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Argumentation Skills of Pre-Service Elementary Teachers on Atmospheric Pressure

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ABSTRACT In the present study, atmospheric pressure, an abstract concept that learners generally have difficulty understanding and explaining, was presented to pre-service elementary teachers (PSTs) with the method of argumentation. The argument levels of the PSTs were examined using the Predict - Observe - Explain (POE) experiments in teaching the subject of "atmospheric pressure." The study includes both the development of the worksheets and the application of the developed worksheets. The researcher developed four POE worksheets and used them in two ways. First, PSTs did two POE experiments in the science lab to learn by doing atmospheric pressure. Second, PSTs watched two videos about atmospheric pressure. Data collection tools consist of POE worksheets and in-class discussion records made during the implementation. The worksheet analysis prepared an argumentation rubric according to the Toulmin argument level. Descriptive analysis was performed on the worksheets according to the argumentation rubric, and the change and development of the PSTs' argument skills were evaluated. Although, as a result of the study, the PSTs had difficulty forming arguments at the beginning, as the practice progressed, their argument-forming skills improved, and the argument levels of the PSTs were moved to higher levels. However, it was noted that the PSTs' level of high-level argument formation was limited. In contrast, most of the PSTs in the experiments made only one claim and had difficulties justifying it.

Keywords Argumentation, atmospheric pressure, Predict-Observe-Explain, science education, teacher education

1. INTRODUCTION

The students think of science as an abstract lesson. This lesson, which has many abstract concepts, is an area in which learners have difficulties understanding information. Therefore, learners must learn science lessons by questioning, doing, experiencing, and making sense of knowledge (Hofstein & Lunetta, 2004; Kelly & Licona, 2018). Modern education can be carried out by educating students with the skills of questioning, inductive and deductive thinking instead of students who learn by memorization and cannot make judgments. Students who can learn by questioning information, discovering new information, or combining pieces of a puzzle are the building block of Education (Hofstein, Kipnis & Kind, 2008).

In a traditional learning environment, the student takes what is taught, and the teacher transfers information following the student's level. In this environment, students accept information without question and can generally turn to memorization. In this case, the science lesson has a problematic course image because students have difficulty understanding science subjects, associating them with other preliminary learnings, and structuring knowledge. The critical point in science teaching is to use the information properly and correctly, to evaluate the data, and to have critical thinking skills (Osborne, Erduran & Simon, 2004). This expectation can be fulfilled by including students in the learning process and being primarily responsible for the production of scientific knowledge. To meet this expectation, students can be included in the learning process and responsible for producing scientific knowledge (Yerrick, 2000). In this regard, it is important to use methods in which students are active in the teaching process and to shape learning according to the learner. The argument method is one of the preferred teaching methods for providing conceptual understandings and obtaining the desired feedback from education (Driver, Newton & Osborne, 2000; Duschl & Osborne, 2002; Erduran, 2007; Wu et al., 2019)

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In the current study, prediction-observation-explain worksheets (POE-W) were used to examine the argument-forming skills of pre-service elementary teachers (PSTs). POE-W was used in the study in two ways. First, PSTs were asked to answer the questions in the worksheets by allowing them the opportunity to do the experimental activities in the science laboratory. In the second, the PSTs were shown two videos and asked to make arguments in line with the directed questions. In this context, The importance of argumentation in science and teacher education and the use of visual elements in argumentation form the theoretical framework of the current study.

1.1 Argumentation in science education

The argument refers to the reasons to support a claim (Walton, 2006). The argumentation relates to the discussion process between individuals with different perspectives (Osborne, Erduran & Simon, 2004; Sampson & Clark, 2008). The argumentation method allows the students to create written and oral discussions in scientific inquiry to help them learn science (Cavagnetto, Hand & Norton-Meier, 2010; Choi, Notebaert, Diaz & Hand, 2010). There has been considerable research on the application of the argument used in the meaning of scientific discussion in science education (Anisa, Widodo, Riandi & Muslim, 2022; Driver, Newton & Osborne., 2000; Duschl & Osborne, 2002; Jimenez-Aleixandre et al., 2000; Khishfe, 2022; Osborne, Erduran & Simon., 2004; Wei et al., 2019; Zohar & Nemet, 2002).

Argumentation in science learning is considered within the scope of constructivist learning, with its features aiming to learn rather than teach and based on research and inquiry (Allchin & Zemplén, 2020; Moje, Collazo, Carrillo & Marx, 2001; Palmer, 2005; Simon, Erduran & Osborne, 2006; Yen, Tuan & Liao, 2011). The argumentation method effectively structures knowledge based on the student's ability to solve problems about any learning topic, critical thinking, and active participation in the process (Zohar & Nemet, 2002). In this respect, argumentation allows students to read, write and discuss with their friends and helps them develop conceptual understanding skills (Keys, Hand, Prain & Collins, 1999, s. 1067). In the argumentation method, students can create arguments that include a claim, data, warrant, backing, and rebuttal while discussing the subject (Toulmin, 1958). In this way, argumentation enables students to reveal their current knowledge, develop conceptual understanding, construct information correctly, and combine it with other information (Sampson & Gleim, 2009). According to the results of the study conducted by Hand, Wallace & Prain (2003), which examined the relationship between students' ability to create arguments and learning outcomes, it was determined that students' scientific literacy improved. Another study stated that argumentation provided conceptual change and in-depth learning (Keys, Hand, Prain & Collins, 1999).

