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Impact of Pre-Service Teachers' Awareness of Using Multiple Representations on the Argumentation-Based Inquiry Process*

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Abstract

This study aimed to investigate how awareness of pre-service teachers is reflected in the process when making oral and written arguments, the effect of using modal representations on the quality of the argument, what modal representations students use when making arguments, and what modal representations they consider important (especially when defending their claims). The method of the research is the convergent parallel design, one of the mixed research methods. The sample of the study consists of 2nd grade pre-service teachers (N=83) studying at a state university in the north east of Turkey, selected by convenience sampling method. In the quantitative dimension of the study, Argumentation-based inquiry (ABI) reports evaluation form was used, while in the qualitative dimension, video recordings, semi-structured interviews and photographs (presentation board pictures) and ABI reports were used as data collection tools. Analysis shows pre-service teachers need an education or an activity to raise awareness. The pre-service teachers who gained this awareness use different types of representation in a larger number and variety and do this in order to serve a purpose (such as defending their claims).

Keywords: Argumentation-Based Inquiry, Multi Modal Representation, Multiple Representation, Quality of the Argument

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INTRODUCTION

The expectation of educators to involve students in scientific research and reasoning has prompted educational researchers to conduct research to better understand how students construct arguments in different laboratory / course applications and what teaching strategies support the development of this scientific practice (Petritis, Kelley & Talanquer, 2020). Because researchers note that opportunities are still missing in science classes for students to discuss (Osborne, 2010). Argumentation is a process in which persuasive conversations can take place that offer students the opportunity to discuss a science topic and involve them in the discussion. In studies on argumentation, Argument-Driven Inquiry (ADI) and Science Writing Heuristic (SWH) teaching models draw attention (Hand & Choi, 2013; Keys et al., 1999; Sampson et al., 2010; Walker et al., 2012) Although their approach to involving students in the discussion is different, they are in the same direction in how they define arguments and evidence in both models (Sampson et al., 2010; Burke et al., 2006). It provides guidance for developing tasks (Walker et al., 2012). The SWH approach allows students to start by identifying a researchable question, to determine their initial thoughts on it, to conduct observations, experiments and/or researches to answer research questions, to make evidence-based claims and to reflect how their opinions changed during their experiences. Similarly, the ADI teaching model directs students to make temporary arguments in the form of claims, evidence and reasoning, and, to participate in a peer evaluation process before reviewing their final arguments (Sampson et al., 2010; Walker et al., 2011). In this study, inquiry-based investigations were conducted using the SWH approach.

Theoretical Framework

Argument-Based Inquiry approach

This study is theoretically grounded by argumentation-based inquiry (ABI), which is based on Science Writing Heuristic (SWH) aprroach. Argumentation is the formation of arguments that can enable the use of scientific data and evidence when defending their claims or making counter-arguments (Simon, Erduran, & Osborne, 2006). At the same time, it is to put forward reasons related to an event or situation and to persuade and convince by providing appropriate evidence (Driver, Newton & Osborne, 2000). An argument is defined as a claim that "consists of either assertions or conclusions and of their justifications, or of reasons or supports" (Zohar & Nemet, 2002, p. 38). According to Toulmin (1958), the basic components of the argument are "*claims, data, warrants, qualifiers, backings, rebuttals*". Choi et al. (2013), on the other hand, defined the structure of questions, claims, and evidence within the structure of arguments as an integral part of completing any interrogation activity.

The ABI was developed for science learning from laboratory activities through written and verbal argumentation (Hand 2008; Keys et al. 1999). This approach is based on students' ability to ask questions, test the evidence, make arguments in parallel, and use decision-making strategies while comparing their claims with existing scientific information (Hand, Wallace & Yang, 2004). The ABI approach emphasizes the importance of negotiating ideas while students create questions, claims, and evidence, and link questions, claims, and evidence (Choi, Hand & Norton-Meier, 2014).

The argument process realizes conceptual understanding, research ability and understanding of scientific epistemology in students, makes students curious and active, encourages them to create explanations by providing in-depth understanding, and provides opportunities for students and teachers to review and solve errors thoroughly (Driver, et al, 2000; Kaya & Kılıç, 2008). In addition, students' understanding of the nature of science and scientific issues are improving (Keys, et al., 1999). At the end of the process, the individual is expected to form an argument. The argument mentioned herein has the characteristics of suggesting a reason for an event or situation and testing the causes of the event/situation from different perspectives with appropriate evidence (Driver et al., 2000).

During ABI applications, students fill out the ABI report form. While they have the opportunity to re-test their effectiveness and think about what they have learned by writing their claims and evidence in their reports, they become aware of what they are doing by writing their reflections in the section on how their ideas have changed, and this writing process helps them establish a connection between what they understand and what they talk about (Burke, Greenbove & Hand, 2006). At the end of the ABI applications, the student completes his scientific argument about the subject he is working on.

