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How Does Argumentation-based Instruction Affect Pre-service Science Teachers' Conceptual Understanding of Organic Chemistry? The Case of Aromatic Compounds[1]

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Abstract

Aromatic compounds are one of the fundamental topics in Organic Chemistry. For this reason, creating learning environments that will contribute to pre-service teachers' meaningful understanding of aromatic compounds is of importance. The purpose of this study was to explore whether argumentation-based instruction has an effect on the conceptual understanding of pre-service science teachers in the topic of aromatic compounds. In pursuit of this aim, the study was conducted in quasi-experimental, pre-test/post-test and control group design during the 2016-2017 academic year at the Science Education Division of a state university in Turkey. Two classes were randomly selected as an experimental group (N=30) and a control group (N=35). The data collection instruments used in the study were pre- and post-tests, consisting of 10 open-ended questions. Following the application of the pre-test, the topic of aromatic compounds was taught in the control group in the line of the current teaching programwhile the experimental group was taught using the argumentation-based instruction. The instruction in the experimental group was carried out with 6 argumentation activities under the headings of "conditions of aromaticity," "properties of aromatic hydrocarbons," and "naming aromatic compounds." The independent samples t-test showed that the pre-test scores of the experimental and control groups had no significant difference between them, but that the experimental group presented a difference as opposed to the other group in the post-test. These findings showed that the pre-service science teachers receiving argumentation-based instruction were more successful in their conceptual understanding of the topic of aromatic compounds than the control group.

INTRODUCTION

The content of organic chemistry covers many interconnected concepts, molecules and reactions. This nature of organic chemistry makes it necessary for learners to not only understand and interpret the concepts, molecules and reactions, but also to question the changes in molecules and explore what these changes lead to (Graulich, 2015). In particular, students taking General Chemistry course, which has more of a concentration of quantitative aspects to it, may have difficulty in adapting to lessons in Organic Chemistry, which is based on the relationship between structure and reactivity. Indeed, it was reported in a study conducted by Anderson and Bodner (2008) that many students who were successful in their general chemistry course had trouble achieving the same success when they transitioned into their organic chemistry classes. Additionally, the results of many studies indicate that there is a high percentage of failure in organic chemistry classes, evidencing that this course is difficult for students (Ratcliffe, 2002; Johnstone, 2006; Grove, Hershberger & Bretz, 2008; Eastwood, 2013; Flynn, 2015; O'Dwyer & Childs, 2017). Ellis (1994) has pointed out that the reason why organic chemistry classes are considered difficult by students is that the course requires three-dimensional thinking, using a new language that is specific to the subject matter, with no problem-solving algorithm available to guide the student. Because of the requirements of organic chemistry, students tend to memorize instead of learn concepts and as a result, they find themselves struggling with unrelated clusters of knowledge that make up the content of organic chemistry (Anderson & Bodner, 2008; Anzovino & Bretz, 2015; Galloway, Stoyanovich & Flynn, 2017; Caspari, Weinrich, Sevian, & Graulich, 2018). Consequently, it is important, to create learning environments that can contribute to students' meaningful learning instead of having them memorize their organic chemistry lessons.

When we look into the content of organic chemistry, we see that the topic of aromatic compounds takes up a good portion of the subject. Basically, the topic of aromatic compounds includes aromatic substitution reactions that are unique to this class of molecules, and multi-step synthetic reactions that make it possible to form more comprehensive relationships between different molecular classes. All of these factors that have made this topic a central element in organic chemistry (Balaban, Oniciu & Katritzky. 2004; Krygowski & Cyranski 2001). Because of this, when students can first identify aromatic compounds correctly, this will help them to distinguish between and name other organic molecules, aiding them also to accurately make associations between other topics in organic chemistry. If this cannot be achieved, not only will the desired level of learning that is targeted with respect to aromatic compounds not be accomplished, but it will be more difficult to prevent the adoption of alternative conceptions. For example, a student who interprets the aromatic compound benzene to be an alkene because of its C=C bond may think that benzene will have a tendency to show an addition reaction like other alkenes. A student who misinterprets this may find it difficult to form a relationship between the electrophilic aromatic substitution reaction unique to aromatic compounds and the synthesis of different organic molecules. Lying at the foundation of such incorrect interpretations is the inability of students to differentiate between aromatic compounds and alkenes and their failure to completely understand the conditions of aromaticity. Indeed, in some studies that have been conducted, it has been concluded that students can interpret reactions incorrectly as a result of their incorrect classification of organic molecules (Sendur & Toprak, 2013; Ealy, 2018).

In studies related to aromatic compounds, it has been shown that students have conceptual difficulties in this topic, leading them to adopt alternative conceptions. One of these studies is the study by Ealy and Hermanson (2006) that was conducted with science undergraduate students. The researchers reported that the students had trouble identifying aromatic molecules and that the main reason for this was that they focused on the Octet Rule and certain atoms, ignoring electron delocalization. Omwirhiren and Ubanwa (2016) established in their study with high school students that students had particular difficulty with identifying aromatic compounds according to their structural formulas. In a study by Topal, Oral and Özden (2007), the researchers examined the levels of success high school students and chemistry undergraduates (1st and 3rd grades) had with the concept of aromatics as well as their alternative conceptions. The study indicated that 3rd year undergraduate students had the highest success in the topics of aromatic compound reactions, Huckel's Rule, conjugation, planarity and the properties of cyclic in aromatic compounds; high school students, however, were the least successful in these topics. Another striking finding in the study was that both high school and undergraduate students commonly resorted to the alternative conceptions of "all molecules with rings are aromatic." Another important finding of the study was that in a question where Huckel's Rule was to be applied to identify the aromatic ion, only a very few of both 3rd year and 1st year undergraduate students were able to respond correctly. These results indicate that the concept of aromatics is still not adequately understood even at the undergraduate level.

Another study on aromatics is by Rushton, Hardy, Gwaltney and Lewis (2008), who conducted their research with 4th year chemistry undergraduates. The researchers reported that students associated the property of being aromatic with molecules that had hexagonal bond-line formulas, which is actually in reality just the opposite. For example, while some of the students identified molecules such as cyclohexane, cyclohexene and cyclohexadiene as aromatic, another group of students wrongly identified a six-carbon arene as cyclohexane or an alkene. Similar findings have been reported in various other studies (Domin, al-Masum & Mensah, 2008; Sendur, 2020). Duffy (2006) conducted a study with undergraduates and found that in identifying aromatic compounds, students usually focused on Huckel's Rule, cyclic structures and conjugated systems and did not adequately consider sp^2 hybridization or the stability of p orbitals.