1.2 Argumentation in Teacher Education

According to previous studies, argumentation improves pre-service teachers' argument-forming skills, their perspective on learning science, and their conceptual understanding (Cebrián-Robles, Franco-Mariscal & Blanco-López., 2018; Robertshaw & Campbell, 2013). Uzuntiryaki-Kondakci, Tuysuz, Sarici, Soysal & Kilinc (2021) stated that in the laboratory conducted with argumentation, the candidates' argumentation skills increased, they successfully explained chemistry concepts at the sub-microscopic level, and over time they started to produce strong arguments, including deep conceptual knowledge. In an experimental study on chemical equilibrium, it was observed that the conceptual understanding of pre-service teachers was better in the experimental group where the argumentation method was applied (Kaya, 2013). Studies are investigating the effect of argumentation, such as the student's understanding of the nature of science, the development of argumentation and inquiry skills (Walker, 2011), the student's argument qualities in the laboratory course (Kind, Kind, Hofstein & Wilson, 2011); the effect of explicit inquiry teaching in science class (Yerrick, 2000); the socio-scientific issues with genetic science content (Dawson & Venville, 2010); the ability of students to construct argument components (Bathgate, Crowell, Schunn, Cannady & Dorph, 2015). In these researches, it is shown that students' argument skills improve and have positive effects on learning, and their participation in a scientific debate increases. For example, Katchevich, Hofstein & Mamlok-Naaman (2011) examined the development of students' argumentation skills in the chemistry laboratory with open-ended inquiry and confirmatory-type experiments. As a result, it was determined that the number and level of arguments formed by students in open-ended interrogative investigations were higher than in confirmatory experiments. It should be noted that, despite the studies that yielded positive results, pre-service teachers still had difficulties in developing arguments (Martín-Gámez & Erduran, 2018).

1.3 Visual Argumentation

Visual argumentation has a specific place in the literature to enrich educational studies (Csordas & Forrai, 2017; Roberts, 2007). Some researchers stated that visual elements could generate arguments (Blair, 1996; Blair, 2012; Csordas & Forrai, 2017; Godden, 2013). In today's information age, it is necessary to involve students more in education and to improve their perspective. Students' ability to debate scientific matters depends on researching, analyzing, and organizing information. In this sense, Visual elements are essential to support argument generation. In science, an abstract theory, which students do not perceive, can be effectively communicated through visual representations (Mathewson, 1999; Roque, 2009). According to Tseronis (2013), visual elements can be used to express and justify a claim, and it is possible to create arguments through visual elements. In other words, the content presented can also be expressed through visual means since what the images or videos mean can be defined, and visual content can be explained verbally, providing an opportunity to create and think about arguments.

Visual elements may require critical thinking to understand the interactions between components in a pictorial diagram. For example, in a science lesson, the student should be able to infer from visual representations, visualize a system (such as moon phases, water cycle, ecosystems), and explain possible consequences (Lee & Jones, 2018). Visual elements can allow students to explore aspects of the topic to support a particular claim and thus potentially increase the persuasiveness of their arguments. Moreover, it was stated that students who link visual representations with written and oral claims tend to form strong ideas (Wu et al., 2019). Godden (2013) answered how to evaluate the arguments created with visual elements. The message is transmitted with an optical element. The difference is only the way the message is presented. Therefore, the evaluation method applied to the traditional argument is also valid for visual statements.

Since many formats (Statements Table, Concept Map, Competitive Theories, POE) can be preferred to create arguments, students should learn how to share their ideas and create qualified opinions. In line with this idea, in the current study, students used experiences in different formats as the basis of their arguments (American Association for the Advancement of Science, 1993; Namdar, 2017; Namdar & Demir, 2016; Tseronis, 2013).

1.4. The importance of the research

Previous studies stated that students and teacher candidates had difficulty learning atmospheric pressure, which is difficult to grasp because it is an abstract concept (Mas, Perez & Harris, 1987; Nelson, Aron & Francek, 1992). Obtaining incomplete or incorrect information on pressure, temperature, and heat causes difficulties in understanding atmospheric pressure (Basca & Grotzer, 2001; Kariotoglou & Psillos, 1993). The existence of these difficulties directs educators to use methods that facilitate learning. Teachers must provide basic information that solves students' problems in learning science concepts. According to Lewthwaite (2014), a teacher should be able to direct a student's attention to the critical points underlying the subject. If teachers plan to teach children air pressure, they can demonstrate the power of this natural phenomenon with simple, fun, and engaging experiments that explain the basics. When the concept of atmospheric pressure is taught by the method of argument, it is ensured that the learner defends, justifies, and presents evidence for the idea. Thus, it is expected to facilitate learning and create permanent knowledge. Besides, it is ensured that the learner asks, "what am I thinking wrongly, or what do I know wrong?".

PST has a lack of knowledge about the application of the argumentation approach. Similarly, pre-service teachers have problems starting and continuing the teaching process based on argumentation, planning, and creating a discussion environment. Karakaş (2022) emphasized that this approach should be used in the study he conducted with primary school teachers to gain multidimensional thinking and discussion skills, to use essential argument elements (claim, data, justification), and to create an active learning process. Lack of familiarity with this method indicates that argumentation cannot be applied effectively (Dori, Tal & Tsaushu, 2003; Kaya, Çetin & Erduran, 2014). The worksheets prepared in the current study provide PST with the experiences necessary to initiate and maintain the argumentation-based teaching process in the science teaching process. The present study examined the argument-forming skills of PSTs about atmospheric pressure. The current study has three goals.

1. Preparation of Experimental and Visual POE worksheets for PSTs in teaching the subject of atmospheric pressure,
2. Implementation of the prepared worksheets,
3. Investigate of PSTs' argument-forming skills in Experimental and Visual POE worksheets.

2. METHOD

This study was carried out according to the case study, which is one of the qualitative research methods. Case study; It is a method in which a single situation or event is examined in depth, data is collected systematically, and what is happening in the natural environment is looked at (Yin, 2003). PST's argumentation skills were examined in the natural environment in the science laboratory.

2.1 Sample

The sample consists of 42 PSTs(24 female, 18 male) who take the Science and Technology Laboratory Applications course in Science Education Department.

The sampling method of the study is the purposeful sampling method. This method allows for in-depth research by selecting information-rich situations. In addition, it is a method that accelerates research because it permits the researcher to move to a case that is close and easy to access.

2.2 Development of worksheets

Stage 1. Creating the content of the worksheets

The worksheets consist of two types of content, experimental and visual. Two of the worksheets were prepared by the researcher as laboratory experiments in line with the relevant literature. Various sources have been used in the subject of atmospheric pressure for content (Kesmez, 2010; Petrucci, Harwood & Herring, 2010). For the preparation of visual content, "Effects of atmospheric pressure" were written on the Google search. The videos found were analyzed in terms of content to be related to other experiments. Experts evaluated the suitability of the proposed videos for the study. As a result of the investigations, it was decided to use the videos in the link (https://bilimgenc.tubitak.gov.tr/makale/acik-hava-basincinin-etkilerini-gozlemleyelim).

