure of the argument is categorized as basic to proficient (Quality Type III).

Evidence Type		Explanation Type		Quality of Structure of Argument
1	+	A	→	I
2	+	A	→	II
3	+	A	→	III
1	+	B	→	II
2	+	B	→	III
3	+	B	→	III
1	+	C	→	III
2	+	C	→	III
3	+	C	→	III

Figure 3. Types of evidence-explanation combinations determining arguments' structural quality.

Scientific relevancy, scientific sufficiency, and scientific plausibility are three aspects of an argument used by Puvirajah (2007) to evaluate scientific credibility. The scientific relevancy of an argument is examined by evaluating the adequateness of the scientific relationship between the claim and other components of the argument, and also by evaluating the adequateness of the scientific relationship among the various components of the argument. The scientific sufficiency of an argument is determined by seeing whether enough evidence has been provided to support the claim. The scientific plausibility of the argument examines whether the components of an argument supporting the claim are true, probable, and trustworthy (Figure 4).

Scoring Rubric for Scientific Credibility				
	Scores			
Component	0	1 – 2	3	4 - 5
Scientific Relevancy	None of the components are related to each other or the claim	Only evidence or explanation is related to the claim	Evidence and explanation are somewhat related to the claim	Evidence and explanation are related to each other and the claim
Scientific Sufficiency	Neither evidence nor explanation is presented	Some evidence is presented to support the claim	Sufficient evidence is presented to support the claim	Sufficient evidence is presented to support the claim; more evidence will not make the claim stronger
Scientific Plausibility	None of the components used to support the claim are true, probable, or trustworthy	Evidence used to support the claim is true, probable, and trustworthy	Evidence and explanation used to support the claim are probable and trustworthy	Evidence and explanation used to support the claim are true and trustworthy

Figure 4. Scoring rubric for determining scientific credibility in the SASC model.

We carried out the analysis independently in accordance with Miles and Huberman (1994), who suggested a formula for reliability. In order to ensure inter-coding agreement, the authors coded the transcribed data separately. According to Miles and Huberman's formula, reliability between coders was initially found to be 73.45%. This means the two coders used 130 of the 177 arguments exactly the same. Then the authors discussed the codes and repeated the coding process, and a reliability of 92.65% was achieved. Finally, the authors discussed small disagreements (13 codes out of the 177) until they obtained full consensus. At the end, the authors agreed on 36 major claims that included the 177 arguments. Using the SASC model (Figures 2, 3, & 4) the two authors both identified the arguments' structural quality and scientific credibility.

Results

The results of the study were presented in four sections following the order of the research questions. In the first section, the number of arguments was identified in detail. In the second section, in-depth qualitative argument descriptions were carried out in order to illustrate the quality of arguments that PSPTs had generated as they performed inquiry-oriented lab work on model rocketry. In the third section, the scientific credibility of the arguments was presented. Finally, in the fourth section, the relationship between the arguments' quality and scientific credibility was examined.

The Quantity of Arguments Developed by PSPTs

PSPTs constructed 177 arguments during the critical discussion sessions. The authors identified 36 major claims from these 177 arguments.

In Table 1, some cases are presented for the number of arguments supporting or opposing major claims. For example, Major Claim 1 has 10 arguments in total, six that support and four that oppose the major claim.

Table 1
Some of the Arguments Developed by PSPTs

Major Claims	Argument Supporting Major Claim	Argument Opposing Major Claim	Total Number of Arguments
Major Claim 1	6	4	10
Major Claim 2	8	6	14
Major Claim 3	6	5	11
Major Claim 14	2	1	3
Major Claim 15	8	5	13
Major Claim 16	2	0	2
Major Claim 31	4	2	6
Major Claim 32	4	1	5
Major Claim 33	3	3	6
Major Claim 34	6	0	6
Major Claim 35	1	0	1
Major Claim 36	2	0	2
TOTAL	115	62	177

According to Table 1, there were 115 arguments supporting major claims, while 62 arguments opposed them. The percentage of arguments that supported was 65% and the percentage that opposed was 35%. The supporting arguments nearly double the number of opposing arguments. Accordingly, PSPTs can be said to have produced major arguments to further support their arguments with evidence.