It can be understood from all of these studies that the concept of having an aromatic property gives students from high school to the university level conceptual difficulties and is a topic for which alternative conceptions have been adopted. When the basic rules involved in the concept of aromaticity are considered, it can be seen that it is very difficult to handle the topic with experimental activities. From this perspective, it has been suggested that students instead can interact with their classmates and have evidence-based discussions, supported by a teaching program that introduces argumentation in a collaborative learning setting to promote agreement and learning.

Argumentation can be described as a form of study in which students use reasoning based on evidence, justification and warrants (Erduran, 2019). This nature of argumentation occupies a place in the methods by which students carry out scientific reasoning and develop conceptual understanding. It can be said in other words that argumentation is at the center of science instruction and learning (Msimanga & Mudadigwa, 2019). Indeed, studies have indicated that argumentation-based instruction on the secondary school and university level has a positive effect on conceptual understanding among chemistry students (Aydeniz & Doğan, 2016; Şekerci & Canpolat, 2014; Kaya, 2013). On the other hand, studies in this context in the field of organic chemistry have remained too limited. In some studies, argumentation is presented not as a teaching strategy but as a tool with which strategies for students' reasoning can be determined. As an example, de Arellano and Towns (2014) examined students' responses to questions on alkyl halide reactions according to the Argumentation model. Similarly, Hand and Choi (2010) looked at students' written arguments after completing a series of activities in the organic chemistry laboratory on the basis of how they used multi-model representations. A teaching activity for argumentation used in organic chemistry was created by Pabuçcu and Erduran (2017). In this study with pre-service science teachers, the researchers tried to determine the degree of conceptual understanding the pre-service teachers had gained from their arguments regarding the conformational analysis of butane.

As can be seen from these studies, there is a need for further in-depth research into the effect argumentation-based instruction in organic chemistry has on students' conceptual understanding. At the same time, in view of the importance of the topic of aromatic compounds in organic chemistry and the existence of alternative conceptions in this area, it is believed that this study on the effect on students' conceptual understanding and conceptual change of argumentation-based instruction in the topic of aromatic compounds will fill an important gap in the literature.

The Purpose of Study

The aim of this study was to analyze the effect of argumentation-based instruction on elimination of the alternative conceptions pre-service teachers have about aromatic compounds and whether or not this instruction is effective in terms of developing conceptual understanding.

For this purpose, answers were sought to the following sub-problems in this study:

1) Is there a significant difference between the mean scores of the experimental and control groups of pre-service teachers on the pre-test?
2) Is there a significant difference between the mean scores of the experimental and control groups of pre-service teachers on the post-test?
3) How effective is argumentation-based instruction compared to current program based-teaching in achieving conceptual change?

METHOD

Study Design

The study was conducted using a pre-test-post-test, control group, quasi-experimental design. This type of design is appropriate for situations where the participants cannot be randomly assigned to experimental and control groups but in which the experiment can be randomly assigned to groups (Hinkle, Wiersma, & Jurs, 1998; Gravetter & Wallnau, 2002). Accordingly, one of the classes in this study was randomly chosen as the experimental group (n=30), another as a control group (n=35). Lessons in the experimental group were taught with argumentation-based instruction; the control group was taught according to the current program.

Participants

The participants in the study consisted of 65 pre-service teachers enrolled in the second-year class of the Science Education Department of a state university in Turkey's Aegean region during the spring term of the 2016-2017 academic year. All of the pre-service teachers had voluntarily consented to participate. The pre-service teachers in the study had received similar scores on the university entrance examination, been accepted at the university and took the same courses leading up to their second year. From this perspective, it can be said that the randomly selected experimental and control groups of pre-service teachers had similar backgrounds.

Data Collection Tools

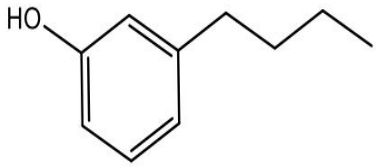
Ten open-ended questions related to aromatic compounds were used in the study as data collection tools. Five of the questions were related to the conditions of aromaticity. The students were given 1,3-Cyclopentadiene, furan, 1,3,5-Cycloheptatriene molecules and 1,3,5-Cycloheptatrienyl cations and 1,3,5-Cycloheptatrienyl anions and asked whether or not these were aromatic and for an explanation as to why they are or are not. In the other five questions, the structural formulas of aromatic compounds were given (4-Chloroaniline, 2-Bromo-5-chlorotoluene; 2-Bromobenzoic acid, 4-Bromobenzyl alcohol and 3-Butylphenol) and the students were asked to name these according to IUPAC. Two members of the chemistry education departments were consulted as these open-ended questions were prepared and in addition, a pilot study was conducted with another group of pre-service teachers who had studied the topic of aromatic compounds. The final form of the questions was applied to the experimental and control groups as a pre-test 2 weeks before the actual instruction, and then a post-test was simultaneously administered a week following the instruction. Two open-ended questions were presented in Figure 1.

1) Please state **whether the compounds below are aromatic and explain why they are or are not.**

a) 

.... Please explain, with reasons
....

2) Please name the compounds according to **IUPAC. Please explain why you identified it in this way.**

a) 

....Because...
....

Figure 1. Sample open-ended questions

The Instruction Process

The argumentation-based instruction on the subject of aromatic compounds was completed in the experimental group in 3 weeks. Training was provided to the pre-service science teachers in the experimental group one week before the instruction. The elements of argumentation according to Toulmin's argumentation model were explained in this training and the students were encouraged to practice writing out arguments. In the next week, 7 groups of 4-5 individuals were created from among the pre-service teachers, after which the argumentation-based activities were launched. In total, 6 activities were organized, two to be carried out each week in 2 class hours, for a duration of 3 weeks. The group activities were executed with the techniques of "pairs to fours technique" and "envoys' arrangement" and the groups first discussed their own claims, evidence, and warrants, then wrote up their arguments. The group spokespeople presented these written arguments to the class for classroom discussion. Table 1 shows the activities carried out in the experimental group as well as the group techniques and argumentation strategies these activities were based on.

