International Journal of Progressive Education, Volume 18 Number 6, 2022

Development of Argumentation-Based Material for Learning the Chemical Equilibrium and Its Micro World

Nagihan Yıldırım [i]
Recep Tayyip Erdoğan University

Çiğdem Çakmak [ii]
Ministry of National Education

Abstract

The aim of the study is to determine the effects of the argumentation-oriented guide material on the academic success of pre-service teachers on chemical equilibrium and their thoughts about the process. In the study, the "Technical/scientific/collaborative action research" pattern, which is one of the action research types, was used due to its compatibility with the nature of the research subject. 33 pre-service teachers studying in the first year of the Science Teaching program of a state university in the Eastern Black Sea Region participated in the research. The subject of Chemical Equilibrium with pre-service teachers was covered using 14 activities developed based on argumentation. Chemical Equilibrium Academic Achievement Test and semi-structured interview were used as data collection tools. The Chemical Equilibrium Academic Achievement Test, which was applied as a pre-posttest in the study, and were analyzed using the SPSS 21.0 statistical program. The data obtained from the interviews were analyzed through content analysis. According to the findings, it was determined that the activities prepared based on argumentation were effective in learning the chemical balance and the micro world of chemical balance. In addition, in the interviews, pre-service teachers stated that the activities used kept the students' attention alive and provided permanent and effective learning, and saved the classroom environment from boredom. The study was concluded with suggestions that activities based on argumentation could be done for different chemistry subjects and concepts, or for subjects and concepts in biology and physics.

Keywords: Chemical Equilibrium, Argumentation, Guide Material

DOI: 10.29329/ijpe.2022.477.10

Submitted: 22/03/2022 **Accepted:** 24/10/2022 **Published:** 01/12/2022

---

[i] **Nagihan Yıldırım,** Assoc. Prof. Dr., Science Education, Recep Tayyip Erdoğan University, ORCID: 0000-0002-2516-4656

Correspondence: nagihan.yildirim@erdogan.edu.tr

[ii] **Çiğdem Çakmak,** Chemistry Teacher, Ministry of National Education, ORCID: 0000-0002-8524-1932

INTRODUCTION

Science education has played a key role in the development of societies from past to present and therefore has been the focus of scientific reform movements and discussions in countries. In this context, among the priority goals of today's science education; research, inquiry, analytical thinking, scientific ways and methods to solve problems, using the knowledge gained to develop new knowledge and processes dec the training of equipped manpower. In order to educate these individuals, it is necessary to create learning environments in which students can improve their social aspects, cooperation and communication skills, and where they are offered the opportunity to choose, collect, question and use information (Hasançebi, 2014; Osborne, 2004).

By its nature, chemistry in the fields of science is a branch of science that includes many abstract concepts, where microscopic events occur outside the observable macro world, and a symbolic language is needed to explain what is happening in these two dimensions. In order for students to understand chemistry, it is necessary to understand and relate these three separate dimensions. However, studies conducted show that students are not able to decisively establish the relationship between these dimensions (Tümay & Köseoğlu, 2011; Yıldırım, 2009). This situation causes students to have difficulty understanding the concepts of chemistry, to have misconceptions and to have a superficial learning instead of meaningful learning (Haidar, 1997; Johnstone, 2000; Van Driel, De Jong & Verloop, 2002; Demircioğlu, 2003; Okumuş et al., 2015; Şatay, 2010; Yavuz Korkmaz, 2019).

One of the most common problems mentioned among chemistry topics is the issue of chemical balance. Decarbonization is one of the most common problems in chemistry. It is stated that this difficulty related to the subject of chemical equilibrium may have been caused by the inability of students to visualize the events that occur at the moment of equilibrium in their minds and the use of this concept (equilibrium) in different meanings in everyday life (Akaygun & Jones, 2013; Akaygun & Jones, 2014; Ergül, 2021; Jusniar et al., 2021; Kousathana & Tsaparlis, 2002; Sepet et al., 2004; Temel, 2021; Tyson & Treagust, 1999; Şen, Varoğlu & Yılmaz, 2019; Ulaşan, 2010; Yavuz Korkmaz, 2019; Yıldırım, 2009; Wheeler & Kass, 1978). In particular, students fail to explain the changes that occur at the micro level at the time of equilibrium. Students should be able to think in macro, micro and symbolic dimensions in order to fully learn the subject of chemical equilibrium (Demircioğlu et al., 2013; Hsin-Kai et al., 2001; Temel, 2021; Şimşek, 2007; Yıldırım, 2009; Yavuz Korkmaz, 2019). However, students can understand the events that occur at the moment of equilibrium, both other concepts of chemical equilibrium and those related to this topic (acid–bases, solubility balances, acid-base balance, batteries, etc.) it is important for them to learn other chemistry subjects (Yıldırım, 2009). It is important that a difficult topic such as the topic of chemical equilibrium is looked at from a different point of view in teaching, and in particular, teaching materials and methods aimed at understanding the changes that occur in the micro-dimension at the time of equilibrium are used in the lessons.

In this context, the argumentation method comes to the fore as a method that can help students examine the events that occur in all three dimensions in detail, dec and establish the correct relationships between the dimensions in terms of chemical equilibrium. Students are encouraged to create arguments in a scientific inquiry (Choi, et al., 2010; Lederman, 1992; Şahin-Kalyon & Taşar, 2020) and the argumentation method (Hand & Keys, 1999), which helps them to structure scientific knowledge in this way, are characterized as an important tool for the teaching process. With this method, it is expected that the communication, cooperation and social aspects of the students will develop as well as the correct configuration of the information with this method (Hasançebi, 2014). In this respect, it can be said that the argumentation method will contribute to the education of the individuals targeted in the future. In this sense, many studies investigating the reflections of argumentation process on learning in national and international dimensions have been presented in recent years (Aktamış & Hiğde, 2015; Cavagnetto, 2010; Çaycı, 2019; Gunel et al., 2012; Kıngır, 2011; Martin & Hand, 2007; Nam, Choi & Hand, 2011; Şahin-Kalyon & Taşar, 2020). The common

point of the conducted studies is that the argumentation method positively affects the learning-teaching process in many ways cognitively, culturally and socially.

Although the argumentation method has been a popular research topic by educational researchers in recent years in these aspects, it is obvious that the success of the method is directly proportional to the competencies of practitioners. In this context, teachers, who are the locomotive of the education process, should be equipped with sufficient knowledge and skills and be more conscious about the application of contemporary learning theories and learning environments (Posnanski, 2002; Shen & Hsieh, 1999; Zohar & Nemet, 2002). In this direction, the researchers stated that the most important role for providing argumentation-oriented environments falls on teachers and emphasized that there is a need for professionally developed teachers (Yıldırım & Şimşek, 2013). In the teaching process, the teacher guides the students to question their own knowledge and create new knowledge. In addition, it is the teacher's responsibility to provide the necessary student interactions for the healthy and effective functioning of the process (Brooks & Brooks, 1999; Öğünç, 2012; Walker, 2011). In this sense, it is thought that the future teachers themselves will personally experience such a process, it will have a positive effect on their professional lives to choose and use this method correctly and guide their students. It is stated that in effectively guided argumentation processes, students will understand the nature of science, their reasoning and research abilities will improve, and their critical thinking skills will increase (Tola, 2016; Walker, 2011; Walker & Sampson, 2013; Yalçınkaya, 2018; Zohar & Nemet, 2002).

In the study conducted in the light of the above paragraphs, a guidance material containing argumentation-based activities for teaching the subject of Chemical Equilibrium has been developed for pre-service teachers in the first grade of the university. In this sense, the aim of the study is to determine the effects of argumentation-oriented guidance material on the academic achievements of pre-service teachers on chemical equilibrium and their thoughts about the process. Within the scope of the study, the students' thoughts on argumentation at different stages of the application process of the developed material were also examined and it was aimed to evaluate the effects of the application process from the perspective of prospective teachers. It is thought that this dimension of the study will provide teachers with a different perspective on organizing learning environments, as well as provide an idea of how a learning environment is evaluated by people who are part of it.

Also, the study of events that occur in the micro world in the teaching of Science in education, argumentation-oriented activities, which allows the use of teaching methods, providing teachers, and it is believed that is important for future studies to shed light on possible.

METHOD

In this study, the “Technical/scientific/collaborative action research” pattern, which is one of the types of action research due to its relevance to the nature of the research subject, was used. In this approach, the aim is to test or evaluate an application within a previously determined theoretical framework. Accordingly, under the guidance of a researcher who has mastered the said theoretical framework, the practitioner can implement a new approach, and this process can be analyzed by the researcher and an assessment of the application can be made. The main objective of the researcher is to describe the process in technical/scientific/collaborative action research (Yıldırım & Şimşek, 2013, p. 334). The process of action research of the conducted study is presented in Table 1.

Table 1 The process of action research of the conducted work.

