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EVALUATION OF PRE-SERVICE SCIENCE TEACHERS' CONCEPTUAL UNDERSTANDINGS ON THE TOPIC OF "COLLIGATIVE PROPERTIES" ACCORDING TO WALTON ARGUMENT MODEL COMPONENTS

(Research article)

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Abstract

The purpose of this research is to determine the conceptual understanding of pre-service science teachers about "Colligative properties", which are aimed to be taught within the scope of Chemistry-II course, within the framework of the argumentation-supported problem based learning (AS-PBL) method. The study, in which 24 pre-service science teachers participated, was conducted as practice-based action research, which is one of the qualitative research methods. The arguments of pre-service science teachers about the related chemistry topic were analysed according to the Walton Argumentation Model (Conclusion-Premise) and were described through content analysis. At the end of the research, it was observed that pre-service science teachers had misconceptions of arguments, which they mostly structured as a "conclusion sentence", about the related chemistry topic before the implications. After the implications, it was observed that the majority of pre-service science teachers showed the ability to present "a conclusion and at least one premise", but the conceptual understanding of all participants did not reach the expected level.

Keywords: Argumentation-supported teaching, pre-service science teacher, colligative properties, problem based learning

1. Introduction

It is a fact that students in science courses need learning-teaching environments that provide opportunities for them to take the necessary decisions accurately and quickly, to do more research and questioning, and to think more critically in the face of the negativities they define as a problem for themselves (Tezel, 2018). In recent years, we frequently encounter studies on science education that include findings on the effectiveness of such learning-teaching environments in helping students' gain 21st century skills. In such learning-teaching environments, students can make claims against problems that reflect real-world problems well, and they can engage in more scientific discussion by supporting these claims with data and grounds. The number of studies examining these alternative approaches that encourage critical thinking, reasoning and scientific decision making skills in the scientific discussion process has increased in recent years (Cook, 2008; Erduran & Msimanga, 2014; Eyceyurt Türk & Tüzün, 2018; Maloney & Simon, 2006; Okur & Güngör Seyhan 2021a; Okur & Güngör Seyhan 2021b; Osborne, Erduran & Simon, 2004; Rieke & Sillars, 2001; Vieira, Tenreiro-Vieira & Martins, 2011).

In the Turkish education system, the science curriculum aims to provide learning-teaching environments where students can present claims about a related problem situation, support these claims with grounds, refute the claims of other friends and develop opposing arguments (MoNE, 2018). When we examine the science textbooks with the renewed program, it is seen that the 3rd, 4th, 5th and 6th grade textbooks include activities to improve argumentation skills (Çapkınoğlu, Metin, Çetin & Leblebicioğlu, 2014).

1.1. Argument and Argumentation

When the relevant literature is examined, it is seen that the concept of "Argument" was first defined by Toulmin in 1958. Toulmin defined the concept of "argument" as "a claim and its justification". For the concept of "argument", many different definitions have been made by many researchers; a concept integrated with a valid claim, reason or evidence (Habermas, 1984), a scientific discussion used in teaching (Chinn & Anderson, 1998); a "sentence" in which individuals express their support and/or justification in support of a claim (O'Keefe, 1977). In summary, definitions can be made for the concept of "argument" as "the statement put forward by an individual", and for the concept of "argumentation", "the discussion process in which two or more individuals interact, enabling the ideas to be put forward to be tested" (Nussbaum, 2008). Argumentation, which has an important place in science education, includes the process of supporting with experimental or theoretical evidence (Erduran & Jimenez-Aleixandre, 2008). While creating their arguments, individuals are involved in thinking, discussing and writing activities as a group or individually (Driver, Newton, & Osborne, 2000; Osborne, Erduran & Simon, 2004). Toulmin Argumentation Model is generally used in science education (Driver et al., 2000; Erduran & Jimenez-Aleixandre, 2008; Erduran et al., 2004; Karışan, 2011; Kutluca, 2012; Özkara, 2011; Simon, Erduran & Osborne 2006). According to the Toulmin Argumentation Model, at a simple argument model level, there are argument, data, and rationale components. In more complex and high-level arguments, in addition to these components, there are supporting, limiting and rebuttals (Erduran, Simon & Osborne, 2004, p.918). It is observed that the Toulmin Model is generally used in argumentation studies conducted in our country (Aldağ, 2005; Altun, 2010; Karışan, 2011; Kutluca, 2012; Özkara, 2011; Simon et al., 2006). However, in these studies, deficiencies and difficulties were encountered due to the implications of argumentation models used between teachers, pre-service science teachers and students. It is stated that the main problem is the inability to clarify what is claim, what data, what grounds and/or support (Erduran et al., 2004, p. 919). Another criticism of Toulmin's Model is that it is suitable for the analysis of one-person discussions and therefore Walton's Model should be used instead of Toulmin's in class discussions, which is more suitable for dialog discussions (Erduran & Jimenez-Aleixandre 2008). The important differences between the Toulmin and Walton Models are that Walton's Model emphasizes the content of the discussion, while Toulmin's Model emphasizes the elements of the discussion.