Table 1. Activities carried out in the experimental group

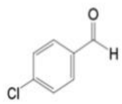
Activity No.	**Name of Activity**	**Strategy**	**Group Technique**
Activity 1.	Properties of aromatic hydrocarbons	Constructing an argument	Pairs to fours technique
Activity 2.	Is cyclobutadiene aromatic?	Competing Theories with Concept Cartoons	Envoys' arrangement
Activity 3.	I Can Identify Aromatic Compounds	Clue Cards	Envoys' arrangement
Activity 4.	My Concept Map of Aromatic Compounds	Constructing a concept map	Pairs to fours technique
Activity 5.	Let’s Name Aromatic Compounds	Table of Statements + clue cards	Envoys' arrangement
Activity 6.	Let’s find the mistakes we made in naming the Aromatic Compounds	Scenario-based task	Pairs to fours technique

The two faculty members in the organic chemistry department were consulted in setting up the 6 activities in the experimental group and the worksheets were applied as a pilot study to another group of pre-service teachers who had learned the topic. Examples of the worksheets used in the study can be seen in Figure 2 and Figure 3.

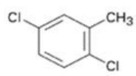
The same subjects were covered in the control group in the same period of 3 weeks but the instruction consisted of the teaching by lecturing and using the question-and-answer technique. The same instructor conducted the lessons in both the experimental and control groups.

Where Did Inci Make A Mistake?

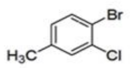
Inci chose the topic of aromatic compounds for her project assignment in organic chemistry. She was very careful in naming the aromatic compounds and researching their areas of utilization. After she handed in her assignment however, her teacher told her that she had made a mistake and gave her the paper back so she could correct the error. Inci was sorry she had made a mistake and immediately started to look for where she had gone wrong. Looking over the assignment, Inci thought she may have made a mistake in the 4 examples she gave in the naming section but realized that she was unable to find the mistake by herself. That is why she is asking you to help her. Where do you think Inci made the mistake?



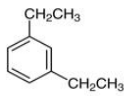
m-Chlorobenzaldehyde



1,3-dichloro-2-methylbenzene



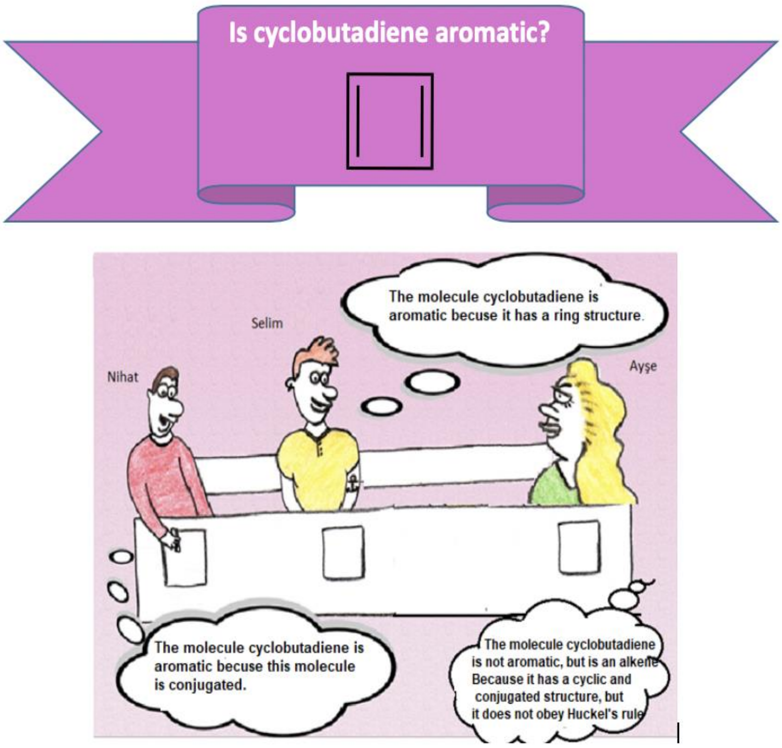
4-Bromo-3-chlorotoluene



1,3-Diethylbenzene

I think that:
This evidence supports my idea because:
Arguments against my idea:
How can you convince someone who doesn't believe you?

Figure 2. Worksheets used in activity 6



The concept cartoon above discusses whether cyclobutadiene is aromatic or not. Accordingly, Whose thought do you think right? Mark the box you think is right with √

Nihat : ☐ Selim : ☐ Ayşe: ☐

I think that:
This evidence supports my idea because:
Arguments against my idea:
How can you convince someone who doesn't believe you?

Figure 3. Worksheets used in activity 2

Data Analysis

The open-ended questions in the study were analyzed under the categories of "sound understanding," "partial understanding," "partial understanding with alternative conception," "alternative conception," and "no understanding" Abraham *et al.* (1992), Çalık (2005) and Ünal *et al.* (2010) used similar categories, containing the following:

- Sound Understanding (SU): This involves responses and explanations that are scientifically accepted as true.
- Partial Understanding (PU): This involves some responses and explanations that are scientifically accepted as true.
- Partial Understanding with Alternative Conception (PUAC): This refers to responses accepted as scientifically true, but which are false.
- Alternative Conception (AC): This refers to responses and explanations that are not completely accepted as scientifically true.
- No Understanding (NU): this category involves irrelevant answers. Also, pre-service science teachers could leave the question empty.

The total scores of the pre-service teachers based on their responses to the open-ended questions were calculated in the analysis in terms of a score of 4 for the category of Sound Understanding (SU), 3 for Partial Understanding (PU), 2 for Partial Understanding with alternative conceptions(PUAC), 1 for Alternative Conception (AC), and 0 for No understanding (NU) on both the pre- and post-tests. The maximum possible score that the pre-service teachers could achieve in their responses to the open-ended questions was 16. The SPSS 15.0 program was used in the statistical analysis of the data and the first step was to find out whether the data showed normal distribution. After the results of the Kolmogorov-Smirnov and Shapiro-Wilks tests indicated normal distribution, the pre- and post-test scores of the experimental and control groups were then compared with the independent samples t-test. The pre-service teachers' responses to the questions by category was evaluated in both the experimental and control groups and percentages were calculated (Table 4 and Table 5). Lastly, in order to clearly set forth the conceptual change displayed by both groups, the percentages of alternative conceptions found in the pre- and post-tests were determined and the differences between these were defined as the percentage of conceptual change (Table 6).