The Quality of the Arguments Developed by PSPTs

In the second part of data analysis, the quality of the 177 arguments developed by PSPTs was examined in detail. For each argument, the type of evidence and explanation used by a PSPT were determined according to Figures 2 and 3, and then using Figure 3, the quality of the argument was identified. Accordingly, 9 out of 177 arguments were determined to be Quality Type I in the study; 22 were Quality Type II, and 146 were Quality Type III. Only 5% of the arguments were Quality Type I, while Quality Types II and III were 12% and 83%, respectively. These results indicate that the PSPTs had failed to develop high quality arguments.

As an example, PSPTs' argument related to Major Claim 1 is given below:

1.1 (The first argument for Major Claim 1): "If we write $\frac{1}{2} mv^2 = mgh$, then the *m*'s will simplify. It is independent of mass."

1.2 "You are using the formula in the wrong place"

1.3 "The weights of the rockets are not the same."

1.4 "This is Galileo's thought experiment."

1.5 "We consider *m* separately for each rocket: $\frac{1}{2} m_1 v^2 = m_1 gh$, $\frac{1}{2} m_2 v^2 = m_2 g$, and so on. The initial speeds of the rockets are the same. When the masses simplify, the altitude of rockets will be the same."

1.6 "You're reading the question wrong. The rockets are not launched at the same speed."

Table 2 shows how to determine the quality of the arguments of Major Claim 1. As an example, Argument 1.1's statement, "If we write $\frac{1}{2}mv^2 = mgh$, then the *m*'s will simplify," is evidence, and the statement "It is independent of mass," is an explanation. As the evidence presented by the PSPT was referential (data that is referred to from a source other than personal experience such as a textbook), it was coded as "2," and because the explanation was based on explicit scientific theory or established scientific authority, it was coded as "A." As a result, Argument 1.1 was coded as Quality Type II (see Figure 3).

Table 2
Quality of the Arguments

Argument	Argument Number	Evidence Type	Explanation Type	Quality Type
Major Claim 1	1.1	2	A	II
	1.2	3	B	III
	1.3	2	C	III
	1.4	2	C	III
	1.5	2	A	II
	1.6	2	C	III

Table 3 shows how evidence and explanation types related to each other for all 177 arguments.

Table 3
The Relationship between Types of Evidence and Types of Explanation for All Arguments

Type of Explanation / Type of Evidence	A	B	C	Total	Percentage
I	9	10	30	49	28%
II	7	6	16	29	16%
III	25	41	33	99	56%
Total	41	57	79	177	
Percentage	23%	32%	45%		100%

According to Table 3, PSPTs presented 49 units of Evidence Type I (28%), 29 units of Evidence Type II (16%), and 99 units of Evidence Type III (56%). However, because 30 of the 49 Evidence Type I units were Explanation Type C, these 30 arguments were coded as Quality Type III. Meanwhile, the 10 out of 49 Evidence Type I units that were Explanation Type B were coded as Quality Type II.

Additionally, PSPTs presented 41 Explanation Type A unites (23%), 57 Explanation Type B units (32%), and 79 Explanation Type C units (45%). However, 25 out of the 41 Explanation Type A units were Evidence Type III and thus coded as Quality Type III. Moreover, 7 out of 41 Explanation Type A units were Evidence Type II and thus coded as Quality Type II. In accordance with this, the PSPTs usually made explanations using unreliable testimonials (45%) and presented evidence unrelated to the claim (56%), which may be a result of gaining knowledge without investigating its source. In fact, if they had acquired knowledge while understanding its source, they would have made better explanations and presented better evidence for their arguments. To make higher quality arguments, the PSPTs should have internalized physics content knowledge. Thus, according to Table 3, the PSPTs cannot be said to have had meaningful learning.

Scientific Credibility of Arguments Developed by PSPTs

In this section, the arguments' scientific credibility is presented. As a result of the scoring performed according to Figure 4, the scientific credibility of 96 arguments (54%) was coded as "absent," 47 (27%) as "low," 23 (13%) as "medium," and only 11 (6%) as "high" scientific credibility. Of the 96 arguments, 68 were coded as "absent" scientific credibility because the PSPTs' arguments had not presented any evidence whatsoever.