Evaluation of scientific argument (Argument quality*)*

As the effects and importance of the argument are understood in the literature, students' ability to make arguments and quality of arguments begin to gain attention (Choi et al., 2013). Most studies focused on Toulmin's (1958) argument components to define and analyze students' argument structure (Kelly, Drucker & Chen, 1998; Bell & Linn (2000). However, various studies have reported that using only Toulmin's argument scheme is not enough to evaluate the structure of the argument built by the students (Choi et al. 2013). Some researchers used Toulmin's argument scheme on this issue, but expanded it or added additional dimensions (Jimenez-Aleixandre et al. 2000; Erduran et al. 2004). A group of researchers has put forward guidelines to analyze the quality of their arguments, arguing that the shared criteria are incorrect (Blair & Johnson 1987; Kelly & Takao, 2002; Kelly & Bazerman, 2003; Sandoval & Millwood, 2005). For example, Blair and Johnson (1987) stated the content and outcome relationship, competence and acceptability criteria for a good argument, while Kelly and Bazerman (2003) stated the epistemic levels of the claims, the verbal adaptations that link the claims as dimensions of the persuasiveness of the evidence, and the rhetorical movements required by the specific academic task. (the epistemic levels of claims, the lexical cohesions tying claims together as dimensions of persuasive uses of evidence, and the rhetorical moves required of the particular academic task) emphasizes. In addition, Sandoval and Millwood (2005) stated that "co-ordination of claims and evidence" should be taken into account in assessing the quality of student arguments, along with "conceptual competence" (such as the conceptual nature of the allegations, the adequacy of the evidence related to the allegations).

Kelly et al. (2005), who put forward eight criteria (e.g. solvable research questions, lines of reasoning that are convergent, overall support of claims etc.) for evaluating the argument, pointed out that a high-quality written argument involves more than one description and convergent reasoning. Similarly, Choi et al.(2013) developed analytical and holistic argument evaluation frameworks to assess the quality of written arguments produced by students using the SWH approach, suggesting questions, claims, question-claim relationship, evidence, claim-evidence relationship, multiple modal representations and reflection components. The importance of using multiple modal representations in science is emphasized by many researchers in the literature (Dolan & Grady 2010; Gilbert 2005; Kozma & Russell, 2007; Lemke, 1998). In this research, ABI Report Evaluation Form, which was prepared similar to the criteria of Choi et al. (2013), was used. Detailed information about the rubric is presented in the data collection tools section.

Argumentation and modal representations

Representations containing modes such as pictures, graphics, mathematical expressions, text, tables, models, diagrams, animations, each with different content and function, with different strength and weakness in the size of accuracy, clarity and connotation meaning, are indicated as modal representations (Ainsworth 2006; Günel & Yesildag-Hasancebi, 2016). Wu and Puntambekar (2012) stated that representations are define as “range of transformations that conceptualize, visualize, or materialize an entity into another format or mode” in education research and representations can be classified in four categories: “verbal-textual (metaphors, oral propositions and written text), symbolic-mathematical (equations, formulas, structures), visual-graphical (animations, simulations, diagrams, graphs, tables), and actional-operational (demonstrations, gestures, manipulatives, physical models)” (p.755). In the literature, there is a consensus that students should understand, develop, use and transfer different modes rather than sticking to certain modes in their description and explanations of

science concepts and phenomena (Ford 2007; Mursia, 2010, Gunel, Hand & Gunduz, 2006; Prain & Waldrip, 2006). Studies emphasize that the use of more than one modal representation supports students to develop a deeper understanding of science (Ainsworth 2006; Nakhleh & Postek 2008) and enables them to learn scientific concepts (Kozma & Russell 2005; Parrill, Nakhleh & Donovan, 2000).

Recent studies in science education emphasize the importance of scientists associating argument and modal representation to generate knowledge (Namdar, 2017). Both empirical and theoretical studies emphasize that using multiple modal representation has the potential to support scientific discourse and argument (Ainsworth, 1999; Airey & Linder, 2009; Kozma, 2003; Pallant & Lee, 2015). Because argumentation leads to greater use of representations to organize information in discussion contexts (Namdar, 2015; Namdar & Shen, 2016).

Given that science concepts are represented in different modal forms and make arguments using different modal forms, and these representations make it easier to understand concepts, students should be given opportunities to create arguments through questioning activities where they can interact with different modal forms (Hand & Choi, 2010). At this point, it can be said that teachers have a critical role in creating such learning environments (Günel & Yesildag-Hasancebi, 2016). Therefore, science teachers are expected to understand argumentation in scientific inquiry and science teaching, to value its importance (Sampson & Blanchard, 2012), to increase the understanding of using representations in the argumentation process (Namdar, 2017), and to create their awareness. For these reasons, the role, effects and the way the use modal representations are used are important in the argumentation process. Highlighting this issue, Namdar (2017) stated that little is known about how pre-service teachers (PSTs) view and use representations. For these reasons, the current research focused on pre-service teachers.

Munfaridah, Avraamidouv, and Goedhart (2021), who examined the articles published in scientific refereed journals between 2002 and 2019 about the use of multiple representations in the context of physics education, noted that in addition to how students use representations to solve problems, there is a gap in the literature of determining the understanding of teaching practice, classroom environment, nature of problems and how students' preliminary knowledge affects their success in solving problems using different types of representations. The researchers recommend a blend of various representations and further research to see how to support students' conceptual understanding of physics concepts. In addition, most of the research on modal representations has focused on the effects of more than one modal representations on students' learning scientific concepts (Kozma & Russell 2005; Parrill et al. 2000). However, research focused less on students' use of multiple modal representations when they are actively engaged in writing activities in the context of scientific inquiry (Hand & Choi, 2010). In this context, the aim of the research is to investigate how this awareness is reflected in the process when making oral and written arguments, the effect of using modal representations on the quality of the argument, what modal representations pre-service teachers use when making arguments, and what modal representations they consider important (especially when defending their claims). Research questions:

1. What modal representations do pre-service teachers use while creating and sharing their arguments in the ABI process?

2. How does the use of multiple modal representations affect the quality of the ABI report?

3. What are the reasons for using modal representations according to the opinions of the pre-service teachers?

METHOD

The method of the research is the embedded design, one of the mixed research methods. In the embedded design, the researchers combines the collection and analysis of both quantitative and qualitative data within a traditional quantitative research design or qualitative research design