FINDINGS

In line with sub-problems 1 and 2, the independent samples t-test was used to compare the pre- and post-test scores of the experimental and control groups. Table 2 displays the results of the analysis for the pre-test, Table 3 the results of the analysis for the post-test.

Table 2. Results of the independent samples t-test for pre-test scores

	Group	n	$\bar{X}$	s	t	df	p
Pre-test	Experimental	30	13.5667	5.84680	.329	63	.743
	Control	35	13.1429	4.53835			

The results of the independent samples t-test in Table 2 show that there was no significant difference between the pre-test scores of the experimental and control groups ($p>.05$). This indicates that the mean scores of the experimental and control groups were very close to each other before the instruction. In other words, the experimental and control groups were similar to each other in terms of their prior knowledge.

Table 3. Results of the independent samples t-test for the post-test scores

	Group	n	$\bar{X}$	s	t	df	p
Post-test	Experimental	30	33.5000	2.56972	9.204	45.078	.000
	Control	35	22.2000	6.71171			

Table 3 shows that there was a statistically significant difference between the post-test scores of the pre-service teachers in both the experimental and control groups (t=9.204; p<.05). The results of the analysis indicate that when the mean scores of the experimental and control groups after the instruction are compared, there is a difference in favor of the experimental group. This reveals that in these two groups that did not have significant differences between them on the pre-test, the pre-service teachers in the experimental group exhibited a higher level of conceptual improvement in understanding after the instruction compared to the control group.

In order to examine in more depth how the conceptual understanding levels of the experimental and control groups in the study changed from their understanding level after the instruction, the distribution of the responses of the pre-service teachers on the pre- and post-tests were calculated by categories and are shown in Tables 4 and 5.

Table 4. Percentages of responses of the experimental group on the pre- and post-tests, by category

Question	Experimental Group									
	Pre-test					Post-test				
	SU(%)	PU(%)	PUAC(%)	AC(%)	NU(%)	SU(%)	PU(%)	PUAC(%)	AC(%)	NU(%)
1	0.0	13.3	33.3	43.3	10.0	63.3	3.3	33.3	0.0	0.0
2	0.0	36.7	10.0	26.7	26.7	83.3	0.0	16.7	0.0	0.0
3	0.0	16.7	6.7	46.7	30.0	86.7	0.0	10.0	0.0	3.3
4	0.0	16.7	13.3	40.0	30.0	33.3	3.3	56.7	6.7	0.0
5	0.0	46.7	13.3	10.0	30.0	90.0	10.0	0.0	0.0	0.0
6	23.3	0.0	46.7	20.0	10.0	100.0	0.0	0.0	0.0	0.0
7	0.0	0.0	73.3	20.0	6.7	90.0	0.0	10.0	0.0	0.0
8	3.3	0.0	43.3	16.7	36.7	46.7	16.7	23.3	6.7	6.7
9	10.0	0.0	30.0	0.0	60.0	90.0	6.7	0.0	0.0	3.3
10	0.0	0.0	16.7	23.3	60.0	33.3	3.3	13.3	13.3	36.7

It can be seen in the distribution of the experimental group's responses on the pre- and post-test in Table 4 that in particular, no response was given to the question on the properties of being aromatic (Q1, 2, 3, 4, 5) that fell in the category of SU. In the post-test however, there was a noticeably increase in the responses falling into the SU category, and in fact, outside of Q4, the percentage indicated for the rest of the questions was over 50%. In Q4 on the molecule furan, 33.3% of the preservice teachers were able to explain all of the conditions of aromaticity. It was found that in the case of the heterocyclic aromatic molecule foran, the preservice teachers could not explain this molecule's aromaticity because they did not consider that one of the lone pairs of electrons on the oxygen atom is delocalized into the ring. When compared with the alternative conception percentages on the pre- and post-test in these questions, it was observed that the percentage on the post-test was slower than on the pre-test and in fact, outside of Q4, the other four responses did not reveal any alternative conceptions in the post-test.

The questions related to the naming of aromatic compounds (Q6, 7, 8, 9 and 10), the examination of the understanding level percentages showed that sound understanding was very low on the pre-test and in fact, there were no responses to Qs 7 and 10 that fell into the sound understanding category. In the post-test, it was seen that the responses in this category had noticeably increased and in fact, Q6 received a 100% response from the pre-service teachers in the experimental group while this rate in Qs 7 and 9 was 90%. The lowest sound understanding percentage of the pre-service teachers was Q10, which was on 4-bromobenzyl alcohol. It was seen here in particular that the pre-service teachers had trouble with naming the benzyl structure. In the examination of the percentages of alternative conceptions related to naming compounds in the experimental group, it was seen that there were no alternative conceptions for Q9 on the pre- or post-test, but the percentages on the post-test were lower than on the pre-test for the other questions. In fact, Qs 6 and 7 exhibited no alternative conceptions at pos-test.

A review of Table 5, which shows the response percentages on the pre- and post-test of the pre-service teachers in the control group, indicates that, as in the experimental group, none of the responses to the questions on aromaticity fell into the SU category. An examination of the sound understanding percentages for the same questions on the post-test shows that although there are responses that fall into this category, the percentage of this is negligible. For example, only one pre-service teacher was able to fully explain that the molecule 1,3,5-cycloheptatriene was not aromatic (Q1). Similarly, only 8.6% of the pre-service teachers were able to fully explain that the molecule 1,3-cyclopentadiene was not aromatic (Q5). In the control group, it was found that the sound understanding percentage in these questions remained lower when compared with the experimental group.

