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Pre-Service Science Teachers' Images and Misconceptions About Chemical Equilibrium*

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Abstract

Determining pre-service teachers' images and removing their misconceptions with scientifically true ones are very important so that these teachers could bring up students without misconceptions. In the current study, it was aimed to highlight pre-service science teachers' images and misconceptions about chemical equilibrium together and in detail. For this purpose, qualitative research was employed. The research was conducted on 20 pre-service science teachers educating at a university in middle Anatolia region. Worksheets were utilized as data collecting tools. In worksheets there was a question about making pre-service teachers draw four different scenarios for a given chemical equilibrium reaction at different times; at the beginning of the reaction, before the chemical equilibrium, at the chemical equilibrium, after the chemical equilibrium, but at a common temperature and then making them explain their drawings. Data was analysed through content analysis. The results lightened that pre-service science teachers' chemical equilibrium concept images were inadequate since their mental images about the concept were scientifically wrong. On the other hand, the pre-service science teachers had different misconceptions. The most common misconceptions of pre-service science teachers were as "Diatomic molecules form atoms and then these atoms form new chemicals (f:10).", "There are only products or activated complexes in the tank during and/or afterwards of the chemical equilibrium (f:15).", "Atoms could disappear and/or reappear (f:14).", and "Products are formed at the chemical equilibrium (f:17)."

Keywords: Chemical Equilibrium, Image, Misconception, Qualitative Research, Pre-Service Science Teachers

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Introduction

Why some students are not able to learn chemistry. Some students try hard to learn chemistry but they are unsuccessful because of the difficulty of understanding the chemistry's submicroscopic nature (Nakhleh, 1992). The students have serious difficulties of understanding the submicroscopic nature of chemistry since the submicroscopic nature of chemistry could not be seen. Nevertheless, sometimes they could a bit understand the submicroscopic nature of chemistry, this would not mean they could construct the chemistry concepts properly in their mental schemes, in other words they could not imagine the concepts properly, because they could have misconceptions about the chemistry concepts due to the chemistry concepts' invisibility, due to the chemistry concepts' submicroscopic nature (Nakhleh, 1992). Today we as scientists still explain the submicroscopic nature of chemistry on the basis of matter's beam-particle interactions outcomes or chemical separation pics' retention times or current caused pics' interpretations. So how the educators must teach these chemistry concepts for making students understand the chemistry concepts properly so to help them to construct proper mental images and schemes without misconceptions. One of the basic ways is to teach to the students by keeping the concepts definitions simple (Taber, 2002, p. 22). Another way for constructing proper teaching environments which would not only make students understand and imagine the chemistry concepts properly but also would prevent their misconceptions, first the educators have some ideas about the students' previous concept images and misconceptions they came with to the teaching domains. For preventing the students' misconceptions, it is needed to bring up candidate teachers without misconceptions. Because for planning their future teaching domains they needed to know the concepts properly (Babacan & Şaşmaz-Ören, 2015). So, it is very important to lighten the pre-service science teachers' current understandings and misconceptions about chemistry concepts too, then academicians could construct proper teaching environments to change their misconceptions with scientifically true imagined chemistry concepts in their mental schemes. Then these candidate teachers without misconceptions would be ready to construct proper teaching environments for their students. In other words, their experiences about chancing the misconceptions with the scientifically proper ones would be base to their teaching experiences. So, in the current study, it was aimed to lighten pre-service science teachers' images and misconceptions on the topic of chemical equilibrium. The reason for selecting "chemical equilibrium concept" was that this concept was much more complex than the other chemistry concepts.

Images are mental pictures formed when we hear or imagine a concept. For example, if a student has an image about an iron atom, then this student could think this iron atom on the basis of a nucleus and electrons, could also imagine the atomic shape and its dimension, and also could have an idea about the metallic mesh formed by lots of iron atoms (Atasoy, 2004, p. 23). Then mental schemas are for encoding, assimilating, and consolidating these newly learned and adopted mental images (Tse et al., 2007). Whereas misconceptions are the ideas, images that provide an incorrect understanding, an unscientifically understanding constructed based on a person's prior experience (Martin et al., 2002, cf., Thompson & Logue, 2006). So proper science learning environments must be designed for making students gain scientific images without misconceptions so then construct proper schemas. A study in literature showed that younger students are much more willingness to put a scientific concept instead of its misconceptions to have a proper scheme whereas the older ones were unwilling to put a scientific concept instead of a misconception in their mental schemas (Thompson & Logue, 2006).