(Creewell & Plano Clark, 2011). The embedded design can be applied to and in cases where the researcher has different research questions that require using different data types to improve the qualitative/quantitative designs, and scrutinize the main purpose of the research (Creewell & Plano Clark, 2018). An experimental process in which two groups (the implementation group that received education on modal representation and comparison group) were compared was used in the research. Qualitative data were embedded in the experimental design. There are research questions that require different data in the research. While quantitative data were required for the second question, qualitative data were needed for the first and third research questions. That is, while the effect of the use of modal representations is explained with quantitative data, in order to scrutinize this result and to determine how meaningful it is, how, how much and for what purpose the representations are used is explained with qualitative data. An experimental process in which two groups were compared was used in the research. Qualitative data embedded in the experimental design. There are research questions that require different data in the research. While quantitative data were required for the second research questions, qualitative data were needed for the first and third research questions. More clearly, while the effect of the use of modal descriptions is explained with quantitative data, in order to examine this result and to determine how meaningful it is, how and for what purpose the representations are used is explained with qualitative data.

Sample / Research Group

The sample of the study consists of 2nd grade pre-service teachers (PSTs) studying at a state university in the north east of Turkey, selected by convenience sampling method. There are 83 (44 implementation group, 39 comparison group) pre-service teachers in the sample.

Application Process

Applications were made in General Physics III Laboratory courses. Course content includes optic topics (light, shadow, reflection of light, mirrors, refraction of light, lenses). The course is taught 2-hours a week in the physics laboratory. In the process, one of the two classes was randomly determined as the implementation group. The pre-service teachers in both groups formed groups of 3-4 people they determined. The lessons in the implementation and comparison group were taught by the same faculty member. The main difference between the two groups is that the implementation group received education on modal representation. The application process is presented in Figure 1.

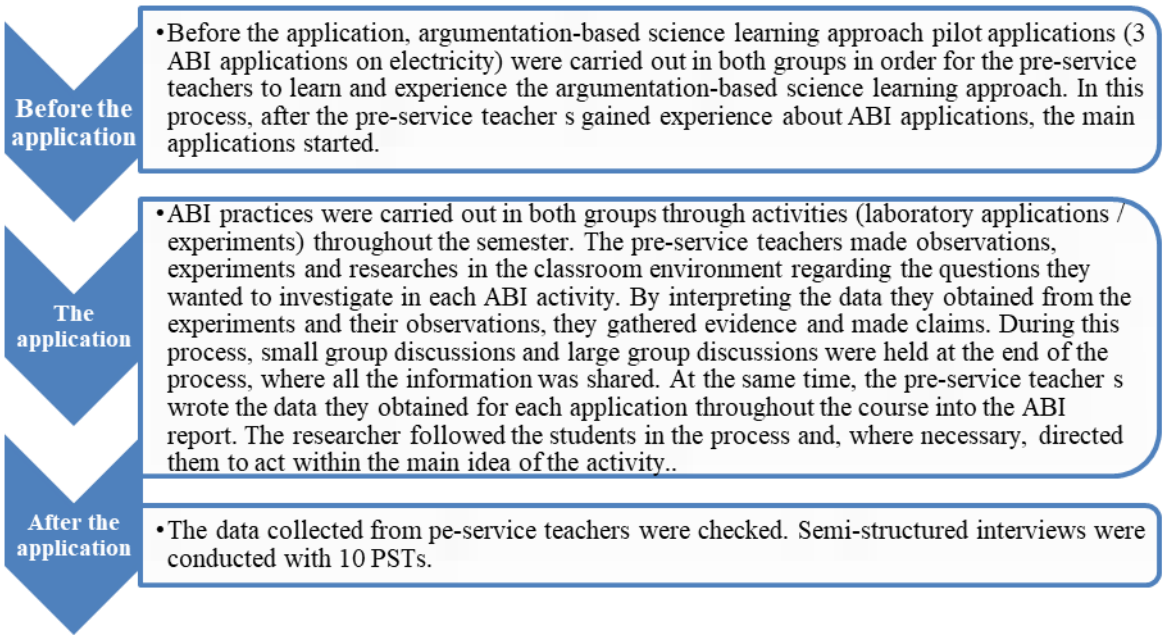

Figure 1. The Application Process

The modal representation education

Simultaneously (in the first week) with the start of the applications, modal representation training was carried out in the application group. This training consists of two stages (Figure 2).