Accordingly, the PSPTs can be said to usually not be able to present sufficient evidence or explanations related to their claim. Even when they had presented evidence and/or an explanation for an argument, the evidence/explanation was not related to either each other or the argument; thus the argument was coded as having low scientific credibility. Only 19% of arguments had medium or high scientific credibility. The PSPTs can be said to have learned the concepts of physics by memorizing, and their physics courses had not been designed for an inquiry approach.

The Relationship between Arguments' Quality and Scientific Credibility as Developed by PSPTs

Finally, the relationship between arguments' quality and scientific credibility has been presented in this section. The results are shown in Table 4.

Table 4
The Relationship between Arguments' Quality and Scientific Credibility

Quality Type	Scientific Credibility				
	Absent	Low Credibility	Medium Credibility	High Credibility	Total
I	0	1	4	4	9
II	2	5	8	7	22
III	94	41	11	0	146
Total	96	47	23	11	177

As shown in Table 4, only 4 out of 9 Quality Type I arguments have high scientific credibility. One has low and 4 have medium scientific credibility. Furthermore, only 2 out of 22 Quality Type II arguments and 94 out of 146 Quality Type III arguments have no scientific credibility. No Quality Type III arguments have high quality scientific credibility.

Furthermore, Table 4 shows that of the 177 arguments developed by the PSPTs, only 4 are both Quality Type I and have a high scientific credibility. The other 7 arguments with high scientific credibility are Quality Type II. Forty-one arguments have low and 11 have medium scientific credibility.

According to Table 4, a majority of arguments were both low quality and without scientific credibility. The PSPTs can be said to be unable to defend their claims scientifically. For example, 96 out of 177 arguments had no scientific credibility. This shows that for these 96 arguments, PSPTs had presented neither evidence nor explanations to support their claims as true, probable, and trustworthy. They were only able to present four arguments with evidence based on experiential data and explanations using explicit scientific theory or established scientific authority. One reason for this might be that the PSPTs in this study had tried developing arguments on the spot, supporting their arguments with information off the top of their heads.

Conclusion and Discussion

Good PSPTs in Turkey can be good test takers in teacher-selection exams (Public Personnel Selection Exam [KPSS] and Teaching Field Knowledge Exam [ÖABT]), but do not necessarily have better scientific literacy. PSPTs with high scores on those tests probably are more diligent or have a better memory, but are not necessarily more knowledgeable in physics. Nowadays, argumentation practices are common in science education and have recently been used for science instruction to promote scientific literacy (Duschl & Osborne, 2002; Heng, Surif, & Seng, 2015). However, studies have shown that intervening in scientific argumentation in class is difficult and challenging because students have difficulty developing argumentation (Heng et al., 2015; Osborne et al., 2004; Sampson & Clark, 2009; Sandoval & Millwood, 2005). Considering this fact, this study has shown that argumentation-based model rocketry experiences might be a good example of argumentation practice. This argumentation intervention was effective at enhancing PSPTs' engagement in class, helping them develop 177 arguments in total. However, only nine developed arguments were Quality Type I and 22 were Quality Type II. The remaining 146 arguments were Quality Type III. The PSPTs used evidence and explanations for their claims during the argumentation process. However, the PSPTs were not able enough to construct Explanation Types A based on Evidence Type I. This result indicates that PSPTs had difficulty constructing quality scientific explanations. Similar results were reported from some studies in the literature (Demircioglu & Ucar, 2015; Kuhn & Reiser, 2005; Sandoval & Millwood, 2005). Moreover, the PSPTs in this activity were unable to produce enough scientifically credible arguments. Only 11 arguments out of 177 (6%) had high scientific credibility. This results show that even scientific argumentation is seen to be needed in science education (Heng et al., 2015); the PSPTs were unable to reflect their SMK into quality and scientifically credible arguments. Methodologically, this study has made progress on several fronts. Most significant is that this work has presented pre-service and in-service teachers with a set of material that can be used to facilitate argumentation in the classroom. As a result, some insights into how to introduce argumentation into science classrooms have been gained. As such, this work is part of a growing body of work on the use of argumentation in classrooms (Duschl & Osborne, 2002; Herrenkohl & Guerra, 1998; Kelly, 2007; Kelly & Crawford, 1997; Osborne et al., 2004; Simon, Erduran, & Osborne, 2002). Secondly, supporting pre-service and in-service teachers in developing formal and informal SMK and PCK learning opportunities are especially productive (Werquin, 2010). In this context, argumentation-based model rocketry physics presents such a formal learning opportunity. Similar work on formal and informal learning opportunities supporting SMK in mathematics has been done by Kleickman et al. (2013).