Deciding the Research Problem	The problem of the research is to determine the effects of argumentation-oriented activities on the academic achievements of pre-service teachers on chemical equilibrium and the thoughts of pre-service teachers about the process.
Identifying Action Research Questions	What is the effectiveness of argumentation-oriented activities on chemical equilibrium in students' academic achievements? What are the students' opinions about the effectiveness of the prepared activities on conceptual understanding and the implementation process of these activities?
Data Collection Literature Scan	During the preparation of the activities, the studies on the topic of chemical equilibrium in the literature, the understanding of the micro world of chemical equilibrium and the argumentation-based learning approach were first examined in terms of objectives, methods, findings, recommendations and materials developed.
Data Analysis and Interpretation	At this stage of the study, the data obtained after the field type survey were analyzed and interpreted.
Developing an Action/Implementation Plan	Within the framework of the analysis and interpretation of the collected data, 14 different activities based on argumentation have been developed as a solution plan for learning chemical balance and the micro world, and a pilot study of these activities has been conducted. After the pilot study, the necessary corrections were made and the activities given in the final version were made available for the main application. In addition, lesson plans have been prepared on how these activities will be implemented in the course.
Developing a monitoring plan	In order to determine the degree of effectiveness of the application in the study, the Chemical Equilibrium Academic Achievement Test (CEAAT) was developed by the researchers and a pilot study of these tests was conducted and the final version was given for the main application. In addition, semi-structured interview questions aimed at conceptual understanding and process were prepared and presented to the expert opinion. CEAAT: It was applied as a pre-test before the application and as a final test after the application Interview: It was conducted after the application in order to understand the conceptual and process, and a voice recorder was used.
Implementation of the Action Plan	At this stage of the study, the main implementation of the activities developed by the researcher with 33 Pre-service teachers for the study of chemical balance and the micro world was carried out within the framework of the prepared plan.
Monitoring the Application	In order to determine the degree of effectiveness of the application, the Chemical Balance Academic Achievement Test (CEAAT) was applied in a predetermined manner and time, and semi-structured interviews were conducted with 12 volunteer pre-service teachers as mentioned above
Analysis and Evaluation of the Application	The results of the application were analyzed by the researchers and evaluations were made regarding the effectiveness of the activities and the plan, the problems arising in the process, the sources of these problems and the degree to which the problem was solved.
Preparing a New Action Plan	Recommendations have been made to other researchers regarding the application.

The sample of the study

The study group of the study was selected using the easily accessible case sampling method. Easily accessible case sampling is most often used in cases where the researcher does not have the opportunity to use other sampling methods (Yıldırım & Şimşek, 2013, p.141). In the faculty where the study was conducted, there are two classes studying in the first year of Science Teaching program. A pilot study was conducted with one of these classes and the main study was conducted with the other. In the fall semester before the study period, the end-of-term academic averages of these two classes were examined and it was determined that they were similar to each other. There are 28 pre-service teachers in the classroom where the pilot study was conducted.

In the main study, 33 pre-service teachers studying in the first year of the Science Teaching program of a state university in the Eastern Black Sea Region participated in the research. In addition, semi-structured interviews aimed at conceptual understanding and argumentation-oriented learning process were conducted with 12 students selected on a voluntary basis from the classroom where the main application was made. Pre-service teachers participating in interviews is coded as T1,T2..... T12.

Data collection tools and process

As a data collection tool, Chemical Equilibrium Academic Achievement Test (CEAAT) and semi-structured interview were used in the study.

Chemical Equilibrium Academic Achievement Test (CEAAT)

In the study, 50 multiple choice questions were created for the developed CEAAT at the first stage. After it was decided that the developed and determined questions should be used in the test, these questions were arranged again exactly according to the level at which students can perceive the unused language, readability and the choice of options. For this purpose, opinions were obtained from a teacher and two academicians who are experts in the field of chemical education. In line with the opinions of teachers and academicians specialized in the field of chemistry education, corrections were made in some questions that were inaccurate in terms of content knowledge, were not suitable for the learning outcomes in the curriculum, and were not suitable for the measurement and evaluation principles, and some questions were removed from the test. In addition, attention has been paid to ensuring the validity of the scope by paying attention to the fact that "CEAAT" includes all the concepts related to the subject. As a result, 37 questions were included in the final part of the test by including question types that poll the same gains in different forms to determine whether students have gained the behaviors they need to gain in the chemical equilibrium unit.

Questions prepared to determine the reliability of CEAAT, Science Education program that did not participate in the study but had previously processed the chemical equilibrium unit 2. it was applied to a group of 60 students studying in a classroom. Due to lower reliability the reliability of the test after the test so as to ensure the validity of the scope of some questions (3, 4, 6, 7, 10, 15, 18, 21, 23, 24, 29 and 32) with the removal of the final test to include 25 multiple choice questions the test has been given. The reliability of the test for CEAAT was found to be 0.65 (Cronbach Alpha). The reliability coefficient of the academic achievement test was low. however, it is thought that the reliability of the study is ensured through detailed interviews.As a result of the pilot study, it was decided to apply the success test in a 50-minute period.

Semi-Structured Interview

In the study, a semi-structured interview prepared for conceptual understanding consists of 5 questions. In the interview prepared for conceptual understanding, questions were asked about adding substances to the equilibrium system, increasing volume and temperature, adding a catalyst through the same reaction given. During the interview, sub-questions were asked within the scope where it was deemed necessary to fully understand what was going on in the students' minds and to reveal the wrong concepts, and students were asked to support their thoughts about the questions asked by drawing. Interview questions are given in the appendices at the end of the study.

Frequently asked questions for conceptual understanding of pre-service teachers then lastly, the arguments work-oriented learning process, and the problems they face in the process for the execution of these applications with gains at the end of the process were asked about overall thoughts.

In this context, semi-structured interviews aimed at conceptual understanding and process were conducted with a total of 12 volunteer students who participated in main study, including four students who scored poorly, moderately and well from the final test at the end of the course process, which was completed by developing and implementing activities. During the interviews with the determined students, which were conducted individually for periods ranging from 18 minutes dec 38 minutes, permission was obtained from the students and audio recording was made. However, in order to minimize communication between students, the interviews were completed within 2 days. dec. In the preparation of the questions used in the interviews, research questions and the opinions of an academician specializing in the field of chemical education were taken into account.

Analysis of the data

Pre-service teachers' responses to the Chemical Equilibrium Academic Achievement Test (CEAAT), which was applied as a pre-final test in the study, were scored by giving 1 correct answers and 0 incorrect answers and analyzed using the SPSS 21.0 statistical program. Obtained from the research data (test scores) in the analysis of parametric or non-parametric analysis techniques which will be used in order to decide, data (test scores) showed examined whether a normal distribution. For this purpose, descriptive statistics and normality test applied in the study belonging to the test of all the calculated measures of central tendency (mean, median, mode, kurtosis, skewness the number of times the data histogram, Kolmogrov-Smirnov and the Shapiro Wilks test and examination of the number of sampling is determined and the result of not having more than 30 decided to implement parametric test normal distribution of the data. Based on these results, whether there is a significant difference between the preliminary and final tests of the students dec analyzed by the dependent group t-test, which is one of the parametric analysis techniques; the results are presented in tables and text. The level of significance in the statistical analyses used in the study (p) .05 has been adopted.

The data obtained from the interviews were analyzed through content analysis. The main goal of content analysis is to reach concepts and relationships that can explain the collected data. For this purpose, it is necessary to conceptualize the collected data first, then organize them logically according to the concepts that have emerged and, accordingly, identify the themes explaining the data (Yıldırım & Şimşek, 2013, p.261). In this context, the data obtained were analyzed and divided into meaningful sections and a code list was created. Based on the list of codes created, themes have been found that can explain the data at a general level and collect codes under certain categories, the found codes and themes have been edited. Finally, the data were systematically described, tabulated, frequency and percentage calculations were made and interpreted according to the resulting codes and themes.

Validity and reliability studies

In order to ensure the validity and reliability of the research, the following studies were carried out:

• Data; it was obtained by two different methods, such as achievement test and interview, and it was compared with each other to see whether they showed consistency or not.

• All interviews were recorded with a voice recorder to prevent data loss during the interviews.

• The fact that the research was carried out in a long time is an important factor for the quality of the research, and it took a total of 6 weeks in this study, together with the preparatory work called the introductory activity. Thus, a long-term interaction including the pre-application was tried to be ensured.

• Three researchers took part in the study and the activities were carried out by the second researcher. While other researchers took part in the course as observers, they also made evaluations about the process and gave feedback to the researcher. These interviews made it possible for the researcher conducting the activities to constantly question and control himself and the process critically, and enabled the researcher to confirm whether his interpretations of the events or phenomena he thought he was observing reflected the truth. In addition, the researcher who carried out the activities reviewed the action plan in line with the decisions taken in the interviews and made changes where necessary and reflected these changes in their practices.

• Care was taken to be objective in the description and interpretation of the data, direct quotations were made from the views of the participants in the interpretation of the data, and the opinions of the other researcher were consulted at all stages of the research.

• In order to ensure transferability in the research, the sample of the research, the materials and the environment in which the study was carried out were tried to be defined in detail at a level that could be visualized in the eyes of the reader and compared with different samples.

• Evidence on how the research results were reached and the inferences made are presented in a clear and detailed way that other people can understand the process.