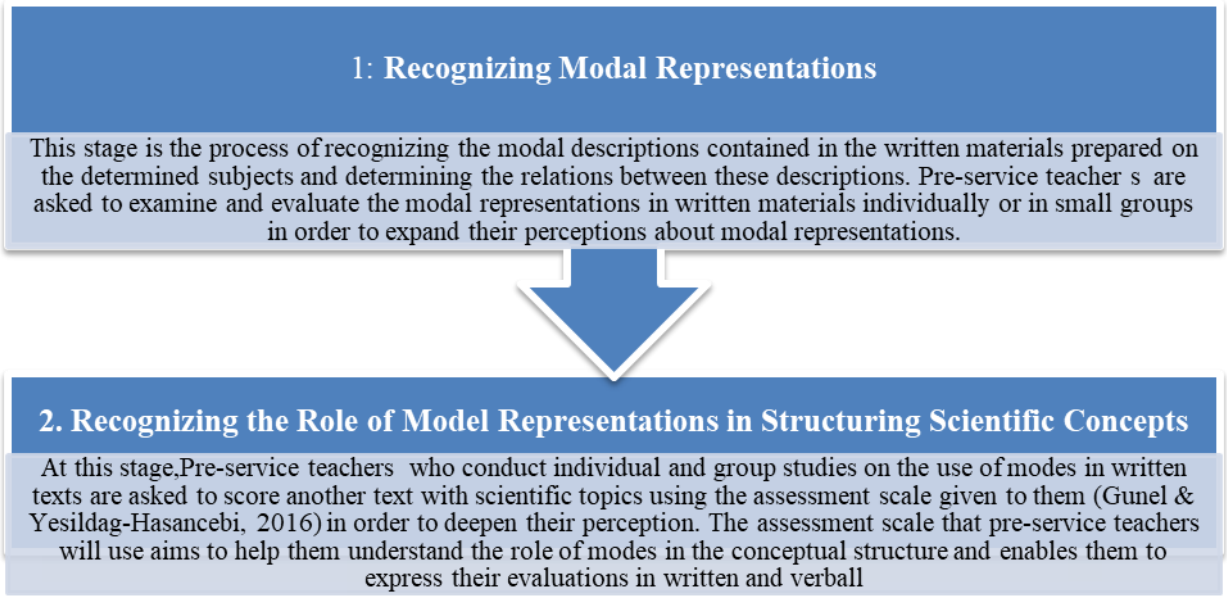

Figure 2. Modal Representation Training

Data Collection Tools

In the quantitative dimension of the study, ABI reports evaluation form was used, while in the qualitative dimension, video recordings, semi-structured interviews and photographs (presentation board photographs) and ABI reports were used as data collection tools. Detailed information on data collection tools are as follows:

ABI report form consists of sections of "what is my research question?, What is my initial thoughts?, What I did? (my experiments observations/research), What I found? (my results/findings), What is my claim? (my claims), What is my evidence?, My ideas compared with others, Comparison with written resources (information from the written resources/comparing science ideas to textbooks or other resources), reflection (my opinions changed?)". The PSTs filled out this report individually during each ABI activity process. These reports were evaluated with the ABI report evaluation rubric (Hasançebi, 2014). The evaluation rubric is scored between 0 and 3.

Semi-structured interviews were conducted with 10 PSTs. The main purpose of the interviews is to reveal the PSTs' thoughts on how much, for what purpose and how they use modal representations in the process of writing and oral argument. The interviews lasted approximately 15-20 minutes.

Video recordings and photographs were used to determine the modal representations that PSTs use while presenting their arguments. Video recordings include processes to defend PSTs ' claims during ABI practices in the classroom environment. Especially since PSTs use the blackboard in their argument presentations, the board is photographed at the end of each application. These video recordings and photos were made for each ABI event of both the practice and the comparison groups.

Data analysis

First, ABI reports were evaluated through the ABI Evaluation rubric. In order to determine the difference between the two groups in the analysis of ABI reports, the Independent Groups T Test, which is one of the predictive analyzes, was applied using the SPSS program.

Content analysis was performed to determine the modal representations used in ABI reports in the qualitative dimension of the research. The modal representations used by the PSTs in the analysis were determined as the type of representation (picture, list, table, etc.), how and how much the representation was used alone or multiple (picture + mathematical expression or picture + table + mathematical expression). Interviews and video recordings were transcribed and prepared for analysis. Since the focus is on the same content in video recordings and photos, they have been analyzed together. All qualitative data were analyzed with content analysis. Content analysis is an analysis method that determines words, concepts, themes or sentences in a text and converts them into numerical data (Seggie & Bayyurt, 2015). The sentences (for semi-structured interviews) and modal representations like text, picture, table or list (for video recordings, photos and ABI reports) were used as analysis unit in this study.

In order to compare the similarities and differences of the findings obtained from both analyzes (quantitative and qualitative) in the research, side-by-side comparison, which is commonly used for data analysis comparisons in mixed methods research, and data transformation in the findings were applied. The data obtained in the analysis of qualitative documents (ABI report, photograph) were transformed into quantitative data. Converting qualitative data to quantitative data involves reducing themes or codes to numerical data (Creeswell & Plano Clark, 2011). This conversion was done by determining the number of times the theme or code was seen (eg. Table 2). In addition, for the side-by-side comparison strategy, qualitative findings in the form of quotations are presented in the continuation of the findings that were converted into quantitative data.

Validity and Reliability

During the evaluation phase of ABI reports, the researcher evaluated the 10 randomly determined reports with an interval of 2 weeks and checked their consistency. All reports were evaluated after 94% consistency was achieved. The questions to be asked during the interview were generally determined in advance and the opinions of the experts of the field were taken. An atmosphere of trust was tried to be created with the interviewees and the other party was informed that what they said would remain confidential. In order not to affect the interview process and to be evaluated in detail, the interview was recorded with a tape recorder and the participant's permission was obtained for recording. During the interview, care was taken to use the terms that the interviewee would understand and the accuracy of what he said was tried to be confirmed. Alternative questions and probes were used to understand the questions well. In addition, since videos and photographs were carried out to determine the impressions that PSTs used while presenting their arguments, these data were analyzed together (simultaneously) in order to be able to confirm the same data while analyzing.