Stage 2: Arrangement of worksheets according to the POE method

The researcher prepared the worksheets in writing to conduct the study in harmony with the argumentation method. The POE, one of the strategies that facilitate and support the process of argumentation in science classes, was used to prepare worksheets (Osborne, Erduran & Simon., 2004). Images used in experimental content are taken from the book (Kesmez, 2010). For visual content, screenshots are taken from the necessary parts of the video. The worksheets include the tools and equipment used in the experiment, how to experiment, and questions of estimation, observation, and explanation.

Stage 3. Validity Study for worksheets

a) Lawshe Technique: Expert opinion was obtained with the "worksheet evaluation form" regarding the developed worksheets (see Table 1). The worksheets were presented to the evaluation of 7 experts with the criteria "sufficient in measuring targeted behaviors" (1), "should be arranged to measure targeted behaviors" (2), and "insufficient in measuring targeted behaviors" (3) (Lawshe, 1975). Experts consist of chemistry (3), science (3), and physics (1) educators. In addition, they have laboratory experience.

In the Lawshe technique, the coverage validity rates for substances are calculated by applying the formula given below (Yurdugül, 2005). When the procedure is used, it is evaluated as follows.

CVR = [(Ns)/(N/2)]-1

Ns = several experts answering "substance is required / suitable."

N = Total number of experts expressing opinions

All experts are suitable CVR = 1,

Half of the experts are reasonable CVR = 0,

More than half of the experts are suitable for CRV> 0 and

Less than half of the experts are ideal for CVR <0 (Venaziano & Hooper, 1997).

Yurdugül (2005) stated that it is important how many dimensions of the feature that is wanted to be measured are collected. He emphasized that if the part is contained in more than one dimension, Cvr should be obtained for each size. For example, most measurements in the working leaves evaluation form have CVR values of 1. This value indicates high content validity (see Table 2).

Table 1 Worksheet evaluation form

Evaluation Category	Review questions	1	2	3
Meaning	Are worksheets appropriate for the purpose?			
	Can the prediction questions in the worksheets raise awareness about the experiment?			
	Are worksheets an ideal example for prospective teachers to develop their experiments?			
	Are the explanations on how to make the worksheets sufficient?			
	Are the visual representations in the worksheets sufficient?			
PSTs-researcher	Do worksheets enable candidates to participate physically and mentally?			
	Can the experiment attract the attention of students?			
	Is the work done according to the student's level?			
Learning	Do worksheets help with effective learning?			
	Can worksheets help relate to previous learning?			
Time and place	Is the time allocated to the experiment sufficient?			
Material	Are the materials used in the experiment easy to use?			
	Does the experiment prioritize student safety?			
	Are the materials used in the experiment economic in terms of cost?			

Table 2 CVR values according to the worksheets evaluation criteria

Worksheets number	Meaning	PSTS-Researcher	Learning	Time and place	Material
1	1	1	1	1	1
2	1	1	1	1	1
3	1	0.71	1	1	1
4	1	1	1	1	0.71
5	0.71	0.71	1	1	1
6	1	1	1	1	0.71
7	1	0.71	1	1	0.71

Table 3 Objectives of experiments and weekly lesson plan

Implementation	Weeks	Experiments	Purpose
Before the implementation	One week	Explaining the purpose of the research, informing about the experiments to be done, forming groups, determining the seating plan, explaining the teaching of the lesson, informing the PSTs about the materials to be used in the laboratory and their places	
	Two week	Rising water	Examining the movement of water by creating a low pressure zone
	Three week	Boiling water	Pressure effect on boiling point
During the implementation	Four week	Volume Reduced Plastic Water Bottle	The effect of low air pressure on a plastic water bottle whose volume is reduced by compression
	Five week	A Glass of Room-Temperature Water	The effect of low air pressure on a glass of water at room temperature

2.3 Implementation Process

Two groups, A and B, take Science and Technology Laboratory Implementations courses in classroom education. Four groups were formed by dividing each of the A and B branches into two groups (A1, A2, B1, B2). The reason for studying small groups is that the number of materials in the laboratory is limited, and the researcher alone conducts the guide role in the application of activities. Each group held activities within one lesson time (30-50 minutes). The implementation process lasted four weeks and was carried out in the science laboratory. The names and objectives of the experiments in the lesson plan are given in Table 3.

Before the implementation: In the first week, laboratory materials were introduced to the students, and their locations were shown. Besides, the points to be considered in laboratory safety are explained. They were informed to learn the arguments and POE methods, and the sample experiment "paper sticking to the glass" was made to get used to this approach.

During the implementation: The researcher handed out the worksheets to the candidates and asked them to read how the experiment was done. The researcher has made the necessary explanations about how to experiment is being done. **a)Prediction stage:** At this stage, PSTs are expected to present claims about the events they may encounter in the experiments based on their current preliminary information. PTSs were asked to read the worksheet carefully and write the questions in the prediction section individually before starting the experiment. Finally, they argued verbally with their friends. PSTs are also expected to support their claims about the experiment's outcome with scientific data. After the PSTs answered the prediction questions verbally and in writing, their experiments started to be applied. **b)Observation stage:** The researcher asked the PSTs to do the experiments progressively, as shown in the worksheets. Groups of 2-3 people conducted the experiments under the guidance of the researcher. Completing the experiment, the PSTs answered the questions in the observation section in their worksheets. Thus, the Psts were able to predict the outcome of the experiment and, at the same time, compare their predictions with their observations. PSTs are also asked to state what they consider essential or notable issues regarding the experiment they observe. **c) Explanation stage:** PSTs were asked to write and discuss the difference between their predictions and observations in the explanation section of the worksheets. PSTs were asked to create warrants and discuss situations where their reasons were not valid. PSTs discussed their predictions, observations, and issues they misunderstood or could not understand about the experiment. They were asked to discuss the inconsistent situations between their observations and predictions and explain the experiment they observed. Differences or similarities between observations and predictions led them to form arguments. Besides, they shared the argument with their friends using the argument components. They defended their opinions and persuaded their counter-claiming friends. The researcher guided the students and explained the subject throughout the study. After the PSTs discussed the experiment and their opinions and thoughts, the researcher explained the matter. **d) Feedback stage:** The implementation process has progressed through continuous interviews, conversations, and Q&A with PSTs. After the experiments, the researcher talked to the students about things they did not understand or misinterpreted. Interviews were conducted with PSTs after the POE phase of the experiments. In these interviews, the issues that the candidates did not understand were evaluated to ensure their conceptual understanding. The researcher explained the results of the experiments. Thus, it was thought that they would be supported to make better arguments for each experiment.