Table 5. Percentages of responses of the control group on the pre- and post-tests, by category

	Control Group									
	Pre-test					Post-test				
Question	SU(%)	PU(%)	PUAC(%)	AC(%)	NU(%)	SU(%)	PU(%)	PUAC(%)	AC(%)	NU(%)
1	0.0	14.3	42.9	37.1	5.7	2.9	8.6	28.6	60.0	0.0
2	0.0	14.3	25.7	22.9	37.1	17.1	25.7	20.0	34.3	2.9
3	0.0	14.3	2.9	48.6	34.3	14.3	28.6	17.1	40.0	0.0
4	0.0	14.3	2.9	62.9	20.0	17.1	11.4	11.4	60.0	0.0
5	0.0	34.3	37.1	8.6	20.0	8.6	54.3	28.6	8.6	0.0
6	28.6	2.9	34.3	28.6	5.7	54.3	2.9	14.3	14.3	14.3
7	8.6	0.0	60.0	25.7	5.7	60.0	0.0	11.4	20.0	8.6
8	0.0	0.0	37.1	22,9	40.0	14.3	11.4	28.6	22.9	22.9
9	0.0	0.0	34.3	11.4	54.3	62.9	2.9	8.6	17.1	8.6
10	0.0	0.0	28.6	11.4	60.0	22.9	2.9	5.7	28.6	40.0

In the review of the alternative conception percentages of the pre-service teachers in the control group for the same questions, various striking points were seen. While the alternative conception percentages of the pre-service teachers did not change for Q5, the percentages in Qs 3 and 4 declined somewhat. On the other hand, in Qs 1 and 2, the percentages of alternative conceptions increased in the post-test. This shows that the system of instruction in the control group was not as effective in eliminating alternative conceptions when identifying aromatic compounds as the argumentation-based instruction applied to the experimental group.

As shown in Table 5, it can be seen from a review of the levels of understanding of the pre-service teachers in the control group regarding naming of aromatic compounds, that no response falling into the sound understanding category was given to Qs 8, 9 and 10 on the pre-test and that in Qs 6 and 7, there only a few responses that fell into this category. In the post-test, it was observed that the responses to all 5 questions displayed an increase in the SU category as compared to the pre-test. On the other hand, when these SU categories were examined, it was understood that the percentages were not as high as in the experimental group. In the review of the percentages in the alternative conception categories, it was seen that the percentages on the pre- and post-tests for Q8 did not change, but that in Qs 9 and 10, there was an increase on the post-test. These results make it evident that the instruction carried out in the control group was not effective in eliminating alternative conceptions with regard to naming of aromatic compounds.

In the context of the third sub-problem of the study, a comparison was made of the conceptual changes occurring in the experimental and control groups. The pre-service teachers' percentages of alternative conceptions on the pre- and post-tests were calculated and are displayed in Table 6. Table 6 also shows the percentage of conceptual change occurring for each alternative conception.

Table 6. Percentages of pre-service science teachers' alternative conceptions

Q.	Alternative Conceptions		Experimental Group			Control Group		
			Pre-test	Post-test	CC	Pre-test	Post-test	CC
Q-1	1	The 1,3,5-cycloheptatriene molecule is aromatic because it has a ring structure.	23.3	-	+23.3	17.1	22.9	-5,8
Q-1	2	The 1,3,5-cycloheptatriene molecule is aromatic because it contains 3 double bonds.	10.0	-	+10.0	11.4	14.3	-2.9
Q-1	3	The 1,3,5-cycloheptatriene molecule is aromatic because it only contains carbon and hydrogen atoms.	10.0	-	+10.0	2.9	5,7	-2,8
Q-1	4	The 1,3,5-cycloheptatriene molecule is aromatic because it contains unsaturated carbon atoms.	-	-	-	2.9	11.4	-8,5
Q-1	5	The 1,3,5-cycloheptatriene molecule is aromatic because all of the carbon atoms form four bonds.	-	-	-	2.9	5.7	-2,8
Q-2	6	The 1,3,5-cycloheptatrienyl anion is aromatic because it has a ring structure.	13.3	-	+13.3	17.1	11.4	+5.7
Q-2	7	The 1,3,5-cycloheptatrienyl anion is aromatic because it only contains carbon and hydrogen atoms.	13.3	-	+13.3	5,7	14.3	-8.6
Q-2	8	The 1,3,5-cycloheptatrienyl anion is aromatic because it contains 3 double bonds.	-	-	-	-	8.6	-8.6
Q-3	9	The 1,3,5-cycloheptatrienyl cation is not aromatic because it lacks a hydrogen atom bonded to a carbon atom.	13.3	-	+13.3	11.4	-	+11.4
Q-3	10	The 1,3,5-cycloheptatrienyl cation is not aromatic because the carbon atom has not completed its number of bonds and has formed 3 bonds.	10.0	-	+10.0	11.4	-	+11.4
Q-3	11	The 1,3,5-cycloheptatrienyl cation is not aromatic because it is not hexagonal.	10.0	-	+10.0	8.6	2.9	+5.7
Q-3	12	The 1,3,5-cycloheptatrienyl cation is not aromatic because it is charged (+).	3,3	-	+3,3	8.6	2.9	+5.7
Q-3	13	The 1,3,5-cycloheptatrienyl cation is not aromatic because it has 7 carbons.	10.0	-	+10.0	8.6	2.9	+5.7
Q-3	14	The 1,3,5-cycloheptatrienyl cation is not aromatic because it does not comply with Huckel's rule.	-	-	-	-	17.1	-17.1
Q-3	15	The 1,3,5-cycloheptatrienyl cation is not aromatic because it does not contain a p orbital.	-	-	-	-	8.6	-8.6

Q.		Alternative Conceptions	Experimental Group			Control Group		
			Pre-test	Post-test	CC	Pre-test	Post-test	CC
Q-3	16	The 1,3,5-cycloheptatrienyl cation is not aromatic because it does not contain a conjugated system.	-	-	-	-	5,7	-5,7
Q-4	17	The furan molecule is not aromatic because it does not have the C_6H_6 molecular formula.	10.0	-	+10.0	11.4	17.1	-5,7
Q-4	18	The furan molecule is not aromatic because the structure of furan contains the oxygen atom.	10.0	-	+10.0	11.4	11.4	-
Q-4	19	The furan molecule is not aromatic because does not contain 6 carbon atoms.	10.0	-	+10.0	17.1	11.4	+5.7
Q-4	20	The furan molecule is not aromatic because it has lone-pair electrons	6.7	3.3	+3.4	8.6	11.4	-2.8
Q-4	21	The furan molecule is not aromatic because it does not contain 3 π bonds.	3.3	3.3	-	8.6	2.9	+5.7
Q-4	22	The furan molecule is not aromatic because not all the atoms in the rink contain a π bond.	-	-	-	5.7	5.7	-
Q-5	23	The 1,3-cyclopentadiene molecule is aromatic because it contains carbon and hydrogen atoms.	6.7	-	+6.7	5.7	5.7	-
Q-5	24	The 1,3-cyclopentadiene molecule is aromatic because it has a ring structure.	3.3	-	+3.3	2.9	2.9	-
Q-6 Q-7	25	When naming aromatic compounds, molecules are classified as alkenes according to the double bond in the ring and in alphabetical order.	30.0	-	+30.0	42.9	8.6	+14.3
Q-6 Q-7 Q-8 Q-9 Q10	26	Aromatic compounds are named alphabetically and the prefix "cyclo" is used when a molecule has rings.	50.0	20.0	+30.0	57.1	74.3	-17.2