RESULTS

Modal Representations that PSTs Use (in writing) While Creating Their Arguments

PSTs formed their arguments in writing through ABI reports (experiment reports). Modal representations were usually included in the *What I did?, What I found?, My evidence* and *Comparison with resources* sections of ABI reports. The representations used in the reports are presented in Table 1

Table 1. PSTs' Use of Modal Descriptions in ABI Reports

ABI Report sections			What I did?		What I found?		My evidence		Comparison with resources	
			(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
Topics	Group	N	%	%	%	%	%	%	%	%
Shadow	Imp.	44	50	50	50	50	66	74	91	9
	Comp.	39	44	54	35	65	68	72	83	17
Reflection	Imp.	41	56	44	37	63	54	66	44	56
	Comp.	40	65	35	40	60	67	43	58	42
Mirrors	Imp.	44	52	48	23	77	37	63	52	48
	Comp.	37	60	40	24	76	68	32	52	48
Refraction	Imp.	44	41	59	30	70	41	59	50	50
	Comp.	40	62	38	16	84	39	61	46	54
Lenses	Imp.	43	28	72	30	70	40	60	46	54
	Comp.	40	48	52	28	72	80	20	55	45
Lenses+Mirrors	Imp.	43	33	67	30	70	42	58	42	58
	Comp.	40	45	55	24	76	79	21	59	41

(-): Indicates that there is no modal description (+): Indicates that there is a modal description.
Imp.: Implementation Group, Comp.: Comparison Group

When Table 1 is examined, it is determined that the number of PSTs using modal representations in the *my evidence* section is close to each other in the first application (shadow), but in other applications, the number of PSTs using modal representations in the implementation group is higher than in the comparison group.

When examining the PSTs' use of more than one modal representations together, it was determined that when each subject and report section (*What I did?, What I found?, My evidence* and *Comparison with resources*) were taken into consideration, the number of PSTs who used 3 or more modal representations together was found to be higher in the implementation group that received modal representations training compared to the comparison group. Related results are given in Table 2.

Table 2. PSTs' Use of Multiple Modal Representations Together

		What I did?			What I found?			My evidence			Comparison with resources		
Topics/ Number of representations used		1	2	3and more	1	2	3and more	1	2	3and more	1	2	3and more
		%	%	%	%	%	%	%	%	%	%	%	%
Shadow	Imp.	18	6	26	34	16	0	23	5	7	2	2	5
	Comp.	33	13	11	23	40	3	28	5	0	13	2	2
Reflection	Imp.	25	7	12	29	34	0	12	10	24	32	10	15
	Comp.	23	12	0	33	20	7	20	13	0	25	12	5
Mirrors	Imp.	23	16	9	52	25	0	36	14	12	25	9	14
	Comp.	30	5	5	43	32	0	27	5	0	24	16	8
Refraction	Imp.	5	36	18	30	40	0	9	41	9	9	30	11
	Comp.	19	19	0	38	27	19	27	35	0	15	23	15
Lenses	Imp.	2	35	35	9	16	44	14	19	27	5	16	33
	Comp.	7	35	10	31	35	7	10	10	0	28	14	3
Lenses+ Mirrors	Imp.	9	40	19	9	35	26	12	16	30	12	16	30
	Comp.	28	24	3	28	37	10	7	14	0	35	7	0

When asked about which parts of the report they used modal representations in their ABI reports where they shared their arguments in writing, the PSTs generally stated that they used them in the part of *What I did?, What I found?,* and *my evidence*. These results coincide with the results obtained from the analysis of the ABI reports presented above. Examples of pre-service teachers discourses are presented below.

ÖŞ: We used tables while recording the data we found at the end of the experiment.

ÖÖ: At the end of the observation, we wrote the data in a table while explaining something, and accordingly we wrote my evidence part making conclusions and interpretation.

ÖR: We were drawing the experiment setup in the section of the experiment (my doings section). We were writing the list of ingredients

When the types of modal representations used in the experimental reports are examined, it is seen that list, pictures and mathematical expressions are mostly preferred by the PSTs in the reports. When Table 3 is examined, it is determined that the implementation group used more modal representations than the comparison group. In addition, when the combined use of more than one modal representation (eg. picture + table) is examined, it is observed that the PSTs in the implementation group used them more than the PSTs in the comparison group.

Table 3. Modal Representations Used Together in ABI Reports

Topics		Picture	Math.	List	Table	Graph	Using more than one representation together	Total number of representation used in reports
Shadow	Imp.	23	16	9	7	-	5	60
	Comp.	14	10	14	10	-	14	62
Reflection	Imp.	10	16	22	-	-	38	86
	Comp.	5	14	19	-	-	21	59
Mirrors	Imp.	18	13	37	4	-	32	104
	Comp.	14	11	25	5	1	17	73
Refraction	Imp.	33	15	35	-	-	16	99
	Comp.	11	8	-	-	-	27	46
Lenses	Imp.	42	7	42		-	17	108
	Comp.	21	4	26	1	-	3	55
Lenses+	Imp.	35	24	14	-	-	15	88
Mirrors	Comp.	22	20	14	-	-	0	56

When examining which modal representations the PSTs used together, it was determined that the use of list + mathematical expression and list + picture together were preferred by the PSTs as seen in Table 4. The modal representation numbers used in ABI reports are presented in Table 4.