• After the process was completed within the scope of the research, the coding process was carried out three times at different time intervals in order to ensure the reliability (0,80) of the analysis results for the interviews. It was also presented for expert opinion.

The Course Implementation Process and Sample Activity

Before the main application, a presentation containing examples not related to chemistry was made by the researchers in order to make the students ready for this process by providing them with information about what argumentation is and what are the components of a quality argument, how an argumentation-oriented course is handled, and in general about the process. In addition to the course, various activities related to argumentation were carried out in this presentation, which was prepared with the Prezi program and lasted for a total of 2 hours, and it was aimed that students would gain awareness about the concepts of questions, claims, data and explanations and distinguish these concepts from each other. In addition, it is aimed that students can understand the general discussion style of small groups with these activities. During the preparatory work, the students made various claims, made statements based on the data and claims, and specified the delimiters expressing how and under what conditions their claims were invalid. There have also been refutations where there have been opposing discussions. After this preparatory work under the name of introductory activity, students were told about the issues that they should pay attention to in this process.

Before starting the application, the class was divided by the researcher into a total of 7 small groups, two for 4 people and five for 5 people. When assigning students to groups, attention was paid to the fact that the groups were heterogeneous in terms of success. Each group is set up in such a way that it is homogeneous with other groups that are heterogeneous in themselves. When groups were created, each group was asked to define a Science-related name for themselves. The name determination process was carried out after all the students' ideas were received in the groups, and after this process was completed, the groups were asked to appoint a spokesperson, writer and file inspector for them. After the course process was started, students were given certain periods of time by distributing the prepared activities in each course, and the students did what needed to be done in these activities themselves within the time given in groups. In addition, students are free to access any resources they can. Two researchers were involved in the study and activities were conducted by the second researcher. The researcher who conducted the activities walked around each group during the group activities and asked questions that would involve the students in the discussion process. Examples of such stimulating questions are:

‘Why do you think so?, What are the data supporting the argument?, How do you know it's like this?, Can an argument be made against your opinion?, What are your proofs?’.

The other researcher, while taking part in the course as an observer, also gave feedback to the researcher by making evaluations about the process.

Sample Activity

REACTIONS IN THE CAR

In batteries that are the electrical energy storage of cars, electricity is generated by reacting and consuming a number of chemicals. If the same battery is charged, this process is reversed, and this time the initial chemicals are reproduced with the spent electrical energy.

In the combustion reaction that takes place in the cylinders of the same car engine, the fuel burns with oxygen, forming carbon dioxide and water vapor, which are the main combustion products. However, it has never been observed that these combustion products return and turn into fuel again.

Do You Think There is a Difference Between the Reactions Dec Took Place at the Above Events?

In these two cases, it is about the desired situation to be described;

1. Think individually and make your own argument.

2. Discuss your own arguments with your friends and create an argument as a group.

3. Write the argument that you created as a group on the paper that is also provided to the group printer.

Conceptual Change Text

Is There a Difference Between One-Dec Reactions and Two-Way (Reversible Reactions) Reactions?

In general, students think that there is no difference between one-way (irreversible) reactions dec two-way (reversible) reactions. This idea is not true. There is a difference between one-dec reactions and reversible reactions.

In one-way (irreversible) reactions, all of the ingredients are converted into products. In other words, after the reaction has started, it goes in one direction so that it cannot return back and ends when one or all of the reagents are exhausted. Such reactions are irreversible. An example of this situation is the combustion reaction in the above-mentioned automobile cylinders. Examples of one-way reactions are combustion of organic substances, precipitation, neutralization of acids and bases. One-way reactions are denoted by ”→". Theoretically, in no chemical event do reagents fully transform into products. This is due to the fact that as products are formed from reagents, the formed products also tend to form reagents again. In closed containers, the particles of the substances that initially react are transformed into a product by effective collisions, while over time, the amount of substance decreases and the rate of further reaction (→) slows down. Meanwhile, the particles of the formed products also -overcoming the activation energy barrier- collide among themselves and turn into starting substances, and this state, called the reaction (←), dec decelerates. That is, the reaction takes place both forward and backward. Such reactions are reversible reactions that can take place in two directions. An example of this situation is the reaction that occurs in batteries that are the electrical energy storage of the above-mentioned cars. Examples of reversible reactions are melting and re-freezing of ice, rechargeable battery. Reversible reactions are denoted by ”↔ (bidirectional arrow)".

Regarding the situation that is to be described in the Conceptual Change Text;

1. Think individually and make your own argument.

2. Discuss your own arguments with your friends and create an argument as a group.

3. Write the argument that you created as a group on the paper that is also provided to the group printer.

* Compare the argument you created after reading the text with the arguments you created first.

* Is there a difference dec the first argument you create and the argument you create after reading the text? If there is a difference, please indicate what these differences are.

FINDINGS

In order to determine the effect of the applied activities on the pre-service teachers' achievements, the dependent group t-test was performed using the scores obtained from the preliminary and final CEAAT. The findings regarding the effect of activities on the academic achievements of pre-service teachers are presented in Table 2.

Table 2 The t-test results of the pre-test and post-test average scores of the CEAAT

CEAAT	N	$\bar{X}$	S	sd	t	p
Pre- test	33	6,91	2,85	32	-7,66	,000
Post- test	33	12,00	3,35	32		

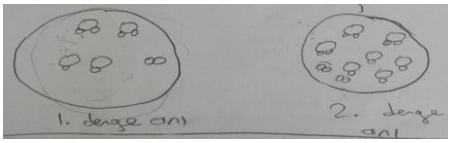
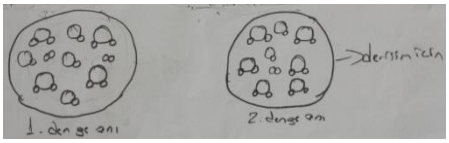
When Table 2 is examined, it is seen that the average academic achievement scores of pre-service teachers before the course was processed (X= 6.91) increased with discussion-oriented activities and after the application (X=12.00). It was determined that this increase was significant in the academic achievements of teachers before the post-application service (t(32)= -7.66, p.05).

12 academic achievements of pre-service teachers for this increase in conceptual understanding, themes, categories, codes, frequencies and percentages of the values obtained from the analysis of the data the data obtained from the relevant findings of more in-depth semi-structured interviews with a review is given below.

To measure conceptual understanding interviews with pre-service teachers in a closed container, the temperature and the volume equilibrium constant gas is added to the system, $2CO_2(g)+786kj \leftrightarrow 2CO(g)+O_2(g)$ CO_2 , increasing the volume and temperature and the catalyst is added, the system will change the concentration of the substance that will go down, how, thoughts, questions, reasons, explanations are not affected by this and also thinking about your thoughts on this question the equilibrium constants of these events the particle size, and at that moment, the first moment of the final balance in the form of are drawn, and the balance was asked to support two separate. The drawings of pre-service teachers that support their thoughts and opinions on these questions are summarized in Tables 3, 4, 5 and 6, respectively.

Table.3 Pre-service teachers' answers to the question about adding an item to the balanced system in the interview for conceptual understanding

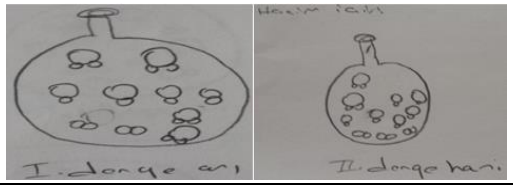
Thema	Categories	Codes	Participants	f
The system shifts to the products direction	shifts to the products direction	shifts to the products direction	**T1-T11**	**11**
	It Moves in a Direction that Will Reduce the Increased Concentration	Slides in the opposite direction to the inserted	**T1**	**1**
		It moves in the direction that will reduce the increased CO_2	**T1-Ö6,T9-T11**	**9**
	Its Concentration Increases	The concentration of products increases	**T1-T11**	**11**
		The concentration of CO_2 increases according to its initial state	**T1-T11**	**11**
	Its Concentration Creases	An amount of CO_2 is spent	**T1-T11**	**11**
	Its Structure Is Changing	CO_2 will want to spoil itself	**T8**	**1**

The system shifts to the reactants direction	Sliding to reactants	Sliding to reactants	**T12**	**1**
	Will Increase the Decreasing Concentration Moves In The Direction	It moves in a direction that increases the decreasing CO_2	**T12**	**1**
	Physical Condition	The product is not added	**T12**	**1**
		Power is not supplied	**T12**	**1**
	My Concentration Increases	The concentration of products increases	**T12**	**1**
	The Concentration Decreases	The concentration of CO_2 decreases	**T12**	**1**
Concentration constant (Cc) Does Not Change	Cc Does Not Change	Cc Does Not Change	**T1-T8,T10-T12**	**11**
	It Only Affects The Temperature	Changes the temperature	**T1,T2,T4-Ö7,T10,T11**	**8**
		The temperature is constant	**T4-Ö7,T10-T12**	**7**
	I don't know	I don't know why	**T3**	**1**
Concentration constant (Cc) Is Affected	Cc Is Affected	Cc Is Affected	**T9**	**1**
	Concentrations are changing	The concentration of entrants is decreasing	**T9**	**1**
		The concentration of products is increasing	**T9**	**1**
	Cc is changing in direct proportion to the product	Cc is directly proportional to the product	**T9**	**1**
		Cc grows from the Product/reactant	**T9**	**1**
Drawing Correctly The Correct Explanation			**T1-T11**	**11**
Wrong Drawing Incorrect Explanation			**T12**	**1**