According to the Walton Argumentation Model, the concept of "Argumentation" refers to the dynamic process of bringing together related arguments for some purpose in a dialogue. The concept of "argument" is to give reasons to either support or criticize a questionable or dubious claim. "Critical argumentation" consists of the objectives of defining, analyzing and evaluating an argument (Walton, 2006). To say that an argument is successful means that the argument provides good reason(s) to support or criticize the claim (Walton, 2006). While the situations that offer reasons are the premises defending an outcome, the outcome is a situation that explains the claim made by a person in response to the doubt about another person's claim (Walton, 2006, p.6). The ability to define an argument by identifying the argument's premises and conclusion is a crucial skill in argumentation. An argument can only be criticized clearly and objectively when it is defined in this way (Walton, 2006, p.7). The argument model expressed by Walton in the form of a set of bases and conclusions is shown in Figure 1.

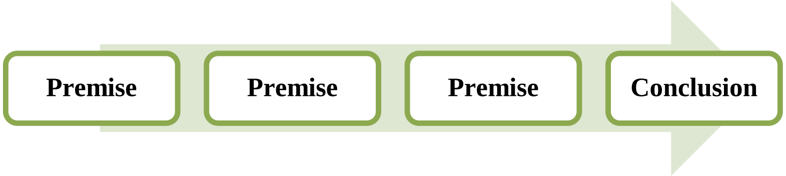

Figure 1. Walton argument model components (Walton, 2006, p.6)

1.2. Argumentation in Science Education

After the regulations made for the science curriculum in the Turkish Education system in 2013, the concept of "argumentation" took its place in the curriculum for the first time and was expressed as "a method" in the curriculum. Tezel (2018) emphasizes that the regulations in the science curriculum are made by defining research and inquiry-based learning as "explanation and argument creation" (MoNE, 2013) rather than just "exploration and experimental". Along with the regulations made, one of the most important reasons for using more argumentation based learning methods in science lessons is that the individual is more active in the teaching process (Aldağ, 2006). In this method, students put forward their possible solution proposals in the form of a "claim" in order to offer a solution to an existing problem situation. They also consider alternative possible solutions in the decision-making process. Students' interest in alternative solutions, apart from possible solution suggestions, will trigger cognitive imbalance and disharmony in the student. As a result, it is expected that the necessary impetus required for the decision-making and thinking process to begin will emerge (Okur & Güngör Seyhan, 2021a). When the national literature on argumentation-based learning is examined, it is stated that the implications carried out with this learning method contribute to the development of students' social understanding and environmental awareness (Kırbağ-Zengin, Keçeci, Kırılmazkaya & Şener, 2011). In addition, it is emphasized that with this method, students' argument skills (Topçu & Atabey, 2017) and higher-order thinking skills (Yıldırır & Nakiboğlu, 2014) develop more and have a positive effect on their academic achievement (Öğreten & Uluçınar Sağır, 2014) and conceptual understanding (Acar, Tola, Karaçam & Bilgin, 2016; Tezel & Yaman, 2017). In addition, it is stated that it is effective in the development of metacognitive strategies in students (Aydın & Kaptan, 2014; Ulu & Bayram, 2014), in gaining a science culture, in the development of scientific reasoning skills and scientific literacy (Erduran & Jimenez-Aleixandre, 2008). In the researches carried out for the argumentation-based learning method, it is seen that there are studies that reveal the existence of negative effects as well as the positive effects of learning-teaching environments in which the method is used on the development of some cognitive and affective variables in students. In some studies, it is stated that the learning method does not provide an expected level of development of argument skills in students and/or students do not actively participate in the implications during the learning method (Demirel, 2015; Namdar & Demir, 2016; Özdemir, 2015). It is stated that one of the reasons why students do not show behavior and/or skills at the expected level in implications where argumentation-based learning is used is that students with low education levels have difficulties in structuring and managing the relationship between argument elements such as claim-data (Kuhn, 2010). In order for students to overcome these difficulties more easily, appropriate teaching strategies, methods and techniques should be used for the development of these skills in science learning-teaching environments. As suggested strategies, methods and/or techniques for the argumentation-based learning to be carried out in science classrooms; table of statements, concept maps, writing an experiment report, competing theories, argument construction, predict-observe-explain, or experimental designs can be said (Osborne, Erduran & Simon, 2004).