Table 4. Modal Descriptions Used Together in ABI Reports

	Picture +math	Picture +list	Math. + list	Math+ table	List+ Table	List+ Graph	Table+ Graph	Picture +math+ list	Picture +math +list	Math.+list+ table	Other
Imp. (f)	26	50	57	11	1	3	1	8	0	0	2
Comp(f)	10	23	36	19	0	0	1	3	2	2	1

Modal Representations Used by PSTs While Sharing Their Arguments Verbally

During the ABI process, each group is asked to write their research questions and claims on the board. The process of defending the PSTs' claims was videotaped and a picture of the board was taken at the end of the process. At the end of the analyzes, it was determined that most of the PSTs showed the result they found directly by using the experimental setups during the oral defense of their arguments. It is also noted that before the defense, they used a representation of paintings, pictures, etc. on the board when writing their claims or presenting their evidence. For example, the group that claims that the shadow height changes according to the angle of light has drawn a table showing the shadow height with the angles of received light. It was determined that another group of PSTs tried to prove that the angle of light coming was equal to the angle of reflection by drawing pictures and using mathematical representations (angle, equality, etc.). The findings obtained as a result of the analysis of the photographs taken of the classroom board at the end of each activity are presented in Table 5.

Table 5. Modal Descriptions Used By PSTs in Verbally Defending Their Arguments

Topics	Group	Picture	Graph	Table	Math.	List	Total
Shadow	Imp.	1			1	5	7
	Comp.	1		1	1	1	4
Reflection	Imp.	1			1	5	7
	Comp.	1				4	5
Mirrors	Imp.			1	1	7	9
	Comp.			2		5	7
Refraction	Imp.			2		6	8
	Comp.		1	1		1	3
Lenses	Imp.			2		4	6
	Comp.					3	3
Lenses+ Mirrors	Imp.	1		4		4	9
	Comp.				1	4	4

When Table 5 was examined, it was found that the PSTs used list while writing their claims on the board, however, pictures, tables and mathematical expressions were mostly used. When looking at the modal representations used in this process where claims were shared and defended, it was determined that the implementation group used more representations than the control group.

As a result of the interviews, it is cleared out that most of the PSTs (f = 9) preferred to use modal representations while defending their claims and evidence as they verbally shared their arguments, and they used this to increase the credibility of their allegations against the refutation of their friends. Sample statements are as follows:

R: We explained our claims and why we think so on the basis of the table. Thus, while defending our claim, the other person understood this better.

A: The demonstrations increase the credibility of what is done.

F: For example, you cannot convince a person with a word, but if you show the tables and graphs you have created with the data you have as evidence, they will be more likely to believe.

I: When we got to the board to explain our claims, we used more tables and lists or drew the picture of the image we found. Because we used these representations to better convince the other group.

Effect of the Representations Used In Written Arguments of PSTs on the Quality of the Argument

The argument quality of the pre-service teachers was evaluated through the report they wrote during the process. When the ABI reports, in which the pre-service teachers formed their written arguments, were evaluated, it was determined that the average of the implementation group for each activity was higher than the average of the comparison group, as it can be seen in Table 6, and therefore the quality of arguments was better. When the PSTs 'use of modal representations in ABI reports (Table 2) and the PSTs' average scores from ABI reports (Table 6) are evaluated together in the process of creating written arguments, it is thought that the higher ABI report averages of the PSTs in the practice group who use the modal descriptions more. (Report 1: Shadow, Report 2: Reflection, Report3: Mirrors Report4: Refraction; Report5: Lens, Report 6: Lenses+Mirrors)

Table 6. Average Scores of PSTs from ABI Reports

Group	Report 1 $\overline{X}$	Report 2 $\overline{X}$	Report 3 $\overline{X}$	Report 4 $\overline{X}$	Report 5 $\overline{X}$	Report 6 $\overline{X}$
Implementation	62.36	69.80	71.53	69.61	72.76	72.14
Comparison	60.00	58.58	57.13	54.00	61.50	57.26

(Report 1: Shadow, Report 2: Reflection, Report3: Mirrors Report4: Refraction; Report5: Lens, Report 6: Lenses+Mirrors)

When the ABI report scores of the implementation group and the comparison group were compared, according to the independent sample t test results, there was a statistically significant difference between the report 3 mean (X = 71.53) of implementation group PSTs studying modal representation training and the report 3 mean (X = 71.53) of the PSTs who did not receive this training [t(66)=5.37, p<.05, η2=.3]. Similarly, a statistically significant difference was observed in favor of the implementation group between the report 4 average of the implementation group PSTs (X = 69.61) and the report 4 average (X = 54.00) of the comparison group PSTs [t (80) = 5.80, p <.05, η2 = .3], implementation group PSTs report 5 average (X = 72.76) and comparison group PSTs report 3 average (X = 61.50) [t(81)=2.22, p<.05, η2=.1], and the implementation group PSTs' report 6 average (X = 72.14) and the comparison group PSTs' report 6 average (X = 57.26) [t (77) = 6.06, p <.05, η2 = .3]. See Table7.

Table 7. Comparison of ABI Report Scores

Reports	Group	N	$\overline{X}$	SS	*T*	df	p
Report 1	Imp.	44	62.36	9.29	1.39	81	.16
	Comp.	39	60.00	11.40			
Report 2	Imp.	44	69.80	22.10	1.34	81	.18
	Comp.	39	58.58	8.95			
Report 3	Imp.	44	71.53	12.87	5.37	66	.00
	Comp.	24	57.13	29.70			
Report 4	Imp.	44	69.61	16.47	5.80	80	.00
	Comp.	38	54.00	23.84			
Report 5	Imp.	44	72.76	25.24	3.22	81	.02
	Comp.	39	61.50	30.44			
Report 6	Imp.	43	72.14	8.20	6.06	77	.00
	Comp.	36	57.26	29.47			

Reasons for PSTs to Use Modal Representations

When the PSTs were asked why they used modal representations in the interviews, it was determined that they talked about the benefits of modal representations as seen in Appendix 2. In this context, PSTs noted that modal representations make it easier to understand (f = 6), provide permanent learning (f =5), the information presented is more understandable (f =7) and remarkable (f =5), and provide the opportunity to compare the information presented.