Table 4 The analytical framework used to assess the quality of arguments developed by Toulmin (Erduran et al., 2004)

Level 1	Level 2	Level 3	Level 4	Level 5
It consists of arguments consisting of a simple claim or a claim against another claim.	This level consists of a claim and arguments that include data, warrant, or backing.	This level is the series of claims with data, justification, or supporting weakly rebuttal.	This level consists of arguments with a identifiable claim containing a rebuttal. Such an argument can make a variety of claims or counter-claims.	This level refers to a comprehensive argument involving more than one rebuttal.

Table 5 The analytical framework used to evaluate the quality of argumentation in the analysis of research findings

Level 1	Level 2			Level 3	Level 4	Level 5
	2a	2b	2c			
The level of argument consisting of claims only or counter-claims	The level of argument supported by false grounds or unscientific data for a claim	The level of argument consisting of a claim and scientific data or a partially correct explain	The level of argument consisting of a claim and scientific data and a warrant, scientifically correct explain	The level of argument consists of multiple claims, scientific data, and warrants, backing, weak rebuttals, with	The level of argument consisting of claims, scientific data, correct warrant, backing, clear rebuttals	It's an advanced argument. It contains multiple claims, scientific data, the right warrant or backing, and multiple rebuttals.

2.4. Evaluation of data

The argument components, levels, and analytical framework constituting the argumentation rubric developed by Erduran et al. (2004) are presented in detail in Table 4.

As stated in some studies in the literature, there are some limitations to using the Toulmin model (Simon, 2008; McNeill, Lizotte, Krajcik & Marx, 2006; Jiménez-Aleixandre, Rodriguez & Duschl., 2000). For example, Sampson & Clark (2008) pointed out that in Toulmin's argumentation model, the content of all arguments in the data set could not be evaluated. Ball (1994), for example, claimed that the model was suitable for analyzing simple discussions rather than real and complex discussions. Some authors, such as Aldag (2006) and Freeman (1991), discussed whether the model should be used to analyze discussion texts. Besides, it was stated that there are limitations in the categories of the Toulmin argument model, and the assessment can be made more accurately with additional levels (Aldag, 2006). In the data analysis of the present study, for the analysis of the answers given by PSTs to their questions in the worksheets, changes were made in the categories due to the reasons mentioned above. Subcategories have been added to the second level of the Toulmin argument model to evaluate the argument correctly and observe the change in creating argumentation during the implementation. False warrant-warrant-backing statements can be considered as a meaningful hierarchy of argument formation. If the PSTs are missing or falsely claiming, they will likely provide a false warrant (2a). PSTs may submit assurances but may not be able to explain them precisely. This case will probably make a medium-quality argument for the second level (2b). If the warrants presented by the PSTs are correct and appropriate, correct and explanatory statements are used for the warrants, the warranties are supported. That can also be described as switching to a higher level of argument (2c). The analytical framework used to evaluate the quality of argumentation in the analysis of the data is given in Table 5.

3. RESULT AND DISCUSSION

A sample of answers given by the PSTs to the questions in the worksheets is presented in Tables **(6-7-8-9)** according to the components of the argument (data, claim, false warrant, warrant, backing, and rebuttal). Data: It is the first information needed to conclude reasoning. Claim: An opinion, conclusion, or opinion about an idea. Warrant: It gives the link between the data and the claim. Basic principles consist of rules. Backings: The basic assumptions that support the acceptability of a justification. It provides the opportunity to consolidate the claim. Qualifiers: Limit the cases where the claim is accepted as accurate. The data strengthen the link between the consolidator and the claim, enabling a persuasive argument to be constructed (absolutely, as if impossible). Rebuttal: It is used when the claims of opposing views are not valid. To better

Table 6 Sample statements of PSTs according to the argument components in Worksheet 1

Argument components	Example expressions
Data	*Water can fill up until the air in the glass balloon cools.* *Since the temperature and pressure are directly proportional, we can use this assumption in the event.* *We're trying to make a difference in temperature and pressure.* *When the glass balloon is heated, the pressure of the air inside increases.*
Claim	*Water vapor may occur if the hot glass is immersed in water.* *The pressure of the air increases, i.e., the internal pressure increases.* *There is no substance or air in the glass balloon. Therefore, if the glass balloon is heated, it will be heated.* *Water can rise in the glass pipe.*
False warrant	*If the heated glass flask in the beaker is immersed, evaporation occurs, and fog is formed.* *As it heats up, the pressure in the glass balloon decreases, and the air begins to enter it from the outside.* *Temperature and pressure are inversely proportional. If the glass balloon heats up, the air pressure decreases*
Warrant	*When the glass bubble is warmed, the air pressure increases, the heated air expands, and the air moves upwards.* *As the temperature increases, the kinetic energy, the molecules accelerate as the air warms, and the water rises in the glass pipe.* *Water can rise in the glass pipe due to the open air pressure.* *The water can rise in the glass pipe when cold water meets hot air.*
Backing	*When the glass bubble is heated, the internal pressure increases. Some air comes out of the glass balloon, and the air becomes diluted; the pressure decreases, and the pressure difference causes the water to rise.* *In the first case, the heated air rose, and the pressure in the glass bubble decreased. In the second case, open-air pressure exerted pressure on the water surface. The water started flowing into the glass balloon in the low-pressure zone.* *Due to the pressure difference, the water rises until internal and external pressure equalizes.*

Table 7 Sample statements of PSTs according to the argument components in Worksheet-2