1.3. Argumentation and Problem Based Learning

As in the argumentation-based learning method, in problem-based learning (PBL), students can pose a problem situation by associating the concepts, facts and/or events that they learned in science classes with the events in daily life. Or, they can offer possible solutions based on the problem situations given to them, and in this process, it is aimed to develop skills such as using the learned information, doing research, and reaching the result by discussing the existing data with group mates. As a result of the researches carried out to use the problem-based learning method in science education, it has been concluded that it is an appropriate approach for student-centered learning-teaching environments and has a positive effect on many cognitive and affective variables aimed at improving students (Ali, Hukamdad, Akhter & Khan, 2010; Birgegard & Lindquist 1998; Cerezo 2004; Chin & Chia, 2004; Dahlgren, Castensson & Dahlgren, 1998; Donnel, Connor & Seery, 2007; Kelly & Finlayson, 2009; Larive, 2004; Marklin Reynolds & Hancock, 2010; Pepper, 2010; Peterson & Treagust, 1998; Ramstedt et al., 2016; Schwartz, Webb & Mennin, 2001; Yuzhi, 2003). It was mentioned above that there are studies that resulted in negative feedback as well as studies that resulted in the effectiveness of the argumentation-based learning method in science classes. When the literature on PBL is examined, attention is drawn to the existence of some disadvantages in the use of the problem-based learning method. In these studies, it is stated that the PBL process is not always effective in increasing the academic success of students. In order to prevent these negativities, Kılınç (2007) emphasizes that more adequate and richer learning will be realized by applying this method together with many other learning strategies (hybrid model). In problem-based learning method, as in argumentation-based learning, it is aimed to develop higher-order thinking skills. While trying to develop these skills, students' interest in concepts, phenomena and/or events related to only a limited topic during the implications and as a result, the emergence of deficiencies in students' knowledge acquisition are some of the disadvantages put forward for PBL (Banta, Black & Kline, 2000). In many studies, it is emphasized that incomplete knowledge acquisition is a disadvantage for problem-based learning (Dochy, Segers, Bossche & Gijbels, 2003; Tatar, Oktay & Tüysüz, 2009; Tosun et al., 2015). In order for the student to construct all the concepts of the subject, the PBL process should be organized very accurately and the student should be made to feel this deficiency. However, in this case, the learner can expand his research by realizing that he has deficiencies in solving the problem and can learn by structuring the whole subject in his mind correctly. However, even if it is not successful in increasing knowledge, PBL is thought to be very important for people to experience teaching environments (Albanese, 2000). While emphasizing the support of hybrid models in which problem-based learning is used together with different teaching strategies, methods or techniques, it has been observed that studies on these implications are limited: PBL with argumentation (Mcghee, 2015; Eyceyurt Türk, 2017; Okur & Güngör Seyhan, 2021a), PBL with computer-assisted teaching (Belland, Glazewski & Richardson, 2011) and PBL with concept maps (Hsu, 2004; Johnstone & Otis, 2006).When the related studies are examined, it was observed that by using argumentation and problem-based learning together, they focused on the extent to which one method affects the other method rather than the effectiveness of learning-teaching environments (Belland, Glazewski & Richardson, 2011; Cassel, 2002; Mcghee, 2015). Many researchers emphasize that implications for argumentation-supported learning should be added to the "discussion" stage in this learning method process in order to prevent the incomplete knowledge acquisition, which is one of the disadvantages in problem-based learning (Kelly & Finlayson, 2009; Nussbaum & Edwards, 2011).

It is a generally accepted fact that chemistry is a difficult-to-learn science because it usually contains abstract concepts and students cannot visualize them. Although most of the students make an effort, they fail to learn chemistry (Nakhleh, 1992). In the meaningful teaching and learning of concepts including chemistry topics, identifying the misconceptions in the students about the relevant chemistry topics has an important place in science education (Canpolat et al., 2004). In addition, identifying existing misconceptions in students will guide program developers and teachers, who provide a basis for conceptual understandings in related students. The starting point of research on concept teaching is to reveal the current knowledge of students (Canpolat et al., 2004). In a study emphasizing that the misconceptions frequently encountered in science education in recent years are the concepts of mass, weight, speed, heat, and temperature, it was stated that the most difficult subjects to be taught were buoyancy, pressure, force and motion, heat-temperature, cell and atom (Güneş et al., 2010). It has been stated in the relevant literature that the misconceptions encountered by students especially in chemistry topics are electrochemistry, acid-base and the particulate nature of matter (Canpolat et al., 2004), gases (Şenocak, Taşkesenligil & Sözbilir, 2007), heat-temperature, chemical balance (Bilgin, Uzuntiryaki & Geban, 2003).

1.4. Purpose and Importance of the Research

In this study, activities that will activate argumentation skills, especially at the "discussion" stage, were included in the problem-based learning process, and argumentation was used to close the "missing information learning" gap of the problem-based learning method. With the updates in teacher training curriculum in 2018, laboratory practices in science courses have been integrated into the course process, where the teaching of concepts, facts and/or events of relevant topic is aimed (CoHE, 2018). It is very important for science education to create an effective university chemistry curriculum and course content, to increase the academic success of pre-service science teachers, to interpret chemistry concepts by making them meaningful and to associate them with daily life (Okur & Güngör Seyhan, 2021a). Based on this main purpose, the effects of argumentation-supported PBL practices in determining the conceptual understanding of pre-service science teachers about "colligative properties" were examined within the scope of present study.

2. Method

In this study, practice-based action research, which is one of the qualitative research methods, was used. In this research method, possible problems that may arise during the implementation, possible factors causing these problems and possible ways of intervention are tried to be determined (Sagor, 2000).

2.1. Study Group

24 pre-service science teachers who took Chemistry II course at the Faculty of Education participated in the research. All implications for the study were carried out in the spring semester of the 2018-2019 academic year. These 24 students are between the ages of 19-20. The implication groups were created from 3 people each. The sample of the study was determined according to the purposive sampling type (Creswell, 2012).

2.2. Data Collection Tools

The data collection tools of the research are the worksheets used by the pre-service science teachers during the implications. These worksheets include the problem situation and the processing steps of the argumentation activities for related chemistry topics. The content validity of the worksheets was ensured by the control of three science educators and two chemistry educators working in teacher training faculties. After receiving expert opinions on the adequacy of the instructions aimed at teaching the concepts, facts or events given in the contents of the worksheets and how effective they would be in teaching, the worksheets were finalized. The reliability of the working papers was ensured by the 95% agreement between the coding and categorization of the data by the same researchers.