In addition, when the results were examined in general, it was found that the awareness of the PSTs (implementation group) who received training on modal representations increased and they used these representations more than the other group. When asked about their views on modal representations training during the interview with the PSTs of the implementation group, it was determined that this training was beneficial based on the PSTs' statements. Sample statements are presented in Appendix 1.

DISCUSSION AND CONCLUSION

In this research, pre-service teachers experimented with the argumentation approach on optical subjects and filled out the ABI report in the process. In this process, the students had the opportunity to share their argument both in writing and verbally. At the end of the study, it was determined that

while PSTs formed their arguments in writing, PSTs who received training on modal representations used more modal representations than PSTs who did not receive this training. Similarly, these PSTs are more likely to use multiple modal representations together. Research has shown that PSTs use evidence from representations to justify their claims when they are given the opportunity to describe (Mendonça & Justi, 2013; Pallant & Lee, 2015). However, it is not possible for PSTs to come to the classroom with sufficient meta-representational competence that expresses the ability to select, create and use representations (Disessa, 2004). With this research, it can be said that the education given to pre-service teachers can raise awareness about multiple modal representations. This awareness may not be the only reason why PSTs who do not receive this education use a limited number of representations. Because some studies have stated that not having sufficient argument understanding is the reason for pre-service teachers to use limited representations (Namdar, 2017; Aydeniz & Ozdilek, 2015). In this context, PSTs' and pre-service teachers' going through argumentation processes in which modal representations are integrated (embedded) may support them in understanding and using the representations appropriately.

When the modal representations used together are examined, it is determined that the PSTs prefer to use the list+mathematical expression and the list+picture together. The list method is preferred more because it is mostly used to list the claims and evidence. Because making a list can provide a more regular presentation of the thought/information that needs to be presented in writing (reference). The use of pictures and mathematical expressions together with the list is due to the pre-service teachers' use of mathematical operation results as evidence. Pictures are seen as PSTs portray the experimental setup (showing the path that light follows, showing where and how the image is formed in a mirror or lens). Fredlund et al. (2012) examined the representations used by PSTs in the undergraduate physics course in discussion and problem solving processes on the properties of light, which is a similar physics subject, and determined that the most used representation types by students were ray diagrams, wave drawings, mathematical expressions, speech and gestures. In this research, ray diagrams are not preferred because teacher candidates prefer to show the path, reflection or refraction of light directly on the experimental device during the defense of their oral claims rather than the ray diagram. Based on this, we can say that if the pre-service teachers have the opportunity to present their evidence visibly, they prefer it.

At the end of each implementation, the PSTs defended their arguments verbally. During their oral defense, many groups tended to show their evidence, primarily in experimental setups. However, when the claims and evidences written by each group on the board were examined, it was determined that the PSTs used the list while writing the claims, as well as drawing pictures, making tables to interpret the data, and using mathematical expressions. Therefore, it is seen that they prefer to use what they write on the class board while preparing for and defending the verbal defense. Considering the total modal representation used in the verbal defense process, it was determined that the modal representation implementation group used more modal descriptions than the comparison group. Interviews with PSTs support these results. In this regard, it was determined that while PSTs defended their claims and evidence, they used modal representations to increase the credibility of their allegations against the refutation of their friends. Namdar and Shen (2016)'s research supports this result by stating that students have revised the representations they use through discussion and discourse. Visual graphical representations in the discussions help participants to refute the other party's claims and synthesize counter arguments (Namdar, 2017). In addition, it was stated in the literature that although preservice science teachers received formal education in the field of science education, they could not determine the roles of representations in argumentation (Namdar, 2017). Therefore, we can say that education received on this subject enables students to have information about the roles of representations and encourages the use of multiple modal representations. However, since preservice science teachers understand the argument and understand the importance of justifying their claims, it is also possible to use descriptions to support their claims (Namdar, 2017). In this research, sample applications (3 ABI activities) performed before the research on both groups in order for pre-service teachers to understand the argument does not make a comparison possible in this sense. However, we can say that using modal representations can affect the formation of arguments, that is, the quality of the argument.

The argument quality of the pre-service teachers was evaluated through the ABI reports they wrote in the process. When the ABI reports, in which the preservice teachers formed their written arguments, were evaluated in terms of argument quality, it was found that there was a significant difference between the average score of the group that received modal representation training and the average of the comparison group after the first two reports, and the average of the implementation group was higher, so the argument quality was better. When the PSTs 'use of modal representations in ABI reports (Table 2) and the PSTs' average scores from ABI reports (Table 6) are evaluated together in the process of creating written arguments, it is thought that the higher ABI report averages of the PSTs in the practice group who use the modal descriptions more. Because representations are the main tools to support arguments in science learning (Namdar, 2017). Likewise, Hand and Choi (2010) proposed that students who could place more than one modal representation in the evidence in the organic chemistry laboratory course, in which they examined the use of modal representation in their written arguments, created strong reasoned connections in order to support their claims and create a consistent argument. The overall quality of the argument is also related to the degree of embeddedness of the multiple modal representations created by the PSTs. It was determined that students who could embed modal representation in an evidence text got higher scores in terms of argument quality (Hand & Choi, 2010). Considering that young students have difficulties in developing quality scientific arguments (Aydeniz & Bilican, 2016), it is important that teachers use modal representations in their argument applications and that students gain awareness about this issue.