The answers given to the pre-service teachers to the question about adding an item to the balanced system in a closed container at a constant temperature of $2CO_2(g)+786kj \leftrightarrow 2CO(g)+O_2(g)$, which is in equilibrium, are presented in Table 4. Examples of the answers given by the pre-service teachers to this question are presented below; "Balance shifts towards products", "…the system will shift in the opposite direction we added", "It moves in the direction of reducing the increasing CO_2", "concentrations of products increase", "Concentration of CO_2 will increase compared to its initial state", "The concentration of CO_2 increases compared to its initial state, but as the system shifts to products, some of it decreases to form CO and O_2"

Table 4 The Pre-service teachers' answers to the question about increasing the volume of the equilibrium system in the interview for conceptual understanding

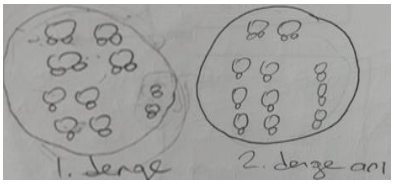
Thema	**Categories**	**Codes**	**Participants**	**f**
The system shifts to the products direction	Shifts to the products direction	shifts to the products direction	**T1-Ö7,T10-T12**	**10**
	It slides from the side with a small number of moles to the side with a lot	His mole shifts from a small one to a large one	**T1-Ö7,T10-T12**	**10**
	Its Concentration Increases	The concentration of products increases	**T1-Ö7-T10-T12**	**10**
	The Concentration Decreases	The concentration of CO_2 decreases	**T1-Ö7,T10-T12**	**10**
		Concentrations are reduced	**T4,T11**	**2**

	Physical Condition	The volume is increasing	**T1-T12**	**12**
		The pressure is decreasing	**T1-T12**	**12**
		It becomes easier to decompose	**T1,T12**	**2**
		Their movement becomes easier	**T5**	**1**
		Its area is expanding	**T8,T12**	**2**
The system shifts to the reactants direction	shifts to the reactants direction	Sliding to reactants	**T8,T9**	**2**
	It slides from the side with a large number of moles to the side with a small number	His mole shifts from a lot to a little	**T8,T9**	**2**
	Its Concentration Creases	The concentration of CO_2 increases	**T8,T9**	**2**
	Its Concentration Increases	The concentration of products decreases	**T8,T9**	**2**
Concentration constant (Cc) Does Not Change	Cc Does Not Change	Cc Does Not Change	**T1-Ö7,T10-T12**	**10**
	It Only Affects The Temperature	Changes the temperature	**T1-Ö7,T10-T12**	**10**
		The temperature is constant	**T4-Ö7,T10-T12**	**7**
Cc Varies	Cc Is Affected	The equilibrium constant is affected by	**T8,T9**	**2**
	Concentrations Are Changing	The concentration of entrants is increasing	**T8,T9**	**2**
		The concentration of products is decreasing	**T8,T9**	**2**
	Cc Varies In Direct Proportion To The Product	Cc is directly proportional to the product	**T8,T9**	**2**
		Cc decreases from the Product/reactant	**T8,T9**	**2**
Drawing Correctly The Correct Explanation			**T1-Ö7,T10-T12**	**10**
Wrong Drawing Incorrect Explanation			**T8,T9**	**2**

Looking at Table 4, 6 different themes were determined from the interviews with pre-service teachers, including system products related to the question, system inputs, Cc does not change, Cc changes, correct drawing-correct explanation and incorrect drawing-incorrect explanation. Examples of the answers given by the pre-service teachers to this question are presented below; "…the system will shift towards products", "…the system shifts from the side with less moles to the side with more moles", "The concentration of the products will increase as it shifts to the products", "Concentration of the incoming (CO_2) decreases again", "Volume is increasing", "Equilibrium constant is not affected"

The answers given to the pre-service teachers to the question about the state in which the temperature of this system is increased by $2CO_2(g)+786kj \leftrightarrow 2CO(g)+O_2(g)$, which is in equilibrium in a closed fixed-volume container, are presented in Table 5.

Table 5 Pre-service teachers' answers to the question about increasing the temperature of the equilibrium system in the interview for conceptual understanding

Thema	Categories	Codes	Participants	f
The System Shifts to the Products Direction	Shifts to the Products Direction	Shifts to the Products Direction	**T1-T12**	**12**
	It moves in the direction that will reduce the increased temperature	It moves in a direction that reduces the effect	**T2,T3,T5,T6,T11,T12**	**6**
	Its Concentration Increases	The concentration of products increases	**T1-T12**	**12**
	Its Concentration Decreases	The concentration of CO_2 decreases	**T1-T12**	**12**
	Endothermic Reaction	Endothermic	**T1-T11**	**11**
		Heat inputters	**T3,T4,T6,T10**	**4**
	Its Structure Is Changing	Its structure is deteriorating	**T8**	**1**
		The energy of CO_2 is increasing	**T1,T2,T4,T5,T11,T12**	**6**
		They collide more often	**T1**	**1**
		More products are formed	**T1,T8,T11,T12**	**4**
Cc Varies	Cc Is Affected	Cc Is Affected	**T1-T12**	**12**
	It Only Affects The Temperature	Changes the temperature	**T1,T5,T6,T11**	**4**
		The temperature is changing	**T2,T4,T5,T7**	**4**
	Concentrations Are Changing	The concentration of entrants is decreasing	**T3,T6-T12**	**8**
		The concentration of products is increasing	**T3,T6-T12**	**8**
	Cc Is Directly Proportional To The Product	Cc is directly proportional to the product	**T1,T4,T5,T9,T10**	**5**
		Cc grows from the Product/Entrant	**T1-T12**	**12**
Drawing Correctly The Correct Explanation			**T1-T12**	**12**

Note: Frequencies are more than 100% of the total due to one student giving more than one opinion).

Looking at Table 5, 3 different themes were identified from the interviews with pre-service teachers, including the system related to the question shifts in the direction of products, Cc changes, and the correct drawing-the correct explanation. Examples of the answers given by the pre-service teachers to this question are presented below; “system shifts to products”, “if I increase the temperature the system will shift to the products to reduce the increased temperature”, “concentrations of products will increase”, “The concentration of CO_2 will decrease”, “An endothermic reaction", “…they fought more”, “Equilibrium constant being affected”

The answers given by pre-service teachers to the question of whether there will be a change in equilibrium when a catalyst is added to a system that is in equilibrium at a constant temperature and volume in a closed container are presented in Table 6.

Table 6 Pre-service teachers' answers to the question about adding a catalyst to the equilibrium system in the interview for conceptual understanding

Thema	Categories	Codes	Participants	f
The Catalyst Does Not Affect Systems that Have Reached Equilibrium	It Does Not Change the Balance	It's already in the balance	**T2,T5,T9,T12**	**4**
		Does not affect the equilibrium system	**T1-T12**	**12**
	The Effect of Catalyst	Shortens the time to reach equilibrium	**T1-T12**	**12**
		Reduces activation energy	**T1,T2**	**2**
		Allows systems that have not reached equilibrium to work faster or slower	**T10**	**1**
Drawing Correctly The Correct Explanation			**T1-T12**	**12**

Looking at Table 6, 2 different themes were identified from the interviews with prospective teachers: the catalyst related to the question does not affect the systems that have reached equilibrium, and the correct drawing-the correct explanation. Examples of the answers given by the pre-service teachers to this question are presented below; “This system is already in balance”, “It does not affect this system that is in balance”, “Reduces activation energy”, “makes unbalanced systems run faster or slower”, “If I add a catalyst, nothing happens because the catalyst doesn't affect the equilibrium, it just makes the unbalanced systems run faster or slower. It will be the same again”.

In interviews with prospective teachers, finally, they were asked what their thoughts were in general regarding the argumentation-oriented processing of the course. The opinions of pre-service teachers about this question are summarized in Table 7.

Table 7 Pre-service teachers' thoughts on the argumentation-oriented course process

Thema	Categories	Codes	Participants
Feelings at the First Meeting	We saw for the first time	**T4,T10**	**2**
	It was unorthodox	**T2,T3**	**2**
	At first I was against it	**T2,T3,T7,T10**	**4**
	I was bored at first	**T10**	**1**
	It sounded ridiculous	**T7,T10**	**2**
	I was saying it wouldn't turn out like this on the exam	**T7**	**1**
Feelings After the End of the Application	Then I liked	**T2-T4,T7,T10**	**12**
	I got used to it later	**T5**	**1**
	A good method	**T1,T2,T6,T9,T10**	**5**
	It should also be applied in other courses	**T7,T10**	**2**
	I will also apply	**T6**	**1**
	It was effective	**T2,T5,T7,T8**	**4**
Negative thoughts	Shortage of time(Prolongation of the lesson)	**T1,T2,T4,T9**	**4**
	Number of students	**T1**	**1**
	Having a lot of sound	**T3,T11,T12**	**3**
	Presentation of the group spokespersons	**T5**	**1**
	Events where we all share the same idea	**T6**	**1**

Positive thoughts	There's nothing I don't like about it	**T7,T8,T10**	**3**
	Group discussion	**T5,T8-T10,T12 T1,T2,T6,T9,T11**	**10**
	It provides more permanent learning	**T2-T4,T6,T7,T10**	**6**
	Learning by living by doing	**T4, T2,T5,T11**	**4**
	Exchanging information	**T5,T9,T12**	**3**
	To interact with each other	**T5,T10**	**2**
	Not memorizing	**T4,T5**	**2**
	Not accepting information directly	**T2,T4,T5**	**3**
	Passing information through mental processes	**T2, T4,T11, T5**	**4**
	Not teacher-oriented	**T2,T4,**	**3**
	Use of justifications	**T1**	**1**
	To see the truth more concretely with refutators	**T1**	**1**
	Learning using the structure of data, claims,explanations (arguments)	**T1,T2,T4,T6,T9,T11**	**6**
	Be excited	**T6**	**1**
	Presenting the arguments of the groups to each other	**T12**	**1**
	Integrating argumentation with materials	**T10**	**1**
	The suitability of the materials for multiple intelligences	**T1,T6,T7,T10**	**4**

Looking at Table 7, it can be seen that 4 different themes were identified from the interviews with prospective teachers, namely the feelings at the first encounter on this question, the feelings after the application was completed, the aspects that they did not like, the aspects that they liked. Examples of the answers given by the pre-service teachers to this question are presented below; *"I saw such a method for the first time", "It even became such that we started arguing in other classes, we got so used to it", "The argumentation method should be used at least in some courses", "If I become a teacher in the future, I will try these too", "There was the group spokesman incident, we were going to the blackboard, we were talking about it, sometimes I didn't like it as a waste of time", "The parts I didn't like were like this, in some events, we all had almost the same opinion", "What I liked was the group discussion with my friends", "it made it more memorable", "Argumentation method versus rote", "Not teacher oriented".*

DISCUSSION AND CONCLUSION

Argumentation focused on the guidance materials developed to the effects on academic achievement of pre-service teachers about their thoughts on the balance of chemical and process CEAAT conducted in order to determine the pre-test and post-Test average scores of the T-test results are examined, the pre-test, the difference between the average scores were determined to be significant (Table 2, p.05). In accordance with this finding, it can be said that the teaching carried out with argumentation-oriented activities significantly increased the academic achievements of pre-service teachers on Chemical Equilibrium. Argumentation-oriented learning environments students generating questions about the topic, and actively participate in class activities is keen to answer these questions in their minds on issues of pre-formed models questioning, defense support of his friends to refute his own model, or models, using reason and evidence, and thinking more in depth on the concepts accordingly provides the possibility to examine issues (Aslan, 2010; Okumuş, 2012). In this process, students contribute to each other's learning, question and evaluate their own and other friends' ideas (Arlı, 2014; Burke & Greenbowe, 2006; Driver et al., 2000; Hand et al., 2004). Students to be in constant interaction with their peers of the claims within the interaction, establish, strengthen, or to give up their claims, demolish, to realize many of the limitations by allowing new ideas to emerge (Cevher, 2015) provides the concepts in a meaningful way at the level of students ' knowledge structures configurations (Çelik & Kılıç, 2007). The findings obtained from the interview conducted with pre-service teachers for conceptual understanding also support these explanations. Because in the

interview conducted, the vast majority of pre-service teachers answered the questions asked correctly, supporting and explaining their answers with the drawings they made correctly. When many studies in the literature were examined, it was determined that students who usually tend to explain events at the macroscopic level could not fully relate the micro dimension to the macro dimension and had various problems understanding the micro dimension (Adadan, 2014; Adadan et al., 2010; Franco & Taber, 2009; Hansen, 2014; Karacöp & Doymuş, 2012; Okumuş et al., 2014; Raviolo, 2001; Stavridou & Solomonidou, 1998; Tsai et al., 2011; Yavuz Korkmaz, 2019). It is believed that the activities prepared in this context are effective for Pre-service teachers to associate the macro dimension with the micro dimension and to learn an abstract concept such as chemical equilibrium, thus increasing their academic success. As a result of the study, this finding is also compatible with the literature data obtained from the results of studies on chemistry subjects at different levels of education where the argumentation method is applied (Aslan, 2010; Arli, 2014; Choi, et al., 2010; Demirel, 2014; Deveci, 2009; Gümrah, 2013; Koçak, 2014; Nam, Choi & Hand, 2011; Okumuş, 2012; Osborne et al., 2004; Özer, 2009; Özkara, 2011; Tekeli, 2009; Untereiner, 2013; Şahin-Kalyon & Taşar, 2020; Yavuz Korkmaz, 2019). Again, in a similar manner, outside of argumentation in the literature of chemistry topics-driven instruction found in many studies that investigated the relationship between student achievement (Aktamıs & Hiğde, 2015; Altun, 2010; Balcı, 2015; Ceylan, 2012; Çaycı, 2019; Demirbağ, 2011; Demircioğlu, 2011; Domaç, 2011; Erdoğan, 2010; Jusniar et al., 2021; Kabataş Memiş, 2011; Uluay, 2012; Walker & Sampson, 2013; Yalçınkaya, 2018; Zohar & Nemet, 2002).

Within the scope of the research, semi-structured interviews were conducted with 12 after the application. Interviews include pre-service teachers' conceptual understanding of the subject and their views on the argumentation process. The purpose of the semi-structured interview with students aimed at conceptual understanding is to try to learn about the effectiveness of activities and get students' opinions about the effectiveness of the method and activities.

In the first question of the semi-structured interview for conceptual understanding, all pre-service teachers except one teacher candidate said that the system will shift to the products direction with the addition of CO_2, the concentration of products will increase, the concentration of CO_2 will increase according to the initial state, but some of it will be spent and will not be affected by the change in the concentration of Cc, and they supported their thoughts by making correct drawings. It is believed that the activities called “Live Witnesses (Role Playing)” and “Concentration Effect” are effective for almost all of the pre-service teachers to make the right drawings by answering this question correctly. Because with these activities, it is aimed that students learn the Le Chatelier principle and how the change in concentration affects the balance. In this context, in the Live Witnesses event implemented with the role-playing strategy, students entered into discussions by portraying Le Chatelier and tried to explain this principle by creating arguments. The fact that the students were fully active while the event was being held motivated them. With the participation of each group member in this event, the students saw the thoughts of their other friends. This situation also allowed students to evaluate different points of view. Based on all this, it is believed that the Live Witnesses event allows students to learn the principle of Le Chatelier. In the Concentration Effect event prepared based on the TGA strategy, students; done digestion, digestion at the end of their discussions, their arguments, and created drawings that support their arguments, the argument is checked with the accuracy of the experiment, at the end of the experiment re-created drawings and illustrations they created the first argument and the arguments by comparing the predictions with observations by checking whether there is a difference between some have made statements. In accordance with all this, it is believed that the efficiency of the concentration effect allows you to find out how the change in concentration affects the balance.

The second question in the interviews was answered by all the pre-service teachers except the two pre-service teachers, saying that the system will shift to the direction of products as the volume increases, the concentration of entrants will decrease as the concentration of products increases, and Cc will not be affected by the volume change, they supported their thoughts by making correct drawings. It can be said that the group discussions at the “Fatih's Problem (Listening Triads)” events with the “Pressure Effect” were effective for the majority of pre-service teachers to answer this

question correctly. Because with these activities, it has been tried to enable students to learn how the pressure-volume change affects the balance. The effect of pressure in the event the Frequently Asked Questions related to cartoons, which are presented with one of the arguments is wrong and why the correct of which were asked to make drawings that supports this idea by explaining that the students, making them the multifaceted debate, opposing arguments, to create first created the opportunity to compare their arguments with the arguments that they created after discovering the issue, and students to be in constant interaction with each other and actively participate in the implementation of learning can be ensured. However, it is thought that the argumentation activity called Fatih's Problem, which is applied with the listening trio strategy to evaluate the students' understanding of how the pressure-volume change affects the balance, also gives all students the opportunity to express their opinion, students with different ideas try to prove their own ideas to other students with group-class discussions, this concept is internalized.

All pre-service teachers supported the third question of the semi-structured interview for conceptual understanding by making correct drawings by saying that the system will shift in the direction of products as the temperature increases, the concentration of inputs will decrease as the concentration of products increases, and Cc will grow by being affected by temperature change. The activity called ”Temperature Effect (Prediction-Observation-Explanation, POE-Structuring an Argument)" is considered to be effective in ensuring that all of the pre-service teachers interviewed answered this question correctly. In the Temperature Effect event prepared with TGA and argument configuration strategies, students made their drawings by configuring the prediction arguments with ready-made claims and evidence cards and checked the arguments and drawings they created after the experiment they conducted and the video they watched. It is believed that doing all this allows students who are constantly in a discussion to learn the effect of temperature change on balance by increasing communication and interaction between them, stating the reasons, evidence, justifications and refutations of the claims they put forward dec In addition, the fact that the claim and evidence cards were given ready, and the students chose the one that suits their thoughts from among them, allowed them to enjoy this activity the most.

All of the pre-service teachers related to the fourth question supported their thoughts with the correct drawings they made, saying that there would be no change with the addition of a catalyst to the balanced system. It can be said that the “Competing Charts” activity is effective in ensuring that all of the pre-service teachers interviewed answer this question correctly. Because with this activity, it is aimed to enable students to learn that adding a catalyst to the equilibrium system will not affect the equilibrium. During the Dec Graphs event, students were asked to defend the claim/claims they supported among the claims given about the question asked. It is believed that the fact that students who are in the position of defending their claims have to use evidence to argue any claim contributes to students learning about the catalyst effect.

According to these findings obtained in the interview for conceptual understanding, it can be said that pre-service teachers with argumentation-oriented activities perform effective learning by making claims and providing justifications, data and refutations that support these claims, and this is effective in understanding the concepts. This achievement also in conceptual understanding pre-service teachers focused on the teaching of argumentation is used as course material in logical thinking process when he answers questions in the event that they use, intensive in-group interaction, consensus decisions, and activities that supports their claims of the reason they left faced with the situation of writing can be connected. In her study Yalçın Çelik (2010), he aimed to determine the difference between the change in the conceptual understanding of students compared to the traditional teaching approach by applying argumentation-based teaching in the teaching of the “Gases” unit in the classroom. As a result of his study, he found that the conceptual understanding of the experimental group students was significantly different from the control group students.

Within the scope of the study, the course was covered with argumentation-oriented activities for five weeks. At the beginning of the application, this model was introduced to prospective teachers, examples of the model were given and sample applications were made to students and brief

information was given about how to process the lessons. However, pre-service teachers in interviews about the process for the first time with such activities committed in creating lesson in argument and counter argument due to microscopic size to understand the events said they would have any difficulty in understanding then, they expressed these difficulties. Although it is thought that pre-service teachers are forced to face both the concept of the micro world, the argumentation method, and such activities for the first time and are timid at first, it is considered that such a situation of strain is normal. Similarly, in an interview with Okumuş (2012), it was found that students had difficulty finding a rationale to defend the claim, but they got more used to the model towards the end of the application and created arguments more comfortably. In the interview conducted by Çınar (2013), while a few of the students stated that they created arguments very comfortably, most of the students stated that they had difficulty creating arguments, they could not create the argument components at first or even confused them, but they could do it in subsequent activities. In this regard, this finding obtained from the interview is in harmony with the interview findings of the studies conducted by Okumuş (2012) and Çınar (2013).

Argumentation includes thought exercises and gives students the opportunity to judge events, situations or facts by thinking deeply (Erduran et al., 2004). More importantly, science education usually proceeds with discussion, disagreement, and proving or refuting claims, rather than agreeing on the same ideas. In this way, students can better understand scientific knowledge (Aktamış & Hiğde, 2015; Cavagnetto, 2010; Clark & Sampson, 2007; Çaycı, 2019; Gunel et al., 2012; Martin & Hand, 2007; Nam et al., 2011; Şahin-Kalyon & Taşar, 2020; Niaz et al., 2002; Walker, 2011; Walker & Sampson, 2013). Deep thinking and practice are important for learning. But in order to ensure effective learning, it is not enough just to make the student think about the subject. In order to structure the thought correctly, it is important to put forward an opposing thought and refute this opposing thought with logical grounds and information from the point of view of effective learning. In this context, pre-service teachers were asked whether the opposite arguments created were useful for them and pre-service teachers were asked to explain their thoughts about the opposite argument. Learning more permanent, fix yourself, I see it the wrong way, to better understand the claims and defend, debate, thought to prove the accuracy of the other side, deeper thinking, better remember to give the opposition the chance to see the shortcomings and complete to teach the emergence of new ideas, like the exchange of ideas is not a single idea and to show that, for different reasons, the arguments themselves are said to be beneficial for all pre-service teachers opposing Table 7).

Finally, Pre-service teachers were asked if this argumentation-oriented course was different from the previous courses they had seen, if it was different, in which aspects it was different, if they wanted other courses to be processed as argumentation-oriented, which courses they wanted to be processed in which subjects if they wanted to be processed. Pre-service teachers note that this course increases interest in the lesson due to the use of activities, traditional teaching, not boring, attention-grabbing; they stated that it is different from other courses in that the student is active, the teacher is in the role of a guide, there is group work, there is learning by understanding logic, there is no memorization, it is effective because it reveals the spirit of the researcher, and there is an exchange of ideas due to constant communication and the exchange of ideas. Pre-service teachers who said that they wanted this method to be used in other courses expressed that they wanted it to be used in Physics, Chemistry, Biology and Educational Psychology courses. Pre-service teachers have stated that they especially want Physics and Chemistry courses to be applied in verbal subjects. In this application, the courses have been processed with activities focused on argumentation. The activities and methods used for pre-service teachers may have sounded different and made the pre-service teachers' learning more permanent. However, the implementation of different activities has enabled students to learn permanently and effectively by keeping their attention alive (Okumuş 2012). The activities used have also saved the classroom environment from boredom.

Recommendations

The study was conducted on the topic of Chemical Equilibrium, which is a subject of Chemistry. According to findings, prepared argumentation focused activities, chemical equilibrium

and chemical equilibrium was effective for learning of pre-service teachers and students of the micro world, considering that in accordance with the wishes of the subjects of Chemistry, Biology and physics in a similar study can be done with other topics.

In chemistry courses, which are full of abstract concepts, it is necessary to embody the topics as much as possible. The concepts of chemistry will be learned to the extent that the macroscopic, microscopic and symbolic level are correctly correlated with each other. In this regard, in order to ensure the relationship between these three dimensions, the events that occur in the micro-world should be fully and decisively learned by students. For this purpose, different materials can be developed that are argumentation-oriented, contain animations and models based on events that occur in the micro-world.

The study was carried out within the scope of action research. Within the scope of the method, it is possible for the practitioner to observe the process much more closely, to examine the problems that arise on the spot, to produce solutions for the healthy progress of the process and to evaluate the process. Therefore, it may be effective to use the action research method in activities and material development studies especially for science subjects that are difficult to understand.

Conflicts of Interest:

No potential conflict of interest was declared by the authors.

Funding Details:

This study was not supported by any funding agency.

CRediT Author Statement:

This study was taken from the second author's master thesis conducted under the supervision of the first author. In this sense,

Author 1: Supervision, Investigation, Conceptualization and Methodology, Writing- Original draft preparation, Reviewing and Editing

Author 2 : Investigation, Conceptualization and Methodology, Writing- Original draft preparation.

Ethical Statement:

In this study, all the rules specified to be followed within the scope of "Higher Education Institutions Scientific Research and Publication Ethics Directive" were complied with. None of the actions specified under the title of "Actions Contrary to Scientific Research and Publication Ethics", which is the second part of the directive, were not carried out. The study was produced from the master's thesis named " Development of Argumentatıon-Based Material for Learning the Chemical Equilibrium and Its Micro World".

REFERENCES

Adadan, E. (2014). Investigating the ınfluence of pre-service chemistry teachers' understanding of the particle nature of matter on their conceptual understanding of solution chemistry. *Chemistry Education Research and Practice*, 15(2), 219-238. http://doi.org/10.1039/C4RP00002A

Adadan, E., Trundle, K. C., & Irving, K. E. (2010). Exploring grade 11 students‟ conceptual pathways of the particulate nature of matter in the context of multi representational instruction. *Journal of Research in Science Teaching*, 47(8), 1004-1035. http://doi.org/10.1002/tea.20366

Akaygun, S., & L.L. Jones. (2013). Research-based design and development of a simulation of liquid-vapor equilibrium. *Chemistry Education Research and Practice*, 14, 324-344. http://doi.org/10.1039/C3RP00002H

Akaygun, S., & Jones L.L. (2014). Words or pictures: a comparison of written and pictorial explanations of physical and chemical equilibria. *International Journal of Science Education*, 36(5), 783-807. https://doi.org/10.1080/09500693.2013.828361

Aktamış, H., & Hiğde, E. (2015). Assessment of argumentation models used in science education. *Mehmet Akif Ersoy University Faculty of Education Journal*, 35, 136-172.

Altun, E. (2010). *Teaching light unit to elementary school students throught argumentation* [Master's thesis, Gazi University].

Arlı, E. E. (2014). *The impacts of argumentation based science inquiry approach on seasonal agricultural worker students' academic achievement and thinking skills* [Master's thesis, Atatürk University].

Aslan, S. (2010). *The effect of argumentation-oriented teaching approach on the improvement of their top scientific process and critical thinking among high school 10. class students?* [Doctoral thesis, Gazi University].

Balcı, C. (2015). *The effect of scientific argumentation based learnings in teaching of 'Cell division and inheritance' units to 8th grade students* [Master's thesis, Adnan Menderes University].

Brooks, M.G., & Brooks, J.G. (1999). The courage to be constructivist. *Educational Leadership*, 57(3), 18-24.

Burke, K. A., & Greenbowe, T. J.(2006). Implementing the science writing heuristic in the chemistry laboratuary. *Journal of Chemical Education,* 83(7), 1033-1038. https://doi.org/10.31274/rtd-180813-16923

Büber, A. (2015). The effects of argumentation based learning activities on conceptual understanding of 7th graders about 'Force and Motion' unit and establishing thinking friendly classroom environment [Master's thesis, Dokuz Eylül University].

Cavagnetto, A. R. (2010). Argument to foster scientific literacy: A review of argument interventions in K–12 science contexts. *Review of Educational Research*, 80(3), 336–371. https://doi.org/10.3102/0034654310376953

Cevher, A. H. (2015). *The effect of eight grade-gifted students' argumentation processes about anomalic cases on scientific creativity levels* [Master's thesis, Inönü University].

Ceylan, K. E. (2012). *Teaching 5th grades elementary students with scientific argument based method in the area of world and universe learning* [Master's thesis, Gazi University].

Choi, A., Notebaert, A., Diaz, J., & Hand, B. (2010). Examining arguments generated by year 5, 7, and 10 students in science classrooms. *Research in Science Education*, 40, 149–169. https://doi.org/10.1007/s11165-008-9105-x

Clark, D. B., & Sampson, V. (2007). Personally-seeded discussions to scaffold online argumentation. *International Journal of Science Education*, 29(3), 253-277. https://doi.org/10.1080/09500690600560944

Çaycı, B. (2019, Eylül 6-8). *Öğrenme stillerine göre sınıf öğretmeni adaylarının argümantasyon becerilerinin analizi.* International Symposium on Active Learning, Adana, Türkiye.

Çelik, K., & Kılıç, Z. (2007, Haziran 20-22). *Öğrencilerin sosyal etkileşim ve iletişim becerilerine bilimsel tartışma tekniğinin etkisi*. 1. Ulusal Kimya Eğitimi Kongresi, İstanbul, Türkiye.

Çınar, D. (2013). *The effect of argumentation based science instruction on 5th grade students' learning outcomes* [Doctoral thesis, Necmettin Erbakan University].

Demirbağ, M. (2011). *The effect of multi modal instruction on student?s science achievement and writing skills in an argument based inquiry classroom* [Master's thesis, Ahi Evran University].

Demircioğlu, G., Demircioğlu, H., & M. Yadigaroğlu. (2013). An ınvestigation of chemistry student teachers' understanding of chemical equilibrium. *International Journal on New Trends in Education and Their Implications*, 4(2),192-199.

Demircioğlu, G. (2003). *Developing and implementing teacher guide materials related to the unit 'acids and bases' at lycee-II* [Doctoral thesis, Karadeniz Teknik University].

Demircioğlu, T. (2011). *To investigate the effect of argument-driven inquiry on pre-service science teachers' laboratory instruction* [Master's thesis, Çukurova University].

Demirel, O. E. (2014). *Effects of problem based learning and argumentation based learning on the students' chemistry achievement, their science process skills and science reasoning aptitudes.* [Master's thesis, Mustafa Kemal University].

Deveci, A. (2009). *Developing seventh grade middle school students? socioscientific argumentation, level of knowledge and cognitive thinking skills in the structure of matter subject.* [Master's thesis, Marmara Universitiy].

Domaç, G. G. (2011). *The effect of the argumentation based learnings in terms socioscientific issues in biology education.* [Master's thesis, Gazi University].

Driver, R., Newton, P., & Osborne, J.(2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84, 287-312. https://doi.org/10.1002/(SICI)1098-237X(200005)84:3<287::AID-SCE1>3.0.CO;2-A

Erdoğan, S. (2010). *Investigate the effects of teaching earth, sun and moon topics through argumentation on the success, attitude and argumentation skills of 5th grade students.* [Master's thesis, Usak University].

Erduran, S., Simon, S., & Osborne, J. (2004). TAP ping into argumentation: developments in the use of Toulmin's argument pattern for studying science discourse. *Science Education*, 88(6), 915–933. http://doi.org/10.1002/sce.20012

Ergül S (2021). A teaching activity based on discovery learning and meaningful learning approaches: the relationship between stociometry and chemical equilibrium reactions. *Journal of Balıkesir University Institute of Science and Technology*, 23(2), 620 - 644. https://doi.org/10.25092/baunfbed.853963

Ersoy, N. (2014). *The effects of case study based group works on students' understanding and using scientific evidence, argumentation skills and conceptual understanding* [Master's thesis, Dokuz Eylül University].

Fettahlıoğlu, P. (2012). *The usage of argumentation-based and problem-based learning approaches intended for developing the environmental literacy of pre-service science teachers* [Doctoral thesis, Gazi University].

Franco, A.G., & Taber, K.S. (2009). Secondary students‟ thinking about familiar phenomena: Learners‟ explanations from a curriculum context where particles is a key idea for organizing teaching and learning. *International Journal of Science Education*, 31(14), 1917-1952. https://doi.org/10.1080/09500690802307730

Gümrah, A. (2013). *The effects of scientific argumentation on secondary students' conceptual understanding of chemical changes, nature of science views, science process, communication and argument skills* [Doctoral thesis, Marmara University].

Günel, M., Kıngır, S., & Geban, Ö. (2012). Analysis of argumentation and questioning patterns in argument- based inquiry classrooms. *Education and Science*, 37(164), 316-330.

Haidar, A. H. (1997). Prospective chemistry teachers' conceptions of the conservation of matter and related concepts. *Journal of Research in Science Teaching*, 34(2), 181–197.

Hand, B., & Keys, C. (1999). Inquiry investigation: A new approach to laboratory reports. *The Science Teacher*, 66, 27-29.

Hand, B., Wallace, C., & Yang, E. (2004). Using the science writing heuristic to enhance learning outcomes from laboratory activities in seventh grade science: Quantitative and qualitative aspects. *International Journal of Science Education*, 26(2), 131-149. https://doi.org/10.1080/0950069032000070252

Hansen, S. (2014). *Multimodal study of visual problem solving in chemistry with multiple representations*. [Degree of Master, University of Columbia].

Hasançebi, F. (2014). *The impacts of argument-based inquiry (ABI) approach on students' science achievements, argument skill and personal development* [Doctoral thesis, Atatürk University].

Hsin-Kai, W., Krajcik, J. S., & Eliot, S. (2001). Promoting understanding of chemical representations: students‟ use of a visualization tool in the classroom. *Journal of Research in Science Teaching*, 38(7), 821-842.

Johnstone, A. H. (2000). Teachıng of chemistry - logical or psychological?. *Chemistry Education: Research and Practıce in Europe*, 1(1), 9-15.

Jusniar, J., Effendy, E., Budiasih, E., & Sutrisno, S. (2021). Eliminating misconceptions on reaction rate to enhance conceptual understanding of chemical equilibrium using EMBE-R strategy. *International Journal of Instruction*, 14(1), 85-104. https://doi.org/10.29333/iji.2021.1416a

Kabataş Memiş, E. (2011). Effects of the argumentation based science learning approach and self evaluation on primary school students? Science and technology course achievement and retention of the achievement [Doctoral thesis, Atatürk University].

Karaçöp, A., & Doymuş, K. (2012). Effects of jigsaw cooperative learning and animation techniques on students‟ understanding of chemical bonding and their conceptions of the particulate nature of matter. *Journal of Science Education Technology*, 22, 186-203. http://doi.org/10.1007/s10956-012-9385-9

Kaya, B. (2009). *A comparision of effects of teaching interventions desinged in the line of inquiry-based learning and scientific argumentation on primary school students' learning acids and bases* [Master's thesis, Marmara University].

Kıngır, S. (2011). *Argümantasyon tabanlı bilim öğrenme yaklaşımının öğrencilerin kimyasal değişim ve karışım kavramlarını anlamalarını sağlamada kullanılması* [Doctoral thesis, Orta Doğu Teknik University].

Koçak, K. (2014). *The effect of argumentation-based science learning on pre-service teachers' achievementin solutions subject and their critical thinking dispositions* [Master's thesis, Hacettepe University].

Kousathana, M., & Tsaparlis, G. (2002). Students errors in solving numerical chemical- equilibrium problems. *Chemistry Education: Research and Practice in Europe*, 3, 5-17.

Kutluca, A. Y. (2012). *Investigating of pre-service science teachers? socio-scientific and scientific argumentation quality in terms of content knowledge level* [Master's thesis, Abant İzzet Baysal University].

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, 29(4), 331-359. https://doi.org/10.1002/tea.3660290404

Martin, A. M., & Hand, B. (2007). Factors affecting the implementation of argument in the elementary science classroom. A longitudinal case study. *Research in Science Education*, 39, 17-38. http://doi.org/10.1007/s11165-007-9072-7

Nam, J., Choi, A., & Hand B. (2011). Implementation of the science writing heuristic (SWH) approach in 8th grade science classrooms. *International Journal of Science and Mathematics Education*, 9, 1111-1133. http://doi.org/10.1007/s10763-010-9250-3

Niaz, M., Aguilera, D., Maza, A., & Liendo, G. (2002). Arguments, contradictions, resistances and conceptual change in students‟ understanding of atomic structure. *Science Education*, 86, 505-525.

Okumuş, S. (2012). *The effects of argumentation model on students achievement and understanding level on the unit of states of matter and heat* [Master's thesis, Karadeniz Teknik University].

Okumuş, S., Çavdar, O., & Doymuş, K. (2015). The understandings of the particulate nature of matter via conductivity of solutions. *Amasya Education Journal*, 4(2), 220-245.

Okumuş, S., Öztürk, B., Doymuş, K., & Alyar, M. (2014). Aiding comprehension of the particulate of matter at the micro and macro levels. *Journal of Educational Sciences Research*, 4(1), 349-368. https://doi.org/10.12973/jesr.2014.41.18

Osborne, J. F., Erduran S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41(10), 994-1020. https://doi.org/10.1002/tea.20035

Öğünç, A. (2012). *Development, application and evaluation of an active learning material based on constructivism related to 'reaction rates and chemical equilibrium' subject in chemistry lesson* [Doctoral thesis, Dokuz Eylül University].

Özcan, R., Aktamış, H., & Hiğde, E. (2018). Computational thinking and integrative education (STEAM) in science education. *Pamukkale University Journal of Education*, (43), 93-106.

Özer, G. (2009). *Investigating the effect of scientific argumentation based instruction approach on students' conceptual change and success concerning the concept of mole* [Master's thesis, Gazi University].

Özkara, D. (2011). *Teaching pressure subject to eighth class students with activities based on scientific argumentation* [Master's thesis, Adıyaman University].

Öztürk, M. (2013). *The impact of argumentation on students' conceptual understanding, argumentativeness, and self-efficacy beliefs* [Master's thesis, Pamukkale University].

Posnanski, T. J. (2002). Professional development programs for elementary science teachers: An analysis of teacher self-efficacy beliefs and a professional development model. *Journal of Science Teacher Education*, 13(2), 189-220.

Raviolo, A. (2001). Assessing students' conceptual understanding of solubility equilibrium. *Journal of Chemical Education*, 78(5), 629-631.

Sepet, A., Yılmaz, A., & Morgil, G. (2004). Lise 2. sınıf öğrencilerinin kimyasal denge konusundaki kavramları anlama seviyeleri ve kavram yanılgıları. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 26, 148-154.

Shen, J., & Hsieh, C. (1999). Improving the professional status of teaching: perspectives of future teachers, currenet teachers and education professors. *Teaching and Teacher Education*, 15, 315-323. https://doi.org/10.1016/S0742-051X(98)00047-X

Stavridou, H., & Solomonidou, C. (1998). Conceptual reorganization and the construction of the chemical reaction concept during secondary education. *International Journal of Science Education*, 20(2), 205-221. https://doi.org/10.1080/0950069980200206

Şahin-Kalyon, D., & Taşar, M. F. (2020). Fourth and fifth grade students' argument structure. *International Journal of Euroasian Researches*, 8(22), 39-71. https://doi.org/10.33692/avrasyad.643598

Şatay, T. (2010). *Determination of the misconceptions of secondary education 11th grade students relating to chemical equilibrium* [Master's thesis, Gazi University].

Şen, Ş., Varoğlu, L., & Yılmaz, A.(2019). Examination of undergraduates' cognitive structures on reaction rates and chemical equilibrium. *Pamukkale University Journal of Education*, 45, 335-352.

Şekerci, A. R. (2013). *The effect of argumentation based instruction on students? argumentation skills and conceptual understanding in Chemistry laboratory* [Doctoral thesis, Atatürk University].

Şimşek, Ü. (2007). *he effects of the Jigsaw and learning together techniques applied in solutions and chemical equilibrium subjects on learning of the particulate nature of matter by the students and their the academic achievements* [Doctoral thesis, Atatürk University].

Tekeli, A. (2009). *The effect of an argumentation-centered class environment on the conceptual change about acid-base and the understanding nature of science* [Master's thesis, Gazi University].

Temel, S. (2021). Le Chatelier's principle: does it provide educational easiness or difficulty?. *Journal of the Turkish Chemical Society Section C: Chemical Education*, 6(1), 1-22. https://doi.org/10.37995/jotcsc.828470

Tola, Z. (2016). *The effect of argumentation instruction on 6th grade students' conceptual knowledge, scientific reasoning and nature of science understanding* [Master's thesis, Kocaeli University].

Tsai, C. C., Ho, H. N. J., Liang, J. C., & Lin, H. M. (2011). Scientific epistemic beliefs, conceptions of learning science and self-efficacy of learning science among high school students. *Learning and Instruction*, 21(6), 757-769. http://doi.org/10.1016/j.learninstruc.2011.05.002

Tümay, H., & Köseoğlu, F. (2011). Kimya öğretmen adaylarının argümantasyon odaklı öğretim konusunda anlayışlarının geliştirilmesi. *Turkish Science Education*, 8(3). 105-119.

Tyson, L., & Treagust, D. F. (1999). The complexity of teaching and learning chemical equilibrium. *Journal of Chemical Education*, 76, 554. http://doi.org/10.1021/ed076p554

Ulaşan, M. (2010). *Chemistry teachers' misconceptions in chemical equilibrium* [Master's thesis, Gazi University].

Uluay, G. (2012). *Investigation of the effect of scientific argumentation based teaching on student's success in teaching Primary School 7th grade Science and Technology course force and motion unit teaching* [Master's thesis, Kastamonu University].

Untereiner, B. (2013). *Teaching and learning the elements of argumentation* [Degree of Master, University of Victoria].

Van Driel, JH., De Jong, O., & Verloop, N. (2002). The development of pre-service chemistry teachers' PCK. *Science Education*, 86(4), 572-590. https://doi.org/10.1002/sce.10010

Walker, J. P. (2011). *Argumentation in undergraduate chemistry laboratories* [Doctor of thesis, University of Florida State].

Walker, J. P., & Sampson, V. (2013). Learning to argue and arguing to learn: Argument-driven inquiry as a way to help undergraduate chemistry students learn how to construct arguments and engage in argumentation during a laboratory course. *Journal of Research in Science Teaching*, 50(5), 561-596. http://doi.org/10.1002/tea.21082

Wheeler, A.E., & Kass, H. (1978). Student misconceptions in chemical equilibrium. *Science Education*, 62, 223–232.

Yalçın Çelik, A. (2010). *An analysis of the influences of the teaching approach based on scientific argumentation on high school students' conceptual understanding, attitudes, and willingness for argumentation and the quality of argumentation* [Doctoral thesis, Gazi University].

Yalçınkaya, I. (2018). *The effect of argumentation based activites in teaching of the circulatory system at the level of 6th grade on students' academic achievement, conceptual understandings and scientific levels of argumentation* [Master's thesis, Pamukkale University].

Yavuz Korkmaz, Ş. (2019). *Investigating preservice chemistry teachers' eye movements while working with macroscopic, symbolic and submicroscopic level of representations for chemical equilibrium* , Boğaziçi University].

Yeşiloğlu, S. N. (2007). *Teaching gases topic to high school students trough argumentation* [Master's thesis, Gazi University].

Yıldırım, A., & Şimşek, H. (2013). Sosyal bilimlerde nitel araştırma yöntemleri (9. baskı). Seçkin Yayıncılık.

Yıldırım, N. (2009). *Developing, implementing and evaluating materials related to "chemical equilibrium topic* [Doctoral thesis, Karadeniz Teknik University].

Zohar, A., & Nemet, F. (2002). Fostering students knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, 39(1), 35-62. https://doi.org/10.1002/tea.10008

Appendices 1

Interview questions
1.When CO_2 gas is added to this system ($2CO_2(g)+786kj \leftrightarrow 2CO(g)+O_2(g)$), which is in equilibrium at a constant temperature and volume in a closed container; a) In which direction does the system shift? Why? b) How do the concentrations of the substances change? Why? c) Is the equilibrium constant affected? Why? Based on these answers you gave, think about this event with the particle size and explain your thoughts about this question by making two separate drawings as the first equilibrium moment and the last equilibrium moment.
2.When the volume of this system, which is in equilibrium at constant temperature in a closed vessel, is increased; a) In which direction does the system shift? Why? b) How do the concentrations of the substances change? Why? c) Is the equilibrium constant affected? Why? Based on these answers you gave, think about this event with the particle size and explain your thoughts about this question by making two separate drawings as the first equilibrium moment and the last equilibrium moment.
3.When the temperature of this system, which is in equilibrium in a closed fixed volume container, is increased; a) In which direction does the system shift? Why? b) How do the concentrations of the substances change? Why? c) Is the equilibrium constant affected? Why? Based on these answers you gave, think about this event with the particle size and explain your thoughts about this question by making two separate drawings as the first equilibrium moment and the last equilibrium moment.
4.When a catalyst is added to this system, which is in equilibrium at a constant temperature and volume in a closed vessel: a) In which direction does the system shift? Why? b) How do the concentrations of the substances change? Why? c) Is the equilibrium constant affected? Why? Based on these answers you gave, think about this event with the particle size and explain your thoughts about this question by making two separate drawings as the first equilibrium moment and the last equilibrium moment.
5.What are your general opinions about the process applied? (the parts you have difficulty with, the ones you like, etc.)