2.3. Analysis of Data

Content analysis was used in the analysis of the data. Before the implication, the codes were determined to determine the existing misconceptions of the pre-service science teachers and the results were given as a percentage (frequency). After the implication, argument analyzes were carried out to determine whether the misconceptions of the pre-service science teachers were eliminated. Walton argument model components (conclusion, premise, premise, premise) (Walton, 2006) were used as codes for the arguments constructed by the students. Categories are structured with combinations of these codes. For example, student arguments containing result and premise codes are in the CP category; student arguments including result, premise, and premise codes in CPP category; Student arguments containing three baseline codes next to the result code are shown in the CPPP category. As the reference point codes next to the conclusion sentence in the student answers increased, the category was added to, and then frequency and percentage calculations were given. The arguments expected in the analysis of the answers given by the pre-service science teachers to all the questions in the worksheets on the relevant chemistry topic and the categories to which the arguments belong are given in Table 1.

Table 1. *Colligative properties expected conclusion and premises*

Expected Arguments	**Category which the Argument Belongs to**
In daily life, the freezing point lowering feature that one of the colligative properties, is used to prevent icing.	CONCLUSION (C)
In this problem case, the type of samples given for icing prevention is actually unimportant. What important is the number of particles (van't Hoff factor) that the aqueous solution of the given sample contains by ionic and/or molecular dissolution. For example, a sodium chloride molecule in aqueous solution completely dissociates into two particles, a Na+ ion and a Cl- ion, thus the “van't Hoff factor” of sodium chloride is “2” (Ionic dissolution). Some solutes, such as sucrose (sucrose) in water, do not dissociate and therefore have a van't Hoff factor of exactly “1” (Molecular dissolution).	PREMISE-1 (P_1)
This actually shows the type of dissolution: Molecular and ionic dissolution and being aware that these dissolutions are different from each other.	PREMISE-2 (P_2)
Accurate determination of van't Hoff factors for solutions that are thought to make a difference in the calculations to be used for freezing point depression	PREMISE-3 (P_3)
To be able to write and interpret scientifically exactly and accurately how much the freezing point can be reduced in case of this problem, according to the following formula: $\Delta T = -(iK_fm)$ The corresponding symbols in this formula are ΔT: temperature difference, i: van't Hoff factor, Kf: freezing point depression constant and m: molality of the solution.	PREMISE-4 (P_4)
Giving the effects of the solutions that are thought to make a difference in the given problem situation on the prevention of icing, in the correct order: $CaCl_2 > KNO_3 \sim NaCl > C_6H_{12}O_6$	PREMISE-5 (P_5)

2.4. Implementation Process

Before the implications, previous studies on the topic of "colligative properties", which are aimed to be taught, were examined by the researchers. In the studies examined by the researchers, the implications carried out for the development of students' conceptual understanding of the relevant chemistry topic were examined. In teaching the topic of "colligative properties" according to the argumentation-supported PBL learning, questions to be directed to the pre-service science teachers were determined, related experiments were designed, and the process steps of the 2-week process were determined and the main implications were concluded.

Before the main implications within the scope of the study, in order to detect and prevent negative situations that may arise during the implications, pilot implications were carried out with 46 sophomore pre-service science teachers who had taken the Chemistry-II course before. In the pilot implications, it was observed that the pre-service science teachers had difficulties in understanding the argument components (claim, data, grounds, support, limiting and rebuttal) and establishing relationships between the elements, and had difficulties in group discussions. These negatives decreased with increasing number of activities. As a result of the pilot implications, expert opinions was used in the arrangement of the contents of the worksheets and the activities.

As an example of the activities of the argumentation-supported learning used in science classes, a POE activity was carried out with pre-service science teachers. Within the scope of these preliminary activities, the "Egg into a glass bottle activity" was designed in order to activate the argument skills of the pre-service science teachers. These preliminary implications started in a way that enables pre-service science teachers to easily express their predictions about a problem situation directed to them. In the "predict" phase, the pre-service science teachers' ability to make a claim about a given problem situation regarding a related chemistry topic was observed. At this stage, pre-service science teachers' ability to justify their claims and to use scientific knowledge about a problem situation they may encounter in daily life was observed. After the predict phase, pre-service science teachers were asked to perform an experimental activity in order to support their claims and grounds with data. During the observation phase, pre-service science teachers were expected to collect sufficient and correct data by making targeted observations and to interpret the results they reached. The pre-service teachers acted as group during the preparatory implications. The pre-service science teachers, who had knowledge about argument construction and its stages during the preparatory studies, were then directed to the main implications for the teaching of the targeted chemistry topics.

In the first week of the argumentation-supported PBL method, which lasted for 2 weeks in total, pre-service teachers wrote their claims and grounds for the problem situation given to them. In this process, examples and questions from daily life about the problem situation were asked to the pre-service science teachers by the researchers. At the end of the first week, a target problem statement was addressed within the framework of all questions. In order to support the claims and grounds created for this target problem statement, it was requested to collect the necessary data within the experimental process. At this stage, the pre-service science teachers created their experimental designs, which were planned to be carried out in the second week, for the solution of the problem statement. In the second week, the designed experiments were carried out in the laboratory, and the relationship of the claims and grounds made in the previous week with the data obtained during the experimental procedures was examined. After performing the experiments, they designed, the pre-service science teachers were asked to interpret the data they obtained and explain them with scientific expressions. The course flow chart (2 weeks) related to this whole process is given in the Figure 2.