At the end of the study, when the PSTs were asked why they used modal representations, PSTs stated that they facilitate understanding, provide permanent learning, and make the information presented more clear and understandable, remarkable, concrete and organized. Therefore, we can say that modal representations can have an important role in facilitating PSTs' learning of science subjects. Munfaridah et al. (2021) state that teaching and learning physics is a difficult task, and the use of more than one representations (MR), which expresses the combination of different representations and enables abstract concepts to be conveyed in more concrete ways, can overcome this difficulty. Similarly, Opfermann et al. (2017) stated that modal representations have great potential to support the learning of physics concepts as they facilitate students' learning physics concepts and can maximize the results of learning processes. Therefore, in order for students to realize knowledge from the point of view of any field of science, applications are needed that allow them to use modes consciously in the learning process (Ford, 2007). Considering that a student's ability to make arguments may not be separate from his or her own science learning (Choi et al., 2013), the execution of modal representations together with argumentation can increase the gain in the learning process.

The basis of science learning is to be able to describe scientific findings and to predict the described information (Waldrip, Prain & Carolan, 2006). Although pre-service teachers frequently encounter modal representations both in their education and training processes and in daily life, they may not frequently apply them to express or defend an idea. For this reason, pre-service teachers need an education or an activity to raise awareness. This research shows that the pre-service teachers who gained this awareness use different types of representation in a larger number and variety and do this in order to serve a purpose (such as defending their claims). Of course, it is important that the modal representations have the correct content and use them according to their purpose, as well as being too much and various. Opfermann et al. (2017), while discussing research on the use of modal representations in education, draws attention to the text, pictures and individual students, suggesting that the text used in modal representations should be simple, well-organized and concise, and he proposed the use of logical pictures. In addition, while using modal representations, the researchers stated that while designing a learning environment embedded in modal representations, students' individual differences, prior knowledge and cognitive loads should be taken into account, which directly affect the way they use representations. In this context, it is important to understand and use modal representations in teacher education. Similarly, researchers state that science teachers still do not have enough pedagogical skills to include discussion in learning-teaching environments (Driver, Newton, & Osborne, 2000; Simon et al., 2006; (Aydeniz & Bilican, 2016). Teachers who have had this experience before are more likely to include basic practice in their classes (Zohar, 2008). For this reason, both K-12 science teachers and university science teachers require teacher training and

professional development, including argument-based pedagogical learning and teaching experiences on how students can participate in rich scientific discussions (Hand & Choi, 2013; Kaya, 2013). Namdar (2017) suggests that science teacher education programs should find ways to integrate argumentation and modal representation applications. With this research, it is proposed that both arguments and modal representations should be included in teacher training and that awareness of modal representations should be raised. In addition, teachers' modal representations in their lessons should both create a learning environment rich in modal representations and encourage PSTs to use them. In applications related to ABI and modal representations, the subject content should be taken into consideration, since there may be individual differences, prior knowledge and subject-specific representations of the PSTs.

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Appendix 1: Students' views on the reasons for using modal representations

Theme	Code	f	Example discourse
Benefits of modal representation	Easy understanding	6	*B: You may not understand much from what you read, but when you turn it into a chart or graph, you will understand it better, for example, you can understand it better by reading a chart or table instead of an text.* *G: Representation can help us understand the subject better.* *S: It is a method that makes it easier for us to understand.*
	Permanent learning	5	*C: For example, used representations rather than writing, makes learning permanent.* *S: It is more permanent in our minds both because we prepare it ourselves and because we make those comparisons in the table ourselves.* *R: For example, we draw a picture of the experimental setup and the materials we use. In this way, maybe we will not forget them for the rest of our lives.*
	Make it understandable	7	*C: Because we express what we are going to say in a more understandable way.* *G: We used representations. Because we thought it would be more descriptive. We also thought that it gave us more information about that subject.* *D: Thanks to the screenings, concrete information is formed.*
	Draw attention (Remarkable)	5	*B: We could express it in writing, but when we use these representations, it becomes more interesting.* *C: It draws attention, for example, it draws more attention when you draw a picture on the board, rather than writing it down* *F: We do not pay much attention to texts, but we pay more attention to tables and graphics.*
	Comparison Provides	5	*L: It makes it easier for students to make comparisons. For example, we use tables to compare measurement results.* *G: We can compare better. We can spot the differences between two or more situations.* *F: it makes it easy for our listeners to compare the results we found.*

Appendix 2: Students' opinions on the reasons for using modal representation

Theme	Code	f	Example discourse
Modal representations training	Learning to use modal representation	6	*C: These trainings have been effective. This is the first time we have prepared such an experimental report. Before, for example, we used to do the experiments in a traditional way. I never used tables, I didn't use graphics, but in this lesson, we both used tables and learned how to make them. For example, in the first weeks of the lesson, I could not use the representations. We started to use the representations better in the following weeks of the lesson. Because now we have learned how to use it and in what situation* *I: After learning modal representations, I started to use it more.* *B: I didn't know beforehand that modal representations were so important. Being educated and using representations in the lessons allows us to learn both the use and importance of modal descriptions.*
	Transfer to other courses	5	*B: Not only in this course, but also in other courses, I draw graphics and use tables. In other words, I establish a relationship between the subjects and the notations with other lessons. Because it is easier to understand the subject. Previously, for example, books with writing, tables, graphics and pictures attracted my attention. But I didn't think it was that important and useful for easier learning.* *ÖG: We make presentations in lectures. We also use modal representations in these presentations. I can say that I understand that "I can use notations in any subject or course".*