Table 6 reflects a review of alternative conceptions by question, showing that there were prominent differences in conceptual change between the experimental and control groups. In the experimental group, only one alternative conception (21st) percentage was the same on both the pre- and post-test, while the percentage of alternative conceptions diminished in the post-test. We can say therefore that a positive conceptual change was seen. On the other hand, the same thing cannot be said of the control group. In the control group, only 9 alternative conceptions (6, 9, 10, 11, 12, 13, 19, 21 and 25) showed positive conceptual change; 4 (alternative conceptions 18, 22, 23 and 24) displayed no change, and 13 (alternative conceptions 1, 2, 3, 4, 5, 7, 8, 14, 15, 16, 17, 20 and 26) displayed a negative conceptual change. These findings indicate that argumentation-based instruction in the topic of aromatic compounds was much more effective in achieving conceptual change compared to current program based-teaching and that it was not feasible to expect an elimination of alternative conceptions using the current program based-teaching. It was seen in fact, that this teaching was responsible for creating an increase of alternative conceptions. Indeed, it has been reported in various research articles that it is difficult to achieve the desired level of conceptual change using traditional teaching methods (Bodner, 1991; Westbrook & Marek, 1991; Hesse & Anderson, 1992; Treagust & Duit, 2008).

In a review of the alternative conceptions presented in Table 6, it can be seen that in Q1, the alternative conception, "*The 1,3,5-cycloheptatriene molecule is aromatic because it has a ring* *structure"* was expressed in both the experimental and control groups on the pre-test. The underlying thought in this alternative conception may be that the pre-service teachers believed that the condition of having a ring structure was sufficient for aromaticity. In the post-test, it was seen that in the experimental group, this alternative conception was not expressed; it was just the opposite in the control group however; in this group, the percentage of alternative conceptions increased among the pre-service teachers. Regarding the alternative conceptions related to this question, namely *"The 1,3,5-cycloheptatriene molecule is aromatic because it contains 3 double bonds"* and "*The 1,3,5-cycloheptatriene molecule is aromatic because it only contains carbon and hydrogen atoms,*" these were not encountered in the experimental group on the post-test but were seen at a higher percentage in the control group following the instruction. The reason that these two alternative conceptions appeared could be because the pre-service teachers were more accustomed to encountering the example of benzene in the topic of aromatic compounds and therefore applied the number of double bonds in benzene and its atoms to the other molecules. In the control group, unlike the experimental group, there were 2 alternative conceptions on the pre-test. These alternative conceptions were, "*The 1,3,5-cycloheptatriene molecule is aromatic because it contains unsaturated carbon atoms"* and "*The 1,3,5-cycloheptatriene molecule is aromatic because all of the carbon atoms form four bonds,"* which displayed a higher percentage on the post-test as compared to the pre-test.

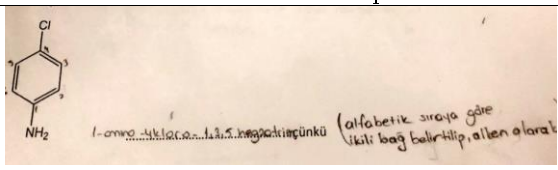
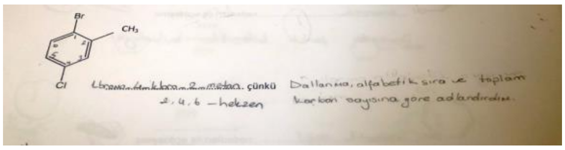
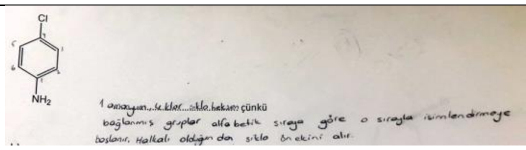
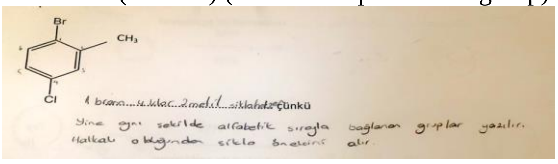
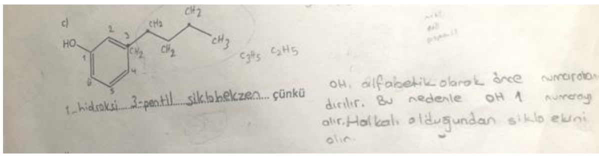
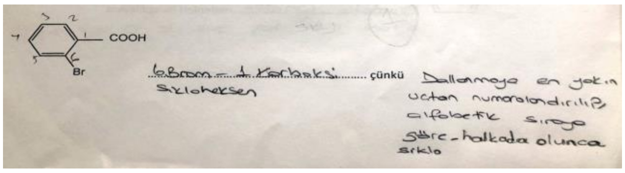
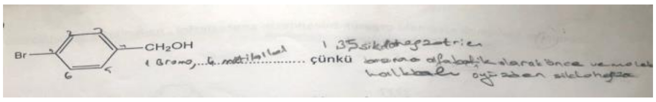
As in Q1, there were both experimental and control group pre-service teachers who displayed their belief in Q2 that a ringed structure was a sufficient condition for aromaticity on the pre-test. In the post-test, while the alternative conception "*The 1,3,5-cycloheptatrienyl anion is aromatic because it has a ring structure*" did not appear in the experimental group; this was seen at 11.4% in the control group. Another alternative conception, "*The 1,3,5-cycloheptatrienyl anion is aromatic because it only contains carbon and hydrogen atoms"* was not encountered in the experimental group on the post-test, but in the control group, no change of percentage was seen from the pre- to the post-test. Another alternative conception in Q2 (8th) did not appear in the experimental group on the pre- or post-test, but did appear in only the post-test in the control group, exhibiting a negative conceptual change. The fact that this alternative conception appeared on the post-test in the control group indicates that the pre-service teachers in the control group had not fully understood the conditions of aromaticity. It was seen that Q3 about the 1,3,5-cycloheptatrienyl cation had the most number of alternative conceptions in both the experimental and control groups. Eight alternative conceptions were found related to this question and 5 of these (9, 10, 11, 12 and 13) were seen on the pre-test in both groups while 3 alternative conceptions (14, 15, 16) were observed only in the control group on the post-test, and indicated a negative conceptual change. In the 9th and 10th alternative conceptions among these, it was observed that the pre-service teachers in the experimental and control groups interpreted aromaticity on the pre-test as related to the number of bonds formed by the carbon atom. In the post-test however, this alternative conception was not encountered in either the experiment or the control group, indicating a positive conceptual change. In the 11th and 13th alternative conceptions related to this question, it was seen that the pre-service teachers in both the experimental and the control group believed that the 1,3,5-cycloheptatrienyl cation could not be an aromatic compound because it had 7 carbons or because it was not hexagonal. This belief may possibly have been based on the fact that the pre-service teachers were accustomed to dealing mostly with the benzene molecule as an aromatic compound. The post-tests did not contain these alternative conceptions in the experimental group, while a few were noted in the control group. Similarly, in the 12th alternative conception, both the experimental and the control group indicated on the pre-test that the 1,3,5-cycloheptatrienyl cation could not be an aromatic compound since it was charged (+). The main reason the pre-service teachers had this alternative conception was possibly that they associated aromaticity with neutral molecules such as benzene. On the post-test however, this alternative conception appeared less in both groups, indicating a positive conceptual change. In Q3, differing from the experimental group, only the control group displayed three of the alternative conceptions appearing on the post-test. A review of these alternative conceptions shows that all of them are related to the conditions for aromaticity. In other words, the pre-service teachers in the control group showed a lack of understanding of the conditions of aromaticity, specifically those of "being in a conjugated system," "fitting Huckel's Rule," and "each atom in a ring containing a p orbital perpendicular to the plane of the ring."