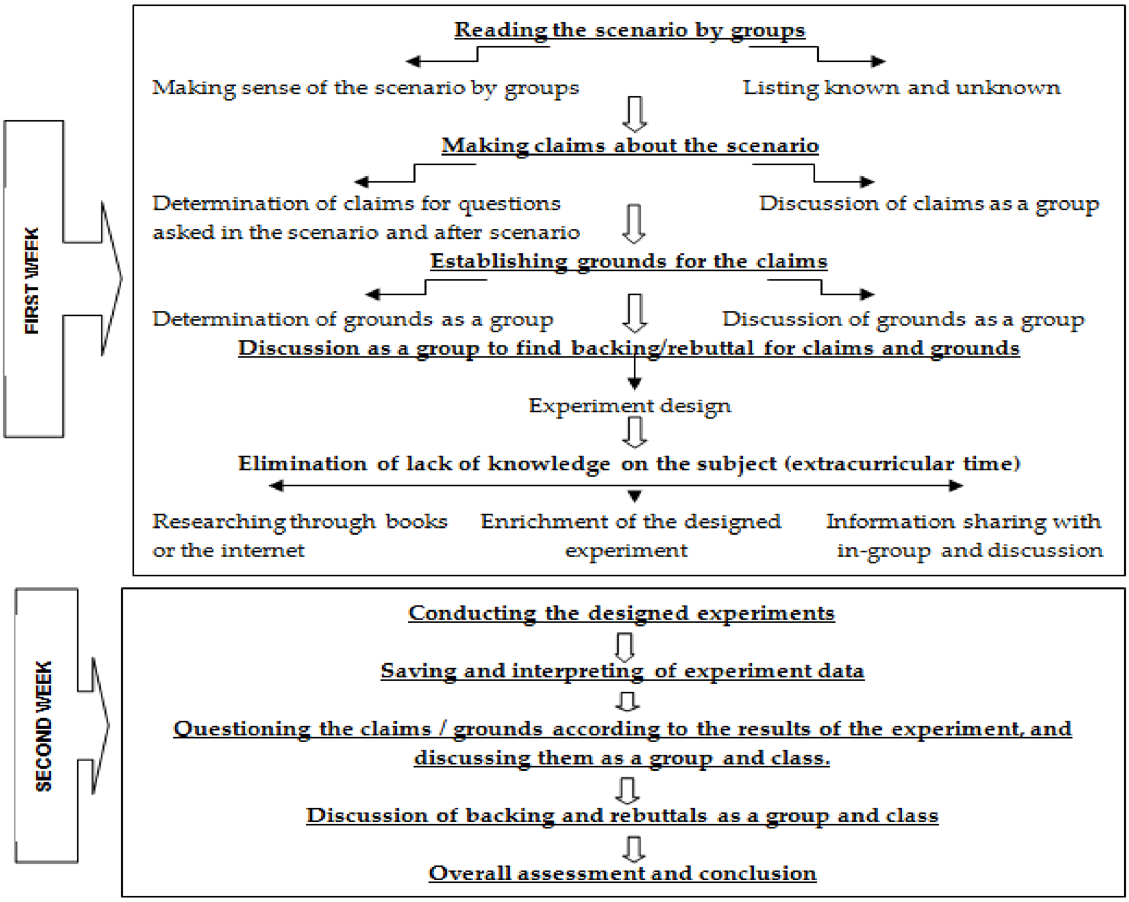

Figure 2. Argumentation-supported problem based learning lesson flow chart

3. Findings

In order to determine the conceptual understanding of pre-service science teachers on "colligative properties", the worksheets given within the scope of argumentation-supported PBL implications first started with a problem situation that aims to reveal the place and importance of colligative properties in solutions in daily life and reflects a real-world problem:

LET'S FIND AN ANSWER!!!

If you add 39 g of salt to 100 milliliters of water, at what temperature will the water freeze?

When the weather gets cold, if your car's wiper fluid is filled with normal water, the grind begins, because that water is frozen and you cannot spray it on the windows. You go to the nearest gas station to get screen wash water. Some are very cheap, some are expensive. There are lots of varieties. Is there a difference between buying the cheapest and getting the expensive one? What is this screen wash water? What is inside?

If you are in a city such as Ankara, Sivas and Erzurum that experience the winter months when the temperature drops below zero, it is recommended to buy the best "concentrated screen wash water" in terms of lowering the freezing point. Because if you are in these cities, it will not be a surprise to wake up to a very cold weather with ice and snow when you wake up one morning during the winter months and look out the window.

In the first stage of the worksheets, pre-service science teachers are told about the feature known as "colligative properties" in chemistry, how these properties are related to solutions, and how the properties of a pure solvent change with the solute. The place of colligative properties in daily life has been emphasized by giving reasons of the municipalities pouring salt on icy roads in cold and snowy weather, from the structure and properties of screen wash water produced for winter. At this stage, the following target problem statement, which will be important in determining the effect of the activities carried out during the implications on their conceptual understanding of the relevant chemistry, was directed to the pre-service science teachers:

LET'S FIND AN ANSWER!!!

Does the type of substance used for cleaning icy roads ($C_6H_{12}O_6$, NaCl, KNO_3, $CaCl_2$, etc.) make a difference in preventing icing? If you were to rank for freezing point depression, what would you conclude?

At this stage, according to the analysis of the answers given by the pre-service science teachers to the target problem statement above, it was observed that the pre-service science teachers had some misconceptions about the relevant chemistry topic. Misconceptions observed in pre-service science teachers are summarized in Table 2.