Argument components	Example expressions
Data	*The boiling point of water depends on the external pressure.* *The boiling point of water depends on the external pressure and the type of liquid.* *The boiling point of water depends on the altitude above sea level where we boil the water.* *As it rises above sea level, the water boils more quickly.*
Claim	*The temperature of the water decreases.* *When ice is put in the* flask, *the water becomes concentrated.* *Water droplets are formed in the flask.*
False warrant	*When the external pressure is reduced with ice, the boiling time extends.* *The boiling point of water depends on the temperature.* *When the pressure decreases, the temperature decreases.* *The boiling point of water depends on the tools, heat source, and equipment used.* *Molecules move away from each other due to the decrease in pressure when ice is placed.*
Warrant	*The ice placed on the glass balloon reduces the pressure, and the boiling point of the water decreases. That's why the water starts to boil.* *When the external pressure is reduced, the water can boil more quickly. Because if the external pressure decreases, the boiling point decreases.* *The ice in the ballon joje caused the water to boil, creating a pressure difference.*
Backing	*The vapor pressure of the water in the glass bubble can be reduced, and boiling can be achieved because the boiling point decreases as the pressure is low at high places.* *The pressure dropped when the hot water suddenly cooled, and the water began to boil again.*
Rebuttal	*If we added salt to sugar, we could change the boiling point in this case because the boiling point depends on the purity of the liquid.* *The water would not boil again without a cooling effect on the system.* *If the pressure drop was not achieved, the water would not boil again.*

understand the argument level formed by a PST, they are exemplified by directly quoting the statements. The argument levels of the PSTs are presented in the same table for each worksheet (table 10). Table 10, created for this purpose, was prepared using the data of 42 PSTs.

Worksheet 1. Rising water

Examples of argument levels for worksheet-1 are presented below.

When the glass balloon is heated, the pressure of the air increases (data). *The hot air rises and comes out of the glass pipe (*warrant*) when the glass balloon is turned over and immersed in the water, we cool the system, and therefore the pressure decreases (*backing*) since all this causes the pressure differentiation (*warrant*) the water rises in the glass pipe* (claim). (The level of argument is 2b).
*I was waiting for the water to rise in the glass pipe. (*Claim*) We apply heating and cooling processes, which cause pressure to increase and decrease (*Warran*t). The warmed air rose, and the air in the glass bubble decreased. Atmospheric pressure exerted pressure on the water surface when immersed in the beaker. The water started to fill the glass balloon in the low-pressure zone. The water rises as the system wants to balance the pressure due to the pressure difference* (Backing*). Because we do not change the atmospheric pressure, we observe the strength of the atmospheric pressure* (Data). (The level of argument is 2c).

Worksheet- 2. Boiling water

Examples of argument levels for worksheet-2 are presented below.

*When ice is placed on the inverted flask, heat exchanges between hot water and ice (*data*), and the ice begins to melt (*claim). *Due to the temperature difference between ice and hot water, water gives heat, and ice takes heat and begins to melt (warrant). Heat exchange is from a hot body to a cold body (*data). *We created a pressure difference with the cooling effect of ice and boiled the water (*backing). *The water would not boil again without a cooling effect on the system* (rebuttal). (The level of argument is 3).
I want to summarize the experiment as follows. Boiling will occur if the internal pressure equals the outside pressure, i.e., atmospheric pressure (data). *I learned from last semester's theoretical lesson that each liquid has a certain boiling temperature* (data). …….*So if we added salt to sugar, we could change the boiling point in this case, too, because the boiling point depends on the purity of the liquid. But we couldn't boil it like this here* (rebuttal). (The level of argument is 4).

Worksheet-3. Volume Reduced Plastic Water Bottle

Implementation of video activities by the researcher: In the science laboratory lesson, the PSTs watched the video whose link is given (https://www.youtube.com/watch?v=ogx_feE5bi4&feature=emb_logo), and the images are presented in Appendix-3. The whole video has been observed in three parts. When it comes to the relevant parts, the video is stopped, and what has been done is explained. The PSTs were asked questions about what they could observe and the reasons for their predictions, and they were asked to note them in their documents.

Part 1: When the first part of the video was watched, the researcher paused the video and explained what was done in the video as follows: "An empty plastic water bottle is squeezed by hand with its mouth open, and then the lid is closed. Then it was put into the bowl, and the air in the bowl was evacuated with the help of the pump". The researcher asked, "How do you think this change will affect the plastic bottle when the air inside the glass bell starts to decrease?" and wanted the PSTs to write and discuss their opinions.

Part 2: Later, the video continued to be watched. The researcher continued to explain. "In the video, we see that the compressed plastic water bottle swells as the air inside the bell is evacuated, as the pressure

Table 8 Sample statements of PSTs according to the argument components in Worksheet 3

Argument components	Example expressions
Data	*Pressure and volume are inversely proportional. Therefore, one is increasing while the other is decreasing.* *We can interpret it with the formula Pv = nRT.*
Claim	*I thought the pet bottle would get smaller when the air in the pump was drawn.* *As the air is discharged, the pressure in the pump decreases. Therefore, it can also be said that the pressure is low in an airless environment.* *If the air of the bell jar is discharged, the volume of the pet bottle may increase due to pressure change.*
False warrant	*The relationship between pressure and force, the pressure and volume relationship, explains this situation.* *It is the volumetric force that allows the change in the shape of the bottle.* *Like when electrical cables pucker up in winter and stretch in summer?* *The pet bottle has returned to its former state as the pressure generated by the gravitational effect in the bell jar has decreased.* *As the bell jar's internal pressure increases, the bottle's volume increases, and the bottle's volume decreases as its pressure decreases.* *Taking the air in the bell jar reduces the effect of gravity on the bottle, and the bottle returns to its original state. When the air re-entered the pump, the gravity applied to the bottle returned to the shape we gave it.*

Table 8 Sample statements of PSTs according to the argument components in Worksheet 3 (*Continued*)

Argument components	Example expressions
Warrant	*As seen in the experiment, pressure affects the compressed plastic bottle.* *If the pressure decreases, the volume of the plastic bottle increases and returns to its original form.* *Since the number of particles in the glass bell decreases, the volume of the shrunken plastic bottle starts to increase.* *As the air in the bell jar decreased, the pressure dropped, and the plastic bottle volume increased.*
Backing	*As the air inside the bell jar is discharged, the volume of the pet bottle increases so that the pressure inside the bottle is equal to the pressure on the bell jar. Therefore, the pressure inside the bottle is reduced.* *As the pressure of the bell jar decreased, the bottle began to grow; its volume began to increase. So I think it's because the external pressure is decreasing; the pressure on the bottle is decreasing, and the bottle's volume is starting to increase.*
Rebuttal	*By closing the bottle lid, the amount of air in the bottle is prevented from being changed. The experiment could have differed if the lid hadn't been closed when the pet bottle was put in the bell jar.* *Episodes I was surprised by in the experiment: I saw this event for the first time. It's fascinating that the pet bottle grows like air is getting into it. We wouldn't have used glass bottles instead of plastic bottles in this experiment because the glass bottle couldn't be compressed. I wonder if the glass bottle would explode or open the lid if it was made in a glass bottle with the lid closed.*

is reduced and returns to its initial state. *How do you think this situation can be explained?"*

Part 3: The video has continued to be re-watched. The researcher stated, "When the air re-entered the bell jar, the water bottle returned to its compressed state." How do we explain this case? What could be the effect that makes you think so? The researcher asked them to write and discuss their views.