Another question that yielded many alternative conceptions in both the experimental and control groups was Q4 on the aromaticity of the furan molecule. In this question, the alternative conceptions appearing on the pre-test were consistent with those that were seen in the first three questions. For example, in both the experimental and control groups, the alternative conception that "*The furan molecule is not aromatic because it does not have the C_6H_6 molecular formula*" showed that the pre-service teachers' knowledge of aromatic compounds was limited to what they knew about benzene. Similarly, the pre-service teachers' conception that "*The furan molecule is not aromatic because the structure of furan contains the oxygen atom.*" may have stemmed from their not having previously encountered a heterocyclic aromatic compound. The other alternative conceptions, namely "*The furan molecule is not aromatic because does not contain 6 carbon atoms*" "*The furan molecule is not aromatic because it does not contain 3 π bonds*" and *"The furan molecule is not aromatic because it has lone-pair electrons"* showed that the pre-service teachers thought about aromaticity on the basis of what they knew about benzene. In the post-tests, most of these alternative conceptions were lesser in the experimental group, indicating a positive conceptual change. In the control group however, some conceptions (19th and 20th) were less, the percentage of some did not change (18th alternative conception), while the percentage of some increased (17th and 20th alternative conceptions), indicating a negative conceptual change. Differing from the experimental group, the control group displayed no conceptual change from the pre- to the post-test in the alternative conception of *"The furan molecule is not aromatic because not all the atoms in the rink contain a π bond"*.

In the last question on aromaticity, Q5, it was seen that the pre-service teachers had fewer alternative conceptions compared to the other four questions. It can be understood from a look at these alternative conceptions that the pre-service teachers in the experimental and control groups, as in Q1, thought that the molecule 1,3-cyclopentadiene was an aromatic compound because it has a ring structure and it contains carbon and hydrogen atoms. In the post-tests, it was observed that these two alternative conceptions did not appear in the experimental group but their percentages in the control group were the same as in the pre-test.

In the questions on naming aromatic compounds, it was seen that there were mainly two alternative conceptions in both the experimental and control groups. The first of these was *"When naming aromatic compounds, molecules are classified as alkenes according to the double bond in the ring and in alphabetical order."* These alternative conceptions were found in both the experimental and control groups on the pre-test, in both Q6 and Q7. The pre-service teachers' naming an aromatic compound as they would an alkene shows that they are not able to differentiate aromatic compounds from alkenes. Another striking point in their responses was that they made their classification as they would a straight chain. In the post-tests, there were no alternative conceptions in the experimental group but in the control group, the percentage of 28.6% showed a slight decline but was still significant. The second alternative conception related to naming aromatic compound was "*Aromatic compounds are named alphabetically and the prefix 'cyclo' is used when a molecule has rings*" The percentage of this alternative conception declined in the experimental group on the post-test, but showed an increase in the control group. Table 7 displays examples of the responses of both experimental and control group pre-service teachers that can be categorized within the scope of these two alternative conceptions.