Table 2. *Misconceptions on "colligative properties" in pre-service science teachers*

Identified Misconceptions	**Percentage (frequency)**
Among the substances given to pre-service science teachers and thought to create impurities, salt classification was made only for NaCl, and it was given the first place in freezing point depression.	58.3% (f:14)
In the determination of the van't Hoff factor, the number of atoms in the molecule was calculated as the number of particles.	33.3% (f:8)
It has been stated that sugar is molecularly dissolved, so the van't Hoff factor is zero and has no effect on freezing point depression.	12,5% (f:3)
It has been stated that sugar dissolves molecularly, so it does not cause the freezing point to decrease, on the contrary, it increases it.	20.8% (f:5)
The KNO_3 molecule is a base and the $CaCl_2$ molecule is an acid. And acids/bases do not show colligative properties.	20.8% (f:5)

In the next step, the following problem statement was directed to the pre-service science teachers:

Do you expect the boiling or freezing point change values of water to be the same or different by adding "Salt and Sugar" to pure water?

After taking the claims and grounds of the pre-service science teachers for the above problem sentence, it was expected that the pre-service science teachers would reach the answers to the following questions related to this problem sentence with observations:

If you add 39 g of NaCl to 100 mL of distilled water, at what temperature does it freeze? / at what degree does it boil?

If you add 39 g of glucose to 100 mL of pure water, at what temperature does it freeze? / at what degree does it boil?

If you add 1 mole of sugar and salt to 100 mL of pure water, at what temperature does it freeze? / at what degree does it boil?

With these questions directed to the pre-service science teachers, it was possible to observe how the characteristics such as boiling point and freezing point, which are distinctive features for pure substances, change with the presence of impurities in pure substances, and it was tried to comprehend where this information is used in daily life. 75% of the pre-service science teachers stated that only NaCl would create impurity among these substances and that "*they put salt at the end so that the water does not boil later when cooking pasta in their daily life*". 58.3% of the students who gave this answer stated that "*the high amount of salt added to the water causes the saturation to be low and the water is diluted*" and "*they do not think that these additions can change neither the freezing nor the boiling point of pure water*". 25% of the pre-service science teachers stated that "*sugar creates impurities, but it will not make a significant change in neither the boiling point nor the freezing point*". 66.6% of the students who gave this answer stated that "*the sugar is not added afterwards, as in salty water, when boiling sherbet in sherbet desserts, they mix it at the beginning and then let it boil*", "*the molecular dissolution of sugar cannot be the reason for increasing the boiling point*".

Pre-service science teachers were also asked to design an experiment on the topic and to make experiments in such a way as to show the situations in which they would prove and/or refute their claims in the experiment they designed. 83.3% of the pre-service science teachers compared the boiling points of pure water, salt water and sugared water samples by boiling them. It was observed that the students who did this experimental procedure did not pay attention to the sugar and salt ratio they added to the pure water and made this comparison by eyeball estimate. Similarly, 16.7% of the pre-service science teachers determined the boiling point of pure water under laboratory conditions, added sugar and salt, and then determined the boiling points of these solutions. The pre-service science teachers then weighed certain amounts of salt and sugar solids and added them to pure water and determined the boiling points of these solutions. None of the pre-service science teachers used corrosive. In the experiments they designed, the pre-service science teachers did not want any other salt compound other than NaCl, which they know as "table salt", to prepare a salty solution.

After the completion of the operational processes for the experiments they designed, the pre-service science teachers were asked to repeat the experiments under the control of the researchers. At this stage, pre-service science teachers carried out their experiments by weighing the sugar and salt ratios they added to pure water in certain masses and continued to record the temperature measurement processes, respectively, by increasing the masses of the substances they added in certain amounts in this process. Afterwards, they were asked to perform the experimental operations for the target problem statement addressed in the second stage of the implications, respectively.

LET'S FIND ANSWER!!!

Does the type of substance used for cleaning icy roads ($C_6H_{12}O_6$, NaCl, KNO_3, $CaCl_2$, etc.) make a difference in preventing icing? If you were to rank for freezing point depression, what would you conclude?

The pre-service science teachers who completed their implications were asked to present a conclusion sentence for the above experimental implications and the premises for these results. The Walton Argumentation Model was based on the analysis of the pre-service science teachers' answers. In order to carry out the analysis according to the Walton model, the expected result and all the reference points that can be presented were determined by the researchers. According to the criteria determined by the researchers in order to investigate whether the misconceptions were eliminated in the arguments that the pre-service science teachers formed after the implication, the misunderstanding of the pre-service science teacher who was able to present "a correct conclusion and at least one premise" was defined as corrected. The answers that the pre-service science teachers could give in the category of "presenting a conclusion and a premise" were placed in the relevant categories (CP, CPP, CPPP, CPPPP and CPPPPP) according to the number of premises besides the conclusion sentence, and the results are summarized in Table 3.

Table 3. *Content analysis of pre-service science teachers' answers according to Walton argumentation model*

Categories/Premises	**CP**	**CPP**	**CPPP**	**CPPP**	**CPPPPP**
P1	S14, S18, S13, S16, S15, S4	S7, S8	S3, S2	S12, S5, S9	S17
P2	S24, S23, S22, S21, S20	S7, S10, S6, S1	S3, S2	S12, S5, S9	S17
P3		S8, S10	S3	S12, S5, S9	S17
P4	S11, S19	S6	S2	S12, S5, S9	S17
P5		S1			S17
Total	**13**	**5**	**2**	**3**	**1**

According to Table 3, it was determined that the misconceptions observed in all pre-service science teachers were eliminated after the argumentation-supported PBL implications on "colligative properties". While 54% of the pre-service science teachers gave feedback in the CP category, it was seen that 20% were in the CPP category, 8% were in the CPPP, 12.5%, CPPPP category, and only 4% were in the CPPPPP category. Examples of answers belonging to the relevant categories are as follows;

CP1; "The type that dissolves in the substances used on icy roads is very effective. The freezing point reduction is inversely proportional to the particle number. The type of solvent and the number of particles of the solute are effective in colligative properties".

CP2; "The substance used for cleaning icy roads is important. Ionization or molecular dissolution of the solute affects freezing. Ionic solutes lower the freezing point even more".

CP4; "According to the ΔT=–(iKfm) formula, it will make a difference. Freezing point depression differs according to the variables in this formula. The freezing point will vary according to the molality, van't Hoff factor values".

CP2P3; "The freezing point of a non-volatile substance decreases as the concentration increases. The ionic dissolution and molecular dissolution of the substance are effective. The van't Hoff factor of the substance affects the lowering of the freezing point. The larger this factor, the lower the freezing point will be. While the van't Hoff factor is the highest in $CaCl_2$ (3), it is the lowest in sugar (1)"

CP1P2P3; "Freezing point depression is a colligative property. Colligative properties depend on the concentration of solute particles. When a non-volatile substance is thrown into a solution, it changes the freezing point of the solution. Since the van't Hoff factor depends on the number of dissolved ions, it is the least influencing factor when taking the dissolved sugar as a molecule. $CaCl_2$ is the most influencing. Other salts are equally effective".

CP1P2P3P4; "It is effective in changing the freezing point. The number of particles of the substance is important in colligative properties. The type of substance does not matter. As seen in the freezing point depression formula, the van't Hoff factor is effective. This indicates the number of solute particles. The number of particles is highest in $CaCl_2$. It creates 3 ions. This allows it to lower the freezing point the most. Sugar, on the other hand, will decrease the least because it dissolves molecularly".

CP1P2P3P4P5; "Of course it makes a difference. The number of particles, not the type of substance, is effective in colligative properties. Because a molecular solute lowers the freezing pointless. Other substances are ionic soluble salts. It is the calcium chloride salt that gives the most ions to the environment. The order will be as $CaCl_2>NaCl=KNO_3>C_6H_{12}O_6$. Because the van't Hoff factor is 3, 2, 2 and 1, respectively. Considering the formula $\Delta T=-(iKfm)$, the ranking will be like this".

4. Discussion

It is stated that the reasons why chemistry is seen as a difficult discipline for students are that students see the way many chemical events in chemistry occur as unusual and the scientific language used to explain these events is difficult and difficult for students to understand. As a result of these difficulties, it is emphasized that students may have misconceptions in some chemistry concepts (Ayas & Demirbaş, 1997; Hewson & Hewson, 1983; Nakhleh, 1992; Pardo & Partoles, 1995; Zoller, 1990). In the studies carried out to identify such misconceptions, it is stated that misconceptions do not belong to a certain age group, but exist at all age levels. It is also emphasized in the relevant literature that these misconceptions can be encountered even in people who have worked in the field of chemistry (Fensham, Gunstone & White, 1995; Gonzalez, 1997; Bar & Travis, 1991; Özmen, 2005). Misconceptions that exist in people are effective in interpreting new information, but they can also prevent the comprehension of new information and lead to the formation of unwanted learning products, that is, new misconceptions (Andersson, 1986; Griffiths & Preston, 1992).

In order to contribute to the development of educational environments of all disciplines such as chemistry education, and therefore to increase the quality of teaching, it is necessary to reveal and eliminate the prior knowledge and existing misunderstandings in students (Hackling & Garnett, 1985; Taber, 1999). In the determination of these existing misconceptions observed in students, tools such as concept map (Hazel & Prosser, 1994), predict-observe-explain (POE) (Liew & Treagust, 1994), interviews (Abdullah & Scaife, 1997; Osborne & Gilbert, 1980; Osborne & Cosgrove, 1983), full/semi-structured student's views, student's drawings (Smith & Metz, 1996), word association (Maskill & Cachapuz, 1989) and three/four-stage diagnostic tests (Karslı & Çalık, 2012; Şahin & Çepni, 2011; Tüysüz, 2009; Treagust & Chandrasegaran, 2007; White & Gustone, 1992) are among the most commonly used strategies, methods and techniques.

When the relevant literature is examined for some misconceptions found in pre-service science teachers about colligative characteristics (Coştu, Ayas, Açıkkar & Çalık, 2007; Çalık & Ayas, 2008; Demircioğlu & Vural, 2014), it has been observed that similar misconceptions are also encountered. When impurities are added to pure solvents, it lowers the boiling point of some impurities (Pınarbaşı & Canpolat, 2003) and raises the freezing point (Coştu et al., 2007; Demircioğlu & Vural, 2014). Colligative properties depend on the type of particles and the total atomic number/particle number of molecules (Eroğlu, 2016). Coştu et al., (2007) emphasized that these misconceptions among pre-service science teachers may be due to their difficulties in understanding that the reason for the increase in the boiling point of some solutions containing impurities is due to the ion concentration. Again, it is stated that students have difficulty in understanding the topic since they see intermolecular interactions as the main reason instead of the number of particles in understanding colligative properties (Azizoğlu & Alkan, 2002; Pınarbaşı et al., 2009). In present study, a limited number of literatures were found in which the relevant literature on colligative properties, which is one of the chemistry topics examined for the detection of misconceptions in pre-service science teachers, was examined. When the aforementioned literature is examined, it is concluded that apart from the findings in the studies, the following misconceptions exist in this study: "*Only NaCl is salt among the substances given for experimental implications and it takes the first place in causing freezing point lowering*"; "*In the determination of the van't Hoff factor, the number of atoms in the molecule is calculated instead of the number of particles*"; "*Sugar is molecularly soluble, so the sugar molecule has a van't Hoff factor of zero and has no effect on freezing point depression*"; "*Sugar is molecularly soluble, so it does not cause the freezing point to decrease, but rather raises it*". As stated in the relevant literature, it is thought that students ignore the concept of "Dissolution" by causing them to think that "an impurity does not affect the properties such as boiling point and freezing point in solutions" (Coştu et al., 2007; Hwang & Hwang, 1990; Paik et al., 2004; Pınarbaşı & Canpolat, 2003; Uzuntiryaki & Geban, 2005; Varelas et al., 2006). Again, the inability to understand the effect of concentration on boiling point elevation and freezing point depression shows that the boiling point elevation and freezing point depression events are not fully understood. The failure to understand the importance of the van't Hoff factor while determining the boiling point elevation and freezing point depression of different types of solutions shows that the effect of the number of particles contained in molecular and ionic solutions on the boiling and freezing points is not understood. This may be due to a lack of understanding of molecular and ionic dissolution. Similarly, the misconception that the magnitudes of boiling point elevation and freezing point depression cannot be compared accurately in ionic and molecular solutions may be due to the inability to fully understand the effect of the number of particles contained in sugar and salts on boiling and freezing points. The use of many strategies, methods and techniques such as argumentation-supported PBL learning implications to increase the conceptual understanding of chemistry topics such as colligative properties in pre-service science teachers has also been observed in the literature as effective in revealing the misconceptions of pre-service science teachers, providing meaningful learning by structuring various chemistry concepts in their own minds, developing more positive attitudes towards chemistry, and increasing motivation (Belland, Glazewski & Richardson 2011; Cassel 2002; Eyceyurt Türk, 2017; Güngör & Özkan, 2017; Ju & Choi, 2018; Köseoğlu et al., 2002; McGhee, 2015; Okur & Güngör Seyhan, 2021a).

5. Conclusions and Recommendations

In the Turkish education system, considering the social needs and demands, restructuring of education faculties in terms of departments and branches and updating teacher training undergraduate programs have emerged as a necessity. Regarding the teacher training undergraduate programs, it was tried to be revised in 2006 by addressing the failing aspects of the 1997 structuring, and accordingly, some arrangements were made in the professional knowledge courses in both primary and secondary education programs. With regard to teacher training undergraduate programs, the field education courses in the Science Teaching Undergraduate Program are also included in these updates, with the CoHE updating it again in 2018. In this context, General Chemistry Laboratory I and II courses given in both fall and spring semesters were removed from the program, and it was decided to conduct Chemistry I and II course as an implication step in addition to the theoretical part. However, it is important to organize educational environments in order to develop the critical thinking skills of pre-service science teachers in the implication step of the relevant course. In this context, it is one of the suggestions of the study that education-teaching environments should be environments where the concepts, facts or events given under the related topics as in this study should be questioned and learners can design their own experiments, instead of traditional laboratory practices during the implications week. In this context, in present study, activities for the use of constructivist approach-based learning methods were designed to represent an example for laboratory implications added to the Chemistry-II course, and in the light of all the results obtained, the applicability of this education-teaching environment was tried to be demonstrated.

After the argumentation-supported PBL implications applied within the scope of the study, the feedbacks from the pre-service science teachers were analyzed according to Walton's argumentation steps after the problem situation about colligative properties was re-directed to the pre-service science teachers. According to the findings, the fact that the pre-service science teachers presented a correct result and at least one premise indicates that their misconceptions were eliminated. However, when the results obtained are examined, it can be said that the conceptual understanding of pre-service science teachers on colligative properties did not increase at the desired level. The short course period allocated for argumentation-supported PBL implications in the study may be effective in the emergence of this situation. In this respect, it can be said that there is a need for longer-term studies to eliminate the existing misconceptions about colligative properties and to develop conceptual understandings. Due to the nature of the “solutions” topic, which is the basis of the topic of colligative properties, it is thought that the inability to fully understand the concept of the particulate nature of matter will lead to misconceptions in other chemistry topics. In this respect, it is thought that the misconceptions about colligative properties identified in this study stem from the previous experiences of the pre-service science teachers. It has been clearly stated by the results obtained from this research and the results obtained in various studies that learning-teaching environments where more permanent experiences will be realized in students will not be possible in a learning-teaching environment that requires implication, such as a laboratory course, that it will not be possible to provide ready-made information in the form of a cookbook before the implications. Instead of using experiment and narrative methods (traditional teaching method) alone, it is recommended to avoid traditionalism by using different learning-teaching environments together in addition to experiment, to enrich teaching and to use them together in a way to support each other and eliminate deficiencies.

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