Thirdly, the PSPTs were good at developing arguments in this study. This may result from PSPTs having found the experience of model rocketry attractive. Some studies in the literature state that pre-service teachers would engage in scientific argumentation more if the topic under discussion were more attractive (Erduran et al., 2004; Kutluca, Çetin, & Doğan, 2014; Zeyer & Roth, 2009). Moreover, this can result from group argumentation. Heng et al. (2015) stated that students involved in group argumentation outperform students involved in individual argumentation. Because collaboration in group argumentation plays an important role in constructing scientific arguments, teachers need to create a collaborative atmosphere wherein the argumentation process can work (Mason, 1996, as cited in Heng et al., 2015).

Finally, previous research in the literature has shown a strong relationship between the quality of an argument and SMK (e.g., Acar, 2008; Sadler & Fowler, 2006;

Sadler & Zeidler, 2005b; Sampson & Clark, 2011; von Aufscnaiter et al., 2008). In contrast, some research has also stated that SMK is not a critical determinant in bettering the quality of scientific arguments (Eskin & Bekiroglu, 2009; Hakyolu & Ogan-Bekiroglu, 2011; Kutluca et al., 2014). However, as Kutluca et al. (2014) stated in their study, conducting argumentation studies on small-sized groups might negatively affect the relationship between SMK and the quality of arguments. For example, Sampson and Clark (2011) found a significant relationship between SMK and quality of argumentation utilizing only two argumentation groups. Moreover, studies in Turkey comparing KPSS test scores in terms of achievement for teacher candidates graduating from faculties of education and for those who had graduated from faculties of arts and sciences show that teacher candidates from education faculties are significantly more successful (Safran, Kan, Üstündağ, Birbudak, & Yıldırım, 2014; Yıldırım & Koca, 2015; Yılmaz & Yıldırım, 2015). Inquiry-based studies conducted in education faculties may be the reason for this success.

Implications

As the study of argumentation within the context of physics education is a young field that has only emerged in the past decade, more research needs to be carried out on new tools and in contexts that can help PSPTs both construct and evaluate scientific arguments.

This study is an example of an attempt to connect PSPTs to an environment that supports argumentation. The model rocketry class was used as such an environment. This study shows that a context (model rocketry experience) that fosters PSPTs' use of argumentation can be established.

The results of this study imply that PSPTs do not have enough even contextual knowledge or content knowledge. In order to develop robust understandings of physics, PSPTs should be introduced to new argumentation-based experiences within meaningful contexts. This study also yields that argumentation interventions are effective at enhancing PSPTs' engagement in class. In this manner, pre-service and in-service physics teachers in Turkey can be convinced to utilize argumentation in physics classes. Moreover, the study's findings indicate the need for more research on SMK and argumentation in physics. Researchers could engage in further research on how different levels of SMK and misconceptions about physics subjects affect the argumentation process.

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Appendix

There were four ill-structured questions related to model rocketry physics used for this study.

Two model rockets (A and B) are launched from a launch pad with the same impulse.

I. If they are equally sized with different masses, which one reaches maximum altitude (height)? Why?

   i) Write your comments neglecting air friction.

   ii) Write your comments including air friction on the rocket.

II. If they have equal mass with different sizes (B has bigger body tube size) which one reaches maximum altitude (height)? Why?

   i) Write your comments neglecting air friction.

   ii) Write your comments including air friction on the rocket.