In literature there are various studies for determining secondary and high school students' chemistry concept images and misconceptions. Yakmacı-Güzel (2013) conducted her study on 465, 12th grade students via "chemistry concept test" consisted of six questions, each of two per a chemistry topic which were particular nature of matter, chemical equilibrium, and acidic force. The chemistry concept test questions made the students either explain their answers or draw their answers. Lots of misconceptions about the topics were found. The investigator highlighted that the misconceptions were universal ones. Eryılmaz-Muştu and Ucer (2018) studied with 90 secondary school students for determining their atom concept images. The students were given two open-ended questions; first making them to draw the atomic image in their mental schemes and then to give an answer where they learned this knowledge. The categorized results showed that the students rarely drew electrons and nucleus, instead they usually drew atom as sphere. The students said that they learned the knowledge from different textbooks and internet. In another study, the 250 high school students' understanding of the particle nature of matter was researched. There were four questions about daily life scenarios making students explain their answer and there was one last question making students draw the states of matter. The analyzed via categories results showed that the students understanding of the concept was insufficient (Ayas & Özmen, 2002). The misconceptions of high school students on the topic of the rate of chemical reactions were searched via "speed and concept of chemical reaction test" developed for this research. 120 students participated in this research and it was found that students had misconceptions about reaction rate, collision theory, activated complex, temperature effect to reaction rate, concentration effect to reaction rate, and equation for reaction rate (Uysal-Bilgin, 2010). Akkuş et al. (2013) revealed the high school students' covalent bonds concept images and misconceptions in their research. 104, ninth grade students from a high school participated in this qualitative study, worksheets for making drawings and explanations, and semi-structured interview forms were utilized, and findings highlighted that the students' covalent bond images were insufficient, and also, they had lots of misconceptions. Yalçın and Kılıç (2005) investigated high school students' misconceptions about radioactivity and the effect of textbooks on these misconceptions. In their research they found misconceptions about radiation, radioactivity, natural and artificial radioactivity, nuclear reactions, half-life, and radioactivity exposure. They also stated that textbooks' explanations and figures fed these misconceptions.

In literature there are also various studies searching pre-service science teachers' chemistry concept images and misconceptions. In one of these studies, Geçgel and Şekerci (2018) adopted survey method for determining 222 pre-service primary and science teachers' misconceptions via "diagnostic branch tree" as an evaluation technique. According the descriptive statistics analysis results, the pre-service teachers have misconceptions in various topics such as matter, elements, compounds, colligative features, physical and chemical changes, acid and base, temperature and heat topics. In another study, 107 pre-service science teachers' concept images and misconceptions about ionic and molecular dissolution were investigated via worksheets allowing them to draw the concepts, and then write their explanations about the drawings. Semi-structured interview forms were also utilized as data collection tools. The findings showed that pre-service science teachers' images about molecular and ionic dissolution were inadequate, and also, they had lots of misconceptions such as "When NaCl (salt) dissolves in water, HCl (hydrochloric acid) and NaOH (sodium hydroxide) are formed." or "Sugar melts in water." (Eyceyurt-Türk et al., 2014). In much more specific research, Eyceyurt-Türk and Tüzün (2017) conducted a study with 68 pre-service science teachers for determining their concept images and misconceptions about ionic structure, diffusion, and allotropy. The pre-service teachers drew and then explain the concepts on worksheets, the results showed that 63 percentages of teachers had scientifically wrong images about diffusion, 60 percentages of teachers had scientifically wrong images about allotropy, and 98 percentages of teachers had scientifically wrong images about ionic structures. It was also found that they had misconceptions such as 'Molecular weight was same with molecular mass', 'Chemical reaction was adjunction', 'Atoms and electrons were same', 'Ionic structure was formed by elements.' Yalçın-Çelik et al. (2017) studied with 109 pre-service chemistry teachers for determining their understanding of acid concept via drawings. An open-ended questionnaire with two questions was used as data collecting tool, and it was determined that the teachers understanding about acidity was not coherent with scientific one. Also, they had misconceptions such as "Strong acids do not ionize." "Acidity increases as the number of H_3O^+ in a solution increase." and, "Concentrated acids do not ionize, but diluted acids do." In another study Eyceyurt-Türk and Tüzün (2018) researched pre-service science teachers' images and misconceptions regarding atomic orbital and self-ionization concepts. The pre-service science teachers made drawings about the concepts according to their mental schemes then they explained their drawings. The results lightened the pre-service science teachers' images about atomic orbital and self-ionization concepts were inadequate and they had different misconceptions about orbital and self-ionization concepts. Ekiz-Kıran et al. (2018) searched four pre-service chemistry teachers' mental images about the factors effecting chemical equilibrium on the basis of phenomenological research design. Open-ended questions and semi-structured interviews were utilized and content analysis was used for the gathered data. The findings showed that the teachers were able to explain the factors effecting the chemical equilibrium on the basis of Le Chatelier principle but they were insufficient while explaining on the basis of the submicroscopic nature of chemistry. Also, Andriani et al. (2020)

studied teachers' chemical equilibrium misconceptions via $CaCO_3$ equilibrium system, NO_2-N_2O_4 equilibrium system, and $FeSCN^{2+}$ equilibrium system. The common misconceptions were about chemical equilibrium, the constancy of equilibrium constant, and the shift of equilibrium.

On the basis of the literature, studies searching pre-service science teachers' chemical equilibrium image and misconