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The Effect of Argumentation-Supported Problem-Based Learning Method in Teaching Chemical Equilibrium and Le-Chatelier's Principle

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Abstract: This study aims to examine the effects of argumentation-supported problem-based learning (AS-PBL) carried out in the Chemistry-II laboratory course on the conceptual understanding of prospective science teachers about "Chemical equilibrium and Le-Chatelier's principle". The prospective teachers' answers were analyzed using content analysis and the existing misconceptions about the relevant chemistry topics were determined and the effectiveness of the relevant method in eliminating the misconceptions was also examined. The prospective science teachers had fewer scientific arguments in writing grounds for their claims before the treatment using AS-PBL. They were able to use their rebuttal skills more in addition to their claims and grounds after the treatment. Suggestions about problem-based learning supported by argumentation in science laboratory environments were presented to prospective teachers, educators and, readers.

Keywords: argumentation-supported learning, chemical equilibrium, chemistry-II laboratory, prospective science teachers, problem-based learning

1. Introduction

In science education, it is very important that students make sense of science concepts such as chemistry concepts, interpret them and associate them with daily life (Fortus, Krajcik, Dershimer, Marx & Mamlok-Naaman, 2005; Osborne, Simon & Collins, 2003). Since chemistry generally includes abstract concepts, most students fail to learn chemistry despite their efforts (Nakhleh, 1992). In concept teaching, first of all, identifying misconceptions in students has an important place in terms of meaningful learning of new concepts (Canpolat, Pınarbaşı, Bayrakçeken & Geban, 2004). Detection of misconceptions in students will be the basis for education programmers and teachers who play a key role in the students' conceptual understanding. Therefore, research on concept teaching was carried out primarily to reveal the existing prior knowledge in students (Canpolat et al., 2004). It is stated in relevant literature that the causes of misunderstandings in students may be due to missing and/or incorrect information, the inability to associate scientific information with daily life, and the lack of motivation (Güneş, 2010). Common misconceptions in science education in recent years are as follows (Güneş, 2010): electrochemistry (Garnett & Treagust, 1992; Yılmaz et al., 2002; Çalık & Ayas, 2005), mass and weight, reaction rate (Garnett & Treagust, 1992; Yılmaz et al., 2002; Çalık & Ayas, 2005), heat and temperature (İşcan & Güngör Seyhan, 2021; Yavuz & Büyükekşi, 2011), colligative properties (Coştu, Ayas, Açıkar ve Çalık, 2007; Çalık & Ayas, 2008; Demircioğlu & Vural, 2014; Eyceyurt Türk & Güngör Seyhan, 2022), acids and bases (Bradley & Mosimege, 1998; Hand & Treagust, 1991; Nakhleh & Krajcik, 1994; Özmen & Demircioğlu, 2003; Sisovic & Bejovic, 2000), particulate nature of matter (Okur & Güngör Seyhan, 2021), lifting force, gases (Eyceyurt Türk & Kılıç, 2020; Yavuz & Çelik, 2013; Şenocak, Taşkesenligil & Sözbilir, 2007), chemical balance (Bilgin, Uzuntiryaki & Geban, 2003), pressure, force and motion, cell and atom.

Research on the students' understanding and interpretation of chemistry found that although the students could solve chemistry problems by memorizing formulas, they could not make meaningful explanations for the solutions, and the association with daily life was not at the desired level (Yıldırım, Ayas,,& Küçük 2013). Meanwhile, the characteristics of an individual who has developed 21st-century skills, which is one of the main objectives of the Science course in the Turkish Education System, are making faster and more adequate/correct decisions against situations that present problems for oneself, developing technology literacy, using research and analysis skills, and questioning and using critical thinking skills more frequently (Tezel, 2018). These expectations have led educators to do more research on improving and enriching both formal and informal learning-teaching environments. In such learning-teaching environments, students are expected to help them deal with cognitive acquisition as a problem associated with events in daily life and to reach a conclusion by using their knowledge in solving related problems, by doing research and discussing the data with their group mates. These learning-teaching environments point us to the "problem-based learning" (PBL) (Torp & Sage, 2002, p.15) method.

The PBL method is student-centered and the student is responsible for their learning. The student's experiences and previous learning are important in solving the problem. In addition, it is more important to learn the solution method rather than the solution to the problem (Peterson & Treagust, 1998). Argumentation-based learning (ABL) is one of the learning-teaching environments that enable students facing problems to deal with the subjects of the lesson as a reflection of real-world problems as in problem-based learning method (Okur & Güngör Seyhan, 2021; Eyceyurt Türk & Güngör Seyhan, 2022). In this learning-teaching environment, students try to reach a conclusion using their knowledge, do research, and discuss the available data with their groupmates during the problem-solving process (Ali, Hukamdad, Akhter & Khan, 2010; Tosun, Tatar, Şenocak & Sözbilir, 2015).

1.1. Problem Statement

Experience and previous learning of an individual who encounters a problem for the first time are important in problem-solving. In addition, it is more important to learn the solution method rather than the solution to the problem (Peterson & Treagust, 1998).

Problem-based learning (PBL) is one of the learning styles that seek solutions to real-life problems, and perhaps the most important one. In this method, lessons are replaced by one-to-one studies and laboratory studies. The basic idea behind problem-based learning is to create a problem and learners' desire to solve it (Kay, Barg, Fekete, Greening, Hollands, Kingston & Crawford, 2000). Studies have shown that PBL method increases cognitive acquisition. On the other hand, there are also studies showing that it does not have a sufficient effect on academic achievement. It is thought that when PBL is applied together with other learning strategies, richer and more effective learning will be achieved (Kılınç, 2007). Some of the criticisms are that students have deficiencies in cognitive acquisition in the process of acquiring high-level thinking skills, which is one of the main features of problem-based learning, and that students cannot reach sufficient cognitive acquisition related to the relevant subjects due to their limited focus on problems (Banta, Black & Kline, 2000). Research on how to overcome the disadvantages and inadequacies of problem-based learning has suggested to integrate argumentation, which supports cognitive gains, into this method (Kılınç, 2017). In argumentation-based learning (scientific discussion), we can often encounter environments where these skills are frequently used. In such environments, students make scientific decisions (Kalemkuş, Bayraktar & Çifçi, 2019).

1.2. Related Research

In a study examining students' misconceptions about the "Particulate, Space, and Motion Nature of Matter", it was observed that students were busy with more unscientific claims before the AS-PBL application and they could not use their supporting and rebuttal skills adequately. As the students repeated and experienced the activities in the practices frequently, it was determined that most of them had targeted arguments and were able to use both their justification and rebuttal skills more frequently (Okur & Güngör Seyhan, 2021). In another study on the use of argumentation-supported problem-based learning (AS-PBL) in pre-service science teachers' learning on the topic of "colligative properties", it was observed that pre-service science teachers had misconceptions about chemistry; They were able to present only one conclusion sentence for the questions asked about the subject before the application. The prospective teachers could present a conclusion sentence and at least one reference point as a result of the repetitive activities with the application (Eyceyurt Türk and Güngör

Seyhan, 2022). In his study, Fettahlıoğlu (2012) examined the effect of using AS and PBL approaches on the development of environmental literacy of prospective science teachers. According to the analysis results of the data obtained in the study, it was found that the students' environmental literacy showed improvement in the dimensions of knowledge, skills, affective tendencies, and behavior.

Eyceyurt (2017) examined the effects of AS-PBL on pre-service science teachers' academic achievement, critical thinking skills, willingness to argue, self-efficacy, and attitudes toward chemistry. it was found that the academic achievement of the students in the experimental group in which AS-PBL was applied was significantly higher than the academic achievement of the students in the other group. When the results were interpreted in terms of critical thinking levels, self-efficacy levels, and willingness to argue, an increase in favor of AS-PBL was observed. In terms of attitude levels, a decrease was observed in the group of students learning with the current program and problem-based learning, while an increase occurred in the group of students learning using AS-PBL. Another study investigated the effect of AS-PBL on seventh-grade students' inquiry learning and problem-solving skills, and conceptual understanding (Yıldırım, 2017). At the end of the research, no significant difference was observed between the inquiry learning and problem-solving skills perceptions of the experimental and control group students. A significant difference was found in students' levels of conceptual understanding in favor of the experimental group. In addition, after semi-structured interviews with the experimental group students, it was discovered that the students had positive opinions about AS-PBL.

1.3. Research Objectives

This study investigated the contribution of the AS-PBL method to the conceptual understanding of pre-service science teachers about the relevant chemistry subject. In addition, the current misconceptions of prospective teachers about the subject were determined and the effectiveness of AS-PBL in eliminating these misconceptions was also examined.

2. Theoretical Framework

Although many studies examining the applicability of strategies, methods, and techniques in teaching concepts, facts, and events alone and their effects on many related variables, the number of studies on hybrid learning-teaching environments is quite low. For learning-teaching environments where the problem-based learning were used together with many different methods and/or techniques, research supported by argumentation (Mcghee, 2015; Eyceyurt Türk & Kılıç, 2020), by computer-assisted teaching (Belland, Glazewski & Richardson, 2011), by concept cartoons (Balım, Inel-Ekici & Özcan, 2016; Inel & Balım, 2013), and by concept maps (Hsu, 2004; Johnstone & Otis, 2006) can be given as examples. However, Research on argumentation-supported and problem-based learning have investigated the extent to which both methods affect each other rather than the effectiveness of learning-teaching environments where these two learning methods are used together (Belland, Glazewski & Richardson, 2011; Mcghee, 2015). It is emphasized that in problem-based learning, it may be advantageous to integrate argumentation-supported applications, especially in the discussion stage, to compensate for the lack of knowledge acquisition in students (Kelly & Finlayson, 2009; Nussbaum & Edwards, 2011). As a result, argumentation-supported PBL has an important role in science teacher education and research revealed that these applications will increase students' science academic achievements and in eliminating misconceptions about chemistry in students (Okur & Güngör Seyhan 2021).

2.1. Misconceptions in Chemistry Education

The fact that the way many chemical events occur is very unusual, especially for students, and the difficult scientific language used by chemistry in expressing these events may cause some students to have misconceptions about chemical concepts (Ayas & Demirbaş, 1997; Nakhleh, 1992; Zoller, 1990; Hewson & Hewson, 1983). The results of the research to determine the prior knowledge and misconceptions in students stated that many related misconceptions are not specific to a certain age group and may be present in students of all levels. Moreover, it is emphasized that existing misconceptions can be encountered even in people who have worked with the science of chemistry for a long time (Gonzalez, 1997; Bar & Travis, 1991).

Existing misconceptions in students prevent not only the interpretation of new information, but also the meaningful learning of new information, and may also lead to new misconceptions. This may increase the formation of unwanted learning products (Andersson, 1986; Griffiths & Preston, 1992). Identifying and then changing this pre-knowledge and misconceptions about concepts in students is effective in increasing the quality of teaching and contributing to the development of science education such as chemistry (Hackling & Garnett, 1985; Taber, 1999). Therefore, research on basic concepts in science education aimed at determining students' understanding levels have become widespread in recent years. For this purpose, methods such as concept maps, interviews, drawings, and multi-stage tests have been used (White & Gunstone, 1992). The different strategies, methods and techniques, and/or their different combinations most commonly used to reveal this unwanted prior knowledge and detect misconceptions in students are: Concept map (Hazel & Prosser, 1994), predict-observe-explain (POE) (Liew & Treagust, 1994), interviews (Abdullah & Scaife, 1997; Osborne & Gilbert, 1980; Osborne & Cosgrove, 1983), student drawings (Smith & Metz, 1996), word association (Maskill & Cachapuz, 1989), two/three/four-stage diagnostic tests (White & Gustone, 1992; Karslı & Çalık, 2012; Şahin & Çepni, 2011; Tüysüz, 2009; Treagust & Chandrasegaran, 2007).

2.2. Argumentation-Based Learning

Argumentation-based learning is one of the educational environments where students often find the opportunity to use their 21st-century skills, such as the ability to use various strategies in the process of solving problem situations that reflect real-world problems, to enter the scientific discussion process by evaluating the claims with data and grounds, to think critically, to make judgments, to use scientific thinking skills, and to make scientific decisions (Eyceyurt Türk & Kılıç, 2020). In relevant literature, argumentation-based learning have shown to provide positive changes in many cognitive and affective variables in students: increase in students' social understanding and environmental awareness (Fettahoğlu, 2016), development of argument skills (Topçu & Atabey, 2017) and higher-order thinking skills (Yıldırır & Nakiboğlu, 2014), increase in science achievement (Öğreten & Uluçınar, 2014) and conceptual understanding (Acar, Tola, Karaçam & Bilgin, 2016; Eyceyurt Türk & Güngör Seyhan, 2022; Okur & Güngör Seyhan, 2021; Tezel & Yaman, 2017), positive change in metacognitive strategies (Aydın & Kaptan, 2014; Ulu & Bayram, 2014), the establishment of science culture in students, activating scientific reasoning and logic skills, and gaining scientific literacy (Jiménez-Aleixandre & Erduran, 2008).

2.3. Problem-based learning (PBL)

PBL is one of the other learning-teaching environments that enable students facing problems to deal with the subjects of the lesson as a reflect real-world problems as in the argument-supported learning method. In this learning-teaching environment, students try to reach a conclusion using their knowledge, do research, and discuss the available data with their groupmates during the problem-solving process (Ali, Hukamdad, Akhter & Khan, 2010; Tosun, Tatar, Şenocak & Sözbilir, 2015). Literature showed that positive results are obtained for many cognitive and affective variables such as academic success, critical thinking skills, self-efficacy, and attitude in science classes where science teaching is carried out with PBL (Özeken & Yıldırım, 2011). In addition to studies emphasizing that PBL has a positive development on students' academic achievement and many cognitive and affective variables, it is also stated that this learning method can be more effective and sufficient on related variables when used together with other learning methods (Kılınç, 2007). In problem-based learning, while trying to gain high-level thinking skills, the lack of knowledge acquisition in students and sometimes focusing on problems that cause them to think only about a limited subject content are some of the criticisms made for this learning method (Banta, Black & Kline, 2000). Several studies stated that the lack of knowledge acquisition in problem-based learning is a disadvantage of this method (Tatar, Oktay & Tüysüz, 2009; Tosun et al., 2015).

3. Method

3.1. Research Design

This research was designed as action research, one of the qualitative research methods. Action research involves the researchers' handling of the implementation process to understand and solve the problems that arise in practice (Yıldırım & Şimşek, 2016, p.74).

3.2. Study Group

24 students/prospective science teachers who studied in the 2018-2019 academic year and took the Chemistry-II laboratory course participated in the study. Each group composed of 3 people. This groups were determined according to purposeful sampling, which is one of the non-random sampling techniques (Creswell, 2012). It was ensured that the study group could best represent the investigated situation.

3.3. Data Collection Tools

The worksheets filled by the prospective teachers during all the applications were the data collection tools of this research. These worksheets consisted of activity papers with a problem situation arranged for each topic and instructions for monitoring the argumentation process. The content validity of the worksheets prepared by the researchers who conducted the study was ensured by the latest revision of four science and chemistry educators working in teacher training faculties. Reliability was achieved by 95% agreement between the same researchers encoding the data and placing them in categories.

3.4. Data Analysis

Content analysis was used to analyze the data obtained. Before analyzing the worksheets, research on students' understanding of many basic science concepts and identifying misconceptions were examined (Abraham, Grzybowski, Renner, & Marek, 1992; Balaydın & Altınok, 2018; Meşeci, Tekin & Karamustafoğlu, 2013). Toulmin's argument model was used in the coding and category structuring of the data. In this analysis, the students were asked to justify their arguments, and the percentage calculations were made assuming that the misconceptions of the students, whose grounds were correct, were eliminated (Okur & Güngör Seyhan, 2021). Toulmin's argumentation model has simple argument, claim, and rationale (evidence, data, and fact) components. In addition to these components, high-level arguments also include grounds, support, qualifying, and rebuttal (Erduran, Simon, & Osborne, 2004). While determining the categories, the students' written answers were analyzed whether they were suitable for the categories of "making claims/writing grounds (fact, evidence)/collecting data/making scientific explanations (warrant, backing, qualifier)/using rebuttal" (Okur & Güngör Seyhan 2021).

3.5. Application Process

The research was a comprehensive university scientific research project, and the effectiveness of the applications carried out according to the AS-PBL method in the teaching of various chemistry topics was examined within the scope of the project; colligative properties in solutions: boiling point elevation and freezing point depression; electrical conductivity; chemical equilibrium and Le-Chatelier's principle and chemical kinetics. All applications carried out within the scope of the project were carried out in Chemistry-II laboratory course and lasted for a total of 8 weeks. In this study, the results of the effect of the argumentation-supported PBL method on the conceptual understanding of prospective science teachers about "Chemical equilibrium and Le-Chatelier's principle" are presented.

The pilot applications of the research were carried out with prospective science teachers studying in the fall semester of the 2018-2019 academic year. The pilot applications were carried out to detect negative situations and take precautions before the main applications. During the pilot applications, it was observed that prospective science teachers had difficulties in forming arguments (especially justifying and creating support) and in intergroup discussions (rebuttal skills). This situation decreased with an increasing number of activities. As a result of the consultations between science and chemistry educators and the researchers who carried out the applications, the worksheets filled by the prospective science teachers during the applications and the contents of the activities were arranged and given their final shape.

Before the applications were carried out within the scope of the AS-PBL method, preliminary research was also conducted with the study group to reveal their argumentation skills. The preliminary research with the study group consisted of "The Life of Pi" implication involving the activities of "writing claim, justifying and designing an experiment afterward" and the implication of "Putting the egg in the glass bottle" with the "Predict-Observe-Explain" activity. During these applications, the skills of recording their observations and establishing the relationship between claim-observation were tried to be activated. After the preparatory work was completed, the teaching of the chemistry topics targeted within the scope of the study with the prospective science teachers started. The AS-PBL applications were carried out for 2 weeks.

The applications started with a problem situation reflecting a real-world problem. In this situation, it mentioned how the relevant chemistry topic was realized in carbonated drinks and inside our bodies:

> *When the mouth of the bottle filled with carbonated beverage is opened and the pressure inside is released, it is informed that the balance will shift to the left according to the equation below and carbonic acid turns into water and carbon dioxide gas again:* $CO_2 + H_2O \Leftrightarrow H_2CO_3$. *We also see the equilibrium phenomenon in this chemical reaction between carbon dioxide and carbonic acid in the plasma of our blood. As the* CO_2 *concentration in the blood rises, this equilibrium reaction shifts to the right and the* H_2CO_3 *carried in the body by the blood circulation increases. When our blood reaches the lungs,* CO_2 *is exhaled. In this case, since the* CO_2 *concentration in the blood decreases, this equilibrium reaction shifts to the left and the* H_2CO_3 *concentration in the blood circulation decreases.*

After the problem situation reflecting the place and importance of the relevant chemistry topic in the real world was given, the prospective science teachers were exposed to experimental applications in which they observed the existence of chemical equilibrium and Le-Chatelier's principle in a laboratory environment. This experimental process consisted of applications in which prospective science teachers know how the common ion effect would occur in four test tubes containing saturated NaCl solutions and how the reaction equilibrium would change. In the second week, they had the opportunity to test the arguments they created in the previous lesson by carrying out the experiments/comparing and explaining them after the experiments. The reason for this was the detection of existing misconceptions and the search for the answer to the question of whether they had been eliminated after the applications.

In the first part of the worksheet, the prospective science teachers were asked to state their claims and grounds about how the chemical equilibrium would change when different solutions that could create a common ion effect were added to a saturated solution at the same temperature. In the second part of the worksheet (Figure 1), claims and grounds on how the temperature change would change the chemical equilibrium in exothermic and endothermic reactions were requested.

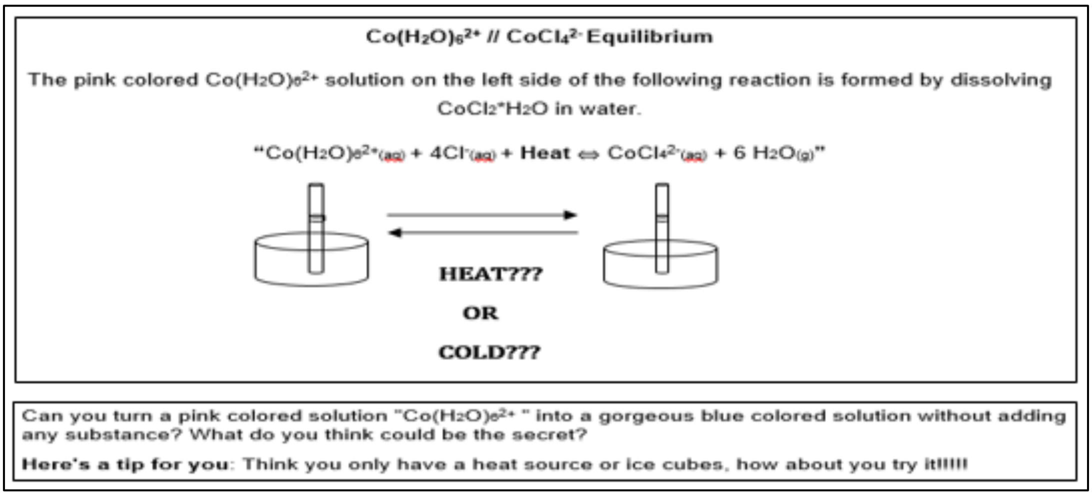

Figure 1. The Worksheet on the Effect of Temperature Given to Prospective Science Teachers

The last stage of the worksheets was aimed to observe the ability of prospective science teachers to transfer the scientific knowledge they learned to new situations (Figure 2). For this, the prospective science teachers were given $Mg(OH)_2$ solution, which was prepared with distilled water and was in equilibrium with its solid. The prospective science teachers were asked what processes should be applied to make the image of the solution given in the first image the same as in the second image. Afterward, the prospective science teachers were expected to put their claims into practice.

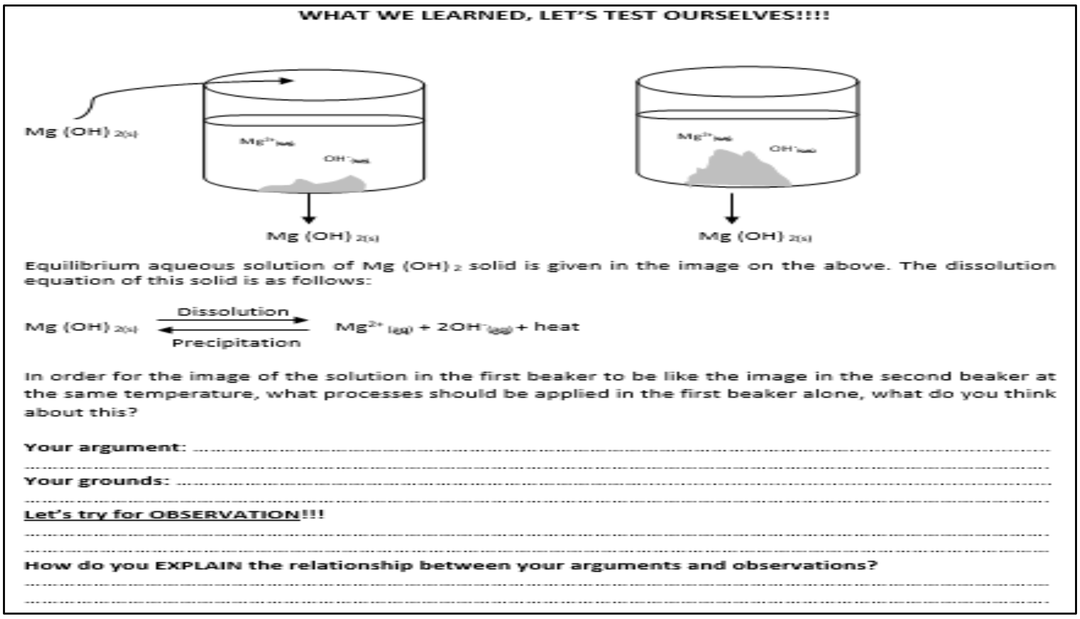

Figure 2. The Worksheets on the Ability to Change the Direction of Chemical Equilibrium Given to Prospective Science Teachers

4. Results

The arguments of the prospective science teachers were criticized based on the scientific arguments determined by the researchers on the topic of "Chemical Equilibrium and Le-Chatelier's Principle". According to the analysis of the answers within the scope of the study, the prospective teachers gave answers in the category of "claim + grounds" before the applications. Before the first experimental applications, the prospective science teachers were asked for their claims and grounds on the effect of the solutions ($HCl/Na_2CO_3/MgSO_4$) and distilled water added to the NaCl solutions on the equilibrium.

12.5 % of the prospective science teachers gave answers both in the "**Completely Correct Claim/Partially Correct Grounds**" category and in the "**Wrong Claim/Wrong Grounds**" category;

> *"In the first and second tubes, the equilibrium shifts to the left. Because NaCl(s) will precipitate. In the third tube, the equilibrium will shift to the left again. Because what precipitates is $MgSO_4$. In the fourth tube, the added distilled water will move the equilibrium towards dissolution".*

37.5 % of the prospective science teachers gave answers in the **"Wrong Claim/Wrong Grounds"** category;

> *"The molecular weights of the solutions we add to the NaCl solutions in the tubes affect the equilibrium and therefore cause the equilibrium to shift to the products side",*

> *"In the first tube: NaCl is the base, and when an acid such as HCl is added to the medium, salt will form and the salt formed will precipitate NaCl",*

> *"In the first part, the saturated NaCl solution in the first tube is the base and when combined with the acid (HCl solution) the medium reaches equilibrium. For the second and third tubes, we think there will be no change in balance. Water added to the NaCl solution will have no effect".*

25 % of the prospective science teachers gave answers in both the "**Wrong Claim/Wrong Grounds**" and "**No Claim/No Grounds**" categories;

> *"In the first tube, NaCl is the base and when an acid such as HCl is added to the medium, salt will form and the salt formed will precipitate NaCl. We did not provide arguments and grounds for the second and third tube or fourth tube",*

> *"When the added acid combines with the metal in the first tube, salt is formed, and as a result, it becomes a supersaturated solution".*

25 % of the prospective teachers submitted their answers in the "**No Claim/No Grounds**" category;

> *"We could not come to a common decision about what kind of reaction would occur with other solutions added to the solutions in the tubes",*

> *"We could not reach consensus for the reactions to take place between NaCl solutions in the tubes and other solutions added. Each of our group friends wrote a different reaction".*

The prospective science teachers' observations during the experimental activities, especially in the first stage of their applications, are important because the prospective science teachers had the opportunity to test the accuracy of the claims and grounds they put forward before the applications with experimental activities;

> *"When we started dropping HCl solution into NaCl solution after a while white precipitation was observed at the bottom of the beaker. When we added Na_2CO_3 solution to NaCl solution, a color change such as in precipitation occurred. No precipitation was observed when we added $MgSO_4$ solution and pure water to the NaCl solution",*

> *"When we added HCl solution to the solution we got, there was a significant color change. When we added the third solution ($MgSO_4$) given to the NaCl solution, we did not observe any change. We added Na_2CO_3 solution to NaCl solution and observed precipitation formation at the bottom of the solution. We added pure water to the NaCl solution, we did not observe any change",*

> *"Observed in the first tube: Turbidity, bottom precipitations were observed; observed in the second tube: Turbidity, bottom precipitations were observed again and observed in the third and fourth tubes: No turbidity, no change was observed".*

After their first experimental applications, 37.5 % of the prospective science teachers could provide answers in the category of "**Being able to give rebuttal**" according to the Toulmin argument model, while 62.5% could **not provide rebuttals** for opposing claims and grounds;

> *"In the first tube, the Cl^- ion is common and the reaction wants to return to equilibrium and the balance shifts to the left, that is, to the side of the reactants. Na^+ ion is common in the second tube; the balance will shift to the left again. Since there is no additive in the third tube that will affect the increase in ions in the balance reaction, it does not affect the balance. In the fourth tube, we add more solvent to the NaCl solution whose solvent is water, so this will increase the solubility of NaCl",*

> *"When we add HCl and Na_2CO_3 solutions to the first and second tubes, our precipitate-like turbidity observation shows that the salt solid increases in the environment, according to the equilibrium reaction, $NaCl_{(S)}$ is located in the reactant part of the reaction. Therefore, the balance will shift towards the reactants. Because, according to Le-Chatelier's principle, the system reacts to the balance reaction in a way that reduces external intervention. In HCl addition, there is an effect due to Cl^- ions and in Na_2CO_3 solution due to Na^+ ions. The direction of the equilibrium reaction in the third tube will not change. Because the added solution has no effect that will make a difference for balance".*

After all the applications, the list of most important findings observed by prospective science teachers are as follows:

- *NaCl in the tubes is a metal;*
- *Since the saturated NaCl solution in the tubes reacts with the new substances added to the tubes, forming a brand-new substance, it will not have any effect on the equilibrium;*
- *We can classify the substances added and/or in the tube as acid/base, and as a result of the reaction between the two substances, precipitation will occur as salt will be formed.*

The second stage of the applications carried out within the scope of the study consisted of guidelines on the effect of temperature on the direction of chemical equilibrium. At this stage, the prospective science teachers were expected to answer questions about which direction the equilibrium would change if the ambient temperature increased or decreased, depending on whether the reaction was exothermic or endothermic. $Co(H_2O)_6^{2+}$ complex compound, which is formed by dissolving $CoCl_2$ x H_2O compound in water and which is found in the reactants part of the below reaction equation, is a pink-colored solution. This solution turns into a blue-colored solution, $CoCl_4^{2-}$, by increasing temperature.

$$Co(H_2O)_6^{2+}{}_{(aq)\ (pink\ colored)} + 4Cl^-_{(aq)} + Heat \Leftrightarrow CoCl_4^{2-}{}_{(aq)\ (blue\ colored)} + 6H_2O_{(g)}$$

With this experimental application, the prospective science teachers were allowed to observe the effect of temperature on the equilibrium depending on the color change in the solutions in the reactants/products. During the experimental application, the prospective science teachers observed that when they put the test tubes containing a pink solution in a beaker filled with water at boiling temperature and waited for a while, the solution turned into a blue-colored solution. In the same way, the prospective science teachers saw the pink color again when they cooled the environment (beaker filled with ice). At the end of these applications regarding temperature change, 62.5 % of the prospective science teachers emphasized that they "pay attention to where the (heat) variable takes place in the reaction equation". They also stated that they did not have any difficulty in answering the questions posed because it was already given that "the solution in the reaction equation written in the worksheet given to them is pink in color and the solution in the product's part is blue". Another group of prospective science teachers wrote that when "they increase the temperature, the solution turns blue and when they pay attention to the reaction equation, this blue color is on the right side of the reaction". As a justification, they stated that the "heat" variable on the left of the reaction creates an imbalance in the reactants when they increased the temperature, and therefore the reaction proceeded from left to right". They also stated that "if the result were not what they said, they would not be able to observe the color blue".

During the applications in the study, the prospective science teachers were able to explain the effect of common ions and temperature on the equilibrium with Le-Chatelier's principle. At this final stage of the study, the researchers wanted to see how the prospective science teachers could apply all they knew to the new situation given to them.

50 % of the prospective science teachers gave answers in the "**Completely Correct Claim-Completely Correct Grounds**" category before proceeding with their experimental applications;

> "In the reaction given to us in the worksheet, the "heat" variable is on the right side of the reaction. This indicates that the reaction is exothermic. In exothermic reactions, if the temperature is increased, the reaction will shift to the left. According to the reaction equation, it will increase because there is a solid $Mg(OH)_{2(s)}$ on the left side",

> "We have seen before that the equilibrium shifts to the right or to the left according to the common ion effect on the equilibrium. Here, too, the equilibrium must shift to the left so that the solid to increase in solution. For this, if we add a solution containing one of the ions on the right side of the reaction, the equilibrium will shift to the left".

All of the prospective science teachers who gave these answers used rebuttals in the category of "**Partially Correct Rebuttal**";

> *"We can try reducing the water of the solution or adding more solids to the solution. Because according to the reaction equation, the reaction must be shifted to the left in order to have more solids in the environment, so we can try to increase or decrease the temperature)".*

75 % of them presented their explanations in the category of "**Completely Correct Explanation**";

> *"At this stage, our teachers asks what we should do to make the first image look like the second image. In the beaker in the second image, the solid at the bottom of the solution is more in quantity, and for this to happen, the solid in equilibrium with the solution should precipitate more",*

> *"According to Le-Chatelier's principle, when a reaction in equilibrium is interfered with, the equilibrium will shift in the direction that will reduce that interference. Therefore, for the solid in the second image to be more in quantity, the reaction should shift to the left".*

n37.5 % of the prospective science teachers gave answers in the "**Partially Correct Claim-No Grounds**" category;

> *"According to this reaction, water addition/evaporation processes at the same temperature will not change the solubility and hence precipitation".*

66.6 % of these prospective science teachers provided explanations in the "**Partially Correct Explanation**" category;

> *"If we add water to the solution without interfering with the temperature, the solution will become sparse. The decrease in water in the solution means that it is a concentrated solution. The more water we can evaporate; the more salt will remain at the bottom".*

12.5 % of the prospective science teachers gave answers in the "**Partially Correct Claim-Wrong Grounds**" category and none of these prospective science teachers used rebuttal;

> "*To increase the solid at the bottom of the solution, the water in the environment must be reduced. For this, some water can be poured from the aqueous part of the solution*".

5. Discussion

It was observed that the misconceptions determined were different for the eight group students participating in the applications. Examples of wrong concepts identified were the following misconceptions:

> *"Acid and base are formed from the reaction of salt and water", "acid is formed by the combination of salt and acid", "when water is added to a saturated salt solution in the tube, it does not affect the balance", "according to Le-Chatelier's principle, even if an external reaction is made to an equilibrated reaction, it will not have any effect", "the saturated solution in the first tube is the base and when combined with the acid, the medium reaches equilibrium", "when acid and metal (NaCl) combine, salt forms and as a result, the supersaturated solution is formed", "in the first and second tube equilibrium shifts to the left. Because NaCl will decompose. In the third tube, the equilibrium will shift to the left again. Because what decomposes is Na_2SO_4. When water is added to a saturated salt solution in the fourth tube, it will not affect equilibrium", "if water is added to a saturated salt solution, it will be over saturated".*

In relevant literature, similar misconceptions about chemical equilibrium and reaction speed were found in the research Piquette and Heikkinen (2005), Azizoğlu, Alkan, and Geban (2006), and Yeo and Zadnik (2001). Based on analysis, it was thought that the misconceptions in students about the topic of "Reaction Speeds and Chemical Equilibrium", which is an important topic in the chemistry curriculum, were due to the misconceptions and lack of basic knowledge about abstract concepts such as the particulate structure of the matter, heat, energy, temperature, bond energy, thermochemistry (Öğünç, 2012). At the same time, misconceptions determined in prospective teachers were thought to be caused by misunderstanding and interpreting Le-Chatelier's principle, and research results in line with this result (Piquette & Heikkinen, 2005) were found. It was concluded that the prospective teachers did not have misconceptions before and after the applications on the topic of "The effect of temperature change on equilibrium in endothermic and exothermic reactions". It was observed that after the AS-PBL applications were applied on "Chemical equilibrium and Le-Chatelier's principle", the prospective teachers solved the problem situation given by the researchers with the experimental activity they carried out with instructions, and then gave the expected arguments and made explanations with the reasons.

In the related literature, the number of research carried out to eliminate students' existing misconceptions with AS-PBL is increasing. Okur & Güngör Seyhan (2021) used the AS-PBL method for teaching the subject of particulate, porous, and mobile structures of matter in their studies. It was observed that all misconceptions of the students were determined at the argument level of "Writing a justification". At the end of their research, there were suggestions that the AS-PBL method could be effective in eliminating the prospective teachers' misconceptions. Eyceyurt Türk & Güngör Seyhan (2022), after their applications with AS-PBL, observed that most of the prospective science teachers showed the ability to present "a conclusion sentence and at least one premise". It is the result of another research (Eyceyurt Türk & Kılıç, 2020), which determined that the increase in the academic achievement of the students who performed their applications with AS-PBL in the teaching of acids/bases and gases was more significant. In the study of Sağlam (2022), academic success and whether they had existing misconceptions of 8^{th}-grade students on "simple machines" were determined by the following teaching methods: the teaching method envisaged in the curriculum, the problem-based learning, and the AS-PBL. The research concluded that that the academic success of the students who carried out their applications with AS-PBL, before and after the applications, showed a more significant increase than the academic success of the other group of students.

6. Conclusion

Concept teaching has an important role in revealing students' misconceptions in learning-teaching environments. The misconceptions identified in students negatively affected the learning of other subjects. For this reason, it is important to detect false pre-knowledge in students and to eliminate misconceptions. Therefore, educators need to plan their learning and teaching environments in a way that takes into account the false pre-knowledge of students and organize them in a way to eliminate existing misconceptions. From this point of view, one of the learning methods that can be used in science education to detect and eliminate misconceptions is the AS-PBL method, which is discussed within the scope of the research. It can be said that AS-PBL applications are learning and teaching environments that reveal the misconceptions of prospective science teachers, make meaningful learning by enabling them to structure various chemistry concepts in their own minds, lead to the development of more positive attitudes towards chemistry, increase motivation, and are easy to apply and effective. According to the results obtained from the scientific research project, within the scope of this research, the scientific information given to the students in line with the instructions in the cookbook format was not effective in revealing the students' prior knowledge and existing misconceptions about the subject. Meanwhile, it was clearly observed that more permanent and meaningful learning in learners such as prospective teachers cannot be possible in such learning and teaching environments.

6.1. Limitation

One of the limitations of this research is the use of the argumentation-supported problem-based learning method, which is the teaching method used in the study. Another limitation of the study is that the students took the General Chemistry-II laboratory course and the teaching method was aimed at Chemistry subjects in the relevant laboratory course.

6.2. Recommendation

Based on the results obtained from this study and various studies, it is thought that giving many cognitive, affective, and/or psychomotor achievements with richer learning-teaching environments rather than giving instructions in a cookbook format will provide more permanent experiences for students.

Students' answers to the questions about chemistry before the applications in the study showed that the prospective teachers almost never used their "rebuttal" skills. Especially in the development of scientific literacy and speaking and writing skills in scientific languages, students should be more engaged in scientific discussion environments. To support students' development of reasoning skills, they should be confronted with well-structured real-world problems more and they should be provided with environments that will engage them more with the scientific research process. Perhaps most importantly, practical course contents such as laboratories at the university level and/or lower grade levels should be freed from cookbook format applications, and students should be provided with more responsibility for their own learning.

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Conflict of Interest

In conducting the research and publishing this article, the authors state that there are no elements that indicate a conflict of interest.

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