Examples of argument levels for worksheet-3 are presented below.

> *It is clearing the air from the bell jar. Therefore, it reduces the pressure on the bell jar (*data). *I thought the bottle could stick to the bell jar, for a moment* (claim)….*Accordingly, the bottle in the bell jar goes back to its original state because internal and external pressure balance should be established (*warrant). *Since the bottle's internal pressure is greater than the pressure in the bell jar, the bottle expands. This condition continues until the pressure in the bottle, and the flask is equalized* (backing). (The level of argument is 2c).

> *In this experiment, I observed the effect of outdoor pressure on the pet bottle (*data). The *pressure changed the physical appearance of the pet bottle (*data). *First, the air inside the bell jar was evacuated. That is, the tension in the bell jar decreased, and the volume of the pet bottle in creased. Then the lid of the bell jar was opened. The pet bottle returned to its original form (*backing) *as the pressure was restored to the starting level. I noticed the lid on the pet bottle was closed. We wouldn't be able to observe this effect if the top of the pet bottle hadn't been completed (*rebuttal). (The level of argument is 3).

Worksheet-4. A Glass of Room-Temperature Water

Implementation of video activities by the researcher:

The entire video is shown in two parts. Regarding the relevant sections, the video is stopped and explains what is done. The PSTs were asked questions about their observations and predictions and expected to write down their worksheets.

Part 1: In the science laboratory lesson, the PSTs watched the video whose link is given ((https://www.youtube.com/watch?v=ciaBaZu0qK0&feature=emb_logo), *and the images are presented in Appendix-4. Halfway through the video, the researcher was stopped and expressed what was done as follows." First, the temperature of a glass of water is measured with a thermometer (18 degrees) and placed on the air discharge pump table. Then, the pump was operated." Finally, the researcher asked the PSTs, "How do you think this change affects the water when the air inside the glass begins to decrease?" and wanted them to write their opinions.*

Table 9 Sample statements of PSTs according to the argument components in Worksheet-4

Argument components	Example expressions
Data	*The relationship between external pressure and the boiling point of water can explain this.* *As the open-air pressure decreases, the boiling point of the water decreases.* *For water to boil, the air pressure and the steam pressure of the water must be equal.*
Claim	*I expected the glass to break when the water started to boil.* *The water can boil.*
False warrant	*Suppose the external pressure and the water vapor pressure are equal; the temperature increases. So the water boils.* *Of course, it's pressure and particle speed. As the particle speed increased, the water began to boil.* *There's probably an inverse ratio between the pressure and the boiling point.* *Under normal conditions and normal pressure, the water can't boil.*

Table 9 Sample statements of PSTs according to the argument components in Worksheet-4 (*Continued*)

Argument components	Example expressions
Warrant	*When the pressure decreases, the boiling temperature of the water decreases. Therefore, the water at room temperature boils after a while.* *If the air pressure that acts on the water decreases, the water boils. When exposed to the same air pressure again, the water stops boiling.* *With the effect of atmospheric pressure, water can boil at different altitudes and temperatures.*
Backing	*I understand from the experiment that you may not need any outside heat to boil. So just lowering the pressure may be enough to boil the water.* *The air pressure in the environment decreases, and the water may also boil at temperatures lower than the normal boiling value. In other words, the pressure affects the degree to which the water boils.* *Water does not boil because the steam pressure of the water at room temperature is smaller than the pressure in the external environment. Thanks to the pump, the pressure that acts on the water decreases, but the steam pressure of the water does not change. When the steam and external pressure of the water are equalized, the water boils.*
Rebuttal	-

Table 10 Change in PSTs numbers based on argument levels at worksheet

		Level 1	Level 2a	Level 2b	Level 2c	Level 3	Level 4	Level 5
W-1	f	27	8	3	4	0	0	0
	%	64	19	7	10	0	0	0
W-2	f	23	6	4	6	2	1	0
	%	55	14	10	14	5	2	0
W-3	f	17	6	6	9	2	2	0
	%	41	14	14	21	5	5	0
W-4	f	20	6	5	11	0	0	0
	%	48	14	12	26	0	0	0

W: Worksheet F: Frequency P: percent

Part 2: the video continued to be shown. The researcher explained: "We see the water boiling in the video. When the air discharge pump stops, and the flask is turned on, the temperature of the water is measured again (18 degrees). How do we explain this? What do you think the effect is that makes you feel that way? "

Examples of argument levels for worksheet-4 are presented below.

> *The pressure decreases as the air in the bowl is evacuated with the help of a pump* (data). *The vapor pressure of the water does not change, but since the pressure in the bell jar decreases, both pressures are equal (warrant). In this case, the water is boiling.* Normally, water does not *boil at room temperature (data). Because the external pressure is greater than the pressure of the water vapor, we cannot wait for the water to boil (backing).* (The level of argument is 2b).

> *Water boils at 100 degrees Celsius at sea level. However, every time you go up 200 meters above sea level, the boiling temperature of the water decreases by 1 degree Celsius* (data). *Because as you go above sea level, the atmospheric pressure decreases, and the boiling temperature of the water decreases* (data). *For example, in Izmir, which has an altitude of 0, water boils at a higher temperature than in Erzurum.* (backing). *That is because Erzurum's atmospheric pressure is less than in Izmir* (warrant). *In this experiment, the water in the glass may boil* (claim). *As the pressure decreases in the flask, the boiling point of the water decreases and can cook in its environment (warrant). While the pressure affecting the water decreases, the steam pressure of the water does not change, and the water boils as the steam pressure of the water is equalized to the atmospheric pressure* (warrant). (The level of argument is 2c).