Table 7. Responses of the experimental and control group pre-service science teachers containing alternative conceptions

<table>
<tr><th>Alternative Conception</th><th>Question</th><th>Pre-service Science Teachers' Response</th></tr>
<tr><td rowspan="2">When naming aromatic compounds, molecules are classified as alkenes according to the double bond in the ring and in alphabetical order.</td><td>Question 6</td><td>
(PST-12) (Pre-test/ Experimental group)</td></tr>
<tr><td>Question 7</td><td>
(PST-6) (Pre-test/ Controlgroup)</td></tr>
<tr><td rowspan="5">Aromatic compounds are named alphabetically and the prefix "cyclo" is used when a molecule has rings.</td><td>Question 6</td><td>
(PST-26) (Pre-test/ Experimental group)</td></tr>
<tr><td>Question 7</td><td>
(PST-9) (Pre-test/ Experimental group)</td></tr>
<tr><td>Question 8</td><td>
(PST-11) (Post-test/ Control group)</td></tr>
<tr><td>Question 9</td><td>
(PST-19) (Pre-test/ Control group)</td></tr>
<tr><td>Question 10</td><td>
(PST- 32) (Post-test/ Control group)</td></tr>
</table>

DISCUSSION, CONCLUSION AND SUGGESTIONS

In this study, where the effect of argumentation-based instruction in the topic of aromatic compounds on the conceptual understanding and conceptual change of pre-service science teachers was compared with the effect of the current program based-teaching, the results of the independent samples t-test (Table 2 and Table 3) showed that argumentation-based instruction was much more effective in achieving conceptual understanding among the pre-service teachers. Similarly, it was found in the analysis of the responses of the pre-service teachers on the pre- and post-tests in terms of their level of understanding that in both groups, the percentage of sound understanding was very low in the pre-tests. In the post-tests, however, the sound understanding percentage in the experimental group was much higher than in the control group. Another important finding in the analysis was related to percentages of alternative conceptions. In the experimental group, it was seen that the percentage of alternative conceptions in all of the questions declined from the pre-test to the post-test and in fact, in some of the questions (Q1, 2, 3, 5, 6, 7 and 9), no response containing an alternative conception was seen in the post-test. The situation was different in the control group. The percentage of alternative conceptions in four questions in the control group declined from the pre-test to the post-test, but did not change in two questions, in fact showing an increase in four other questions (Table 6). These results indicate that argumentation-based instruction was more effective in improving the pre-service science teachers' level of understanding of the topic of aromatic compounds and was more useful in eliminating their alternative conceptions as compared to the current program based-teaching. Indeed, these results are consistent with those reported in the field literature (Aydeniz & Doğan, 2016; Şekerci & Canpolat, 2014; Kaya, 2013). Moreover, the way in which alternative conceptions showed an increase in some of the questions after the instruction in the control group was evidence that this teaching not only failed to achieve the desired level of understanding but also was not very effective in achieving conceptual change. Various study results support this finding (Wandersee et al. 1994; Özkan & Selçuk, 2012). The instruction given in the experimental and control groups was analyzed in terms of the percentage of conceptual change achieved for each alternative conception in order to be able to more clearly evidence the effect of the respective teaching methods on conceptual change. The analysis results shown in Table 6 indicate that a positive conceptual change was achieved in almost all of the alternative conceptions in the experimental group while in the control group, where the current program based-teaching was employed, negative changes were in the majority. This supports the conclusion that argumentation-supported instruction is much more effective in eliminating alternative conceptions as compared to current program based-teaching. The underlying factor playing a role in this is the fact that the pre-service teachers were able to discuss their claims, data, supporting arguments and reasoning in the instruction process, thus becoming aware of any alternative conceptions and being helped to dispel these (Cross, Taasoobshirazi, Hendricks & Hickey, 2008). Also, as Venville and Dawson (2010) have pointed out, the writing frames that are used in argumentation-based instruction supported and contributed to the decision-making and learning process.

Another important finding of the study was related to the alternative conceptions that were discovered. Most of the alternative conceptions that had to do with aromaticity showed that the pre-service teachers thought that aromatic compounds were all benzenes and treated the topic according to this premise. For example, the alternative conceptions "*The 1,3,5-cycloheptatriene molecule is aromatic because it contains 3 double bonds*," *"The 1,3,5-cycloheptatrienyl cation is not aromatic because it is not hexagonal,"* "*The furan molecule is not aromatic because it does not have the C_6H_6 molecular formula*," "*The furan molecule is* *not aromatic because the structure of furan contains the oxygen atom.,"* and "*The 1,3-cyclopentatiene molecule is aromatic because it contains carbon and hydrogen atoms"* show that the pre-service teachers accepted only benzene as an aromatic compound. The main reason for this could be that especially in secondary school chemistry lessons, benzene and its derivatives are usually provided as examples of aromatic compounds and it is not generally pointed out that a heterocyclic molecule or an ion can be classified as an aromatic compound. Another point that arose in the responses of the pre-service teachers was that they considered it sufficient for a compound to be aromatic if it had a ring structure. Domin, Al-Masum and Mensah (2008) explained this by stating that students perceived aromaticity as a structural concept rather than a functional one. Rushton et al. (2008) suggested in this context that students usually classify molecules with hexagonal bond-line formulas in the same molecular category. Researchers have emphasized that to avoid this, it would be necessary to review the various molecules with hexagonal bond-line formulas and clarify the differences between them. Still another important finding in the study regarding aromaticity was witnessed in the control group. It was seen that when the pre-service teachers were applying the properties of being aromatic to molecules or ions, instead of taking all of the rules into consideration, their interpretations were focused on only a few of these rules. One of these rules was Huckel's Rule. When the pre-service teachers in the control group were applying Huckel's Rule in particular after the instruction, they took into consideration only the π electrons in the ring, meaning that they did not take into account the electrons that did not participate in the bond but were a part of the π system in the ring. This may have been because the pre-service teachers could not fully identify the hybrid type of atoms in the ring. Indeed, Duffy (2006) reported that because students were wrong in identifying the hybrid types of atoms in aromatic compounds, they made a mistake in calculating the number of electrons according to Huckel's Rule and consequently could not identify the aromatic compounds correctly. This points to the importance of making sure that hybridization and types of hybrids are sufficiently learned before introducing the concept of aromaticity. It was observed from the alternative conceptions related to naming aromatic compounds that the pre-service teachers accepted aromatic compounds to be alkenes. This indicates that organic chemistry lessons need to emphasize the differences between aromatic compounds and alkenes.

The recommendation to be made in the light of all of the findings in the study is that researchers involved in education, especially in the field of organic chemistry, should conduct further studies argumentation-based instruction in different topics of organic chemistry in a continued effort to investigate the effect of this mode of teaching on learning outcomes. At the same time, although the present study was an attempt to explore the level of conceptual understanding and conceptual change among preservice science teachers using pre- and post-tests, a retention test was not employed and therefore the extent of retention gained by the application could not be determined. Because of this, it is also recommended that a retention test is explored in future studies.

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