The findings of this study, which examined PSTs' ability to create arguments through POE activities, are presented in figure 1 and table 10. The figure and table give a change in the number of PSTs according to the level of argument.

When table 10 was evaluated in general, there was no significant and regular increase or change. When the level of the argument of the PSTs is examined, it is seen that they initially struggled to make arguments and were often only able to produce claims worksheet-4 (see Table 10). Level 1 reduction can be considered as an indication that the level of the argument of the PSTs is moving from claim to justification and support (see figure 1). At the beginning of the implementation, PSTs generally discussed the ideas by creating observation notes explaining the experiment. However, they were found to have difficulty explaining the experiment scientifically. Challenges in making scientific statements cause low levels of argumentation. As the implementation progressed, the number of candidates who could interpret, explain and evaluate from a different point of view increased.

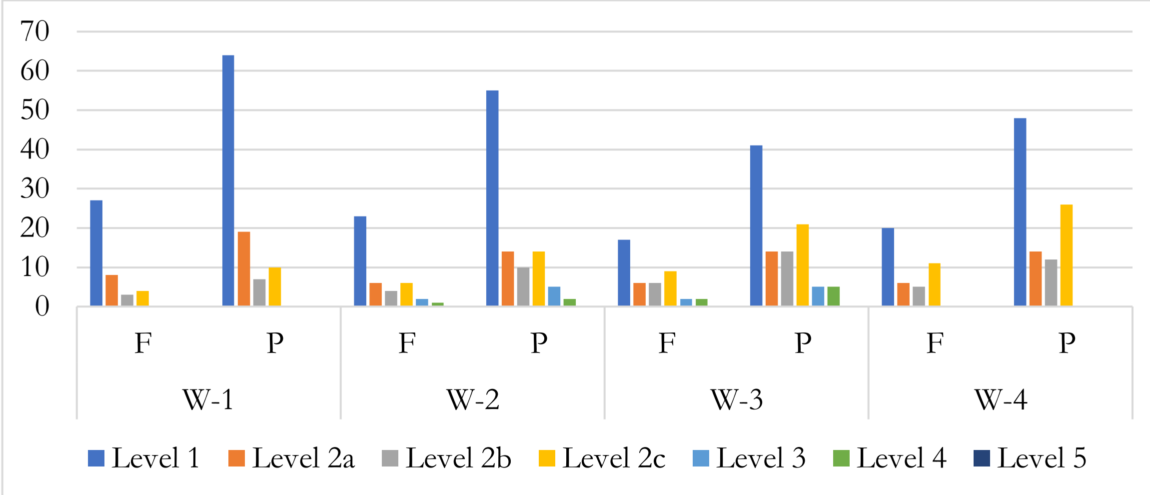

Figure 1. Change in PSTs numbers based on argument levels at experiments

In contrast, the number of the PSTs who made only claims remained almost half the total number of participants throughout the application. Among the reasons for this situation, candidates have not encountered the course process in which the argument approach has been applied before and do not know about the argument. They have taken a limited number of science courses. The small number of science courses means that the PSTs are trained with less science content. This result is in line with the research results in the relevant literature (Anisa, Widodo, Riandi & Muslim, 2022; Dawson & Venville, 2010; Erduran, Simon & Osborne, 2004; Maloney & Simon, 2006; Nussbaum & Edwards, 2011; Zohar & Nemet, 2002). Jiménez-Aleixandre & Erduran (2007) stated that argumentation is a form of discourse that students should learn. According to them, it is a process that must be taught explicitly through appropriate instruction, task structuring, and modeling. Therefore, they argued that practices should be carried out that encourage the forms of communication necessary to obtain an opinion on science learning and to maintain scientific discourse. Faize, Husain & Nisar (2017) stated that discussion environments should be created with students who have no prior knowledge or have different beliefs during the course. Hiğde & Aktamış (2016) stated that the teacher candidates generally lacked experience in science lessons. The observation and interview data they examined throughout their studies revealed that teacher candidates had difficulty forming arguments. Another study with teacher candidates pointed to the importance of professional practices for argumentation and the need to support cooperation with other individuals (Simon, Davies & Trevethan, 2012).

Apart from Worksheet-1 and Worksheet-4, some PSTs argue between Level-3 and Level-4. This result can be considered an indication that their thinking and writing skills have improved. Besides, it can be evaluated meaningfully in terms of the course of the study and target evaluation. In recent years, it has been stated that argumentation increases students' ability to make arguments and supports them in effectively learning concepts (Ortega, Alzate & Bargallo, 2015; Sampson & Clark, 2009; Uzuntiryaki-Kondakci, Tuysuz, Sarici, Soysal & Kilinc, 2021; Weng, Lin & She, 2017). Hand, Wallace & Prain (2003) examined teacher and student changes. In the study, teachers' diaries and notes they kept about the field and classroom environments were monitored for two years, and interviews were done with student groups. At the end of their studies, they reported that teachers' ability to produce arguments increased, and their scientific literacy improved. The focus of Hand, Wallace & Prain's (2003) work with the current study is that students' ability to form arguments can improve over time

4. CONCLUSION

During the implementation, it is seen that the PSTs in worksheet-1 and 4 cannot make arguments at level-3. In worksheet-1, it can be said that they could not use rebuttal in the counter-claim due to their unfamiliarity with the implementation. In Worksheet-4, on the other hand, they had difficulty predicting that the water in the glass could boil. Thus, they could not form an argument about the situation where their claim could be invalid. Besides, it can be said that PSTs try to make more scientific statements in experiments where video is used about visual elements. Although their use of rebuttal remains limited, according to the discussions in the study, PSTs make more arguments when they watch videos. This situation causes the candidates to adapt to the process and examine the event by finding it fascinating. The effect of two factors can be considered. Firstly, when the candidates watched the video, they curiously examined the events by finding them interesting and developing different perspectives. Considering that people learn 10% of what they listen to and more than 80% of what they see (Heinich, Molenda & Russell 1993), visual elements functionally offer candidates a different potential perspective in the configuration of an argument (Roberts, 2007). Using a variety of visuals (Hmelo-Silver & Pfeffer, 2004) as a way to explain complex ideas provides an easier way to explain what is meant. Secondly, it can be thought that the candidates are accustomed to the situation as they experienced argumentation by doing and participating in it before they were shown videos. Therefore, the PSTs can be considered to have gained experience at the end of each experiment during the implementation, and their tendency to make scientific discourses increases. As a result, they came prepared for visual argument and acquired some information.

For the learners to form rebuttals, long-term studies should be carried out, they should be more present in the science learning environment, and such applications should be used continuously in the learning environment. Although PSTs' use of rebuttal is limited, it is a positive result that the candidates make correct claims, provide valid reasons, and establish a cause-effect relationship regarding the test result. Regarding the limitation of the use of rebuttal, some problems related to handling these concepts in the Turkish education system can be addressed. For example, the boiling phenomenon is usually given by the relationship between steam and external pressure (Şimşek, Öztuna-Kaplan, Çorapçıgil & Mısırlı, 2018). The best example in the current study findings is that the candidates try to explain the boiling event in Worksheet-2 with the change of atmospheric pressure as it rises too high. Likewise, in Worksheet-4, their confusion about how the water boils without heating is an example that can be given to this situation. Since the PSTs generally consider external pressure atmospheric pressure, they think the external pressure remains the same as long as the environment does not change. Students often associate boiling with temperature, and the boiling of a liquid is evaluated according to the height of the sea level (Şimşek, Öztuna-Kaplan, Çorapçıgil & Mısırlı, 2018; Paik, 2015). In scientific terms, giving the essence of the event can minimize this problem. Besides, when teaching abstract scientific concepts, although teaching materials are limited (McNeill, Katsh-Singer, González-Howard & Loper, 2016), comparisons should be made with the relationship between two or more concepts, or each idea should be explained independently by presenting contrasting examples

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APPENDICES

Worksheet 1

Rising water

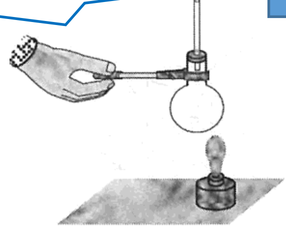

Figure A

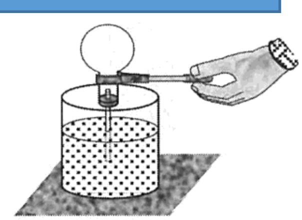

Figure B

Materials used for the experiment:
* flask, * single-hole rubber stopper, * spirit stove, *water, * Beherglass (beaker) * tube tongs *match* thin glass tube (15cm)
Experiment Procedure:
1. Fill ¾ of the beaker with water and place it on the table.
2. Place the one-hole rubber stopper into the mouth of the flask.
3. Insert the glass tube into the plug's hole, so there is no air from the edges.
3. Heat the flask by turning and moving it from a distance in the flame of the spirit stove.
4. After the flask heats up, turn it upside down and immerse the glass tube in the water inside the beaker.

Prediction
How would you expect a change in the air inside the flask as it warms up? Can you explain your predictions? (see Figure A)
What would you expect to happen to the water in the beaker in the arrangement in Figure B? Can you explain your predictions?
Observation
What did you observe during the experiment?
Explanation
Make comparisons between your predictions and your observations. If your observation results and your predictions do not match, explain why.
How did the air inside it change as the flask heated up? Can you explain? (see Figure A)
What did you observe in the water in the beaker when you experimented? (see Figure B)

Boiling water

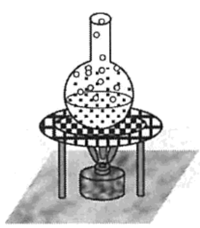
Figure A

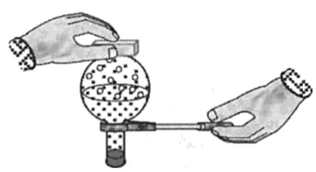
Figure B

Materials used for the experiment:
* flask, * rubber stopper, * spirit stove, * trivet, * yarn
* cage, * water, * ice chips, * tube tongs * matches
Experiment Procedure:
The flask is filled with ¼ water and placed on the spirit burner (see Figure A).
Spirit stove is burned, and water is boiled.
After boiling the water, it is expected that the boiling will stop.
When the water stops boiling, the mouth of the flask is tightly closed with a rubber stopper.
The flask is held by the tube tongs and turned upside down (see Figure B).
Ice pieces are placed on the top of the flask.
While doing this, follow the water in the flask.
Prediction
What would you expect to happen when cold water or ice is placed on the flask?
What do you expect to happen when cold water or ice is placed on a flask
Observation
What did you observe during the experiment? Can you write down the results of the observation?
Explanation
Can you make comparisons between your predictions and your observations? Can you explain the similarities and differences between your observations and predictions?
According to your observations, what do you think water boiling depends on?
Why does water boil faster in high places? How do you think we can relate this situation to our experiment?

Worksheet 3

Volume Reduced Plastic Water Bottle



Figure A Figure B Figure C

Materials used for the experiment:

· air discharge coverall (vacuum pump)
* bell jar
* empty plastic water bottle

When the bell jar is placed on the circular plate and operated, the pump discharges the air inside the bell jar (see Figure- A). Although the pump can remove most of the air inside the bell jar, a minimal amount of air may remain in the bell jar.

Experiment Procedure:

An empty plastic water bottle is manually compressed when the lid is open and closed (see Figure B). It is then placed in the bell jar, and with the help of an air drain coverall, the air in the jar is emptied (see Figure C).

When the lid of an empty plastic water bottle is open, it is tightened by hand, and the top is closed ((Figure B). Then it is placed in the bell jar. The air in the bell jar is evacuated with the help of the air discharge coverall (see Figure C).

Prediction

How do you think this change can affect the pet bottle when the air inside the bell jar decreases?

Observation

What did you observe?

Explanation

What did you observe at the end of the experiment?

Worksheet 4

A Glass of Room-Temperature Water



Figure A Figure B Figure C

Materials used for the experiment:

· air discharge coverall (vacuum pump)
* bell jar
glass

Water
When the bell jar is placed on the circular plate and operated, the pump discharges the air inside the bell jar (see Figure- A). Although the pump can remove most of the air inside the bell jar, a minimal amount of air may remain in the bell jar

Experiment Procedure:

The temperature of a glass of water is measured with a thermometer (see figure-B), put into the air discharge pump, and operated (see Figure-C).

Prediction

How do you think this change can affect the water when the air inside the bell jar decreases?

Observation

What did you observe?

Explanation

What did you observe at the end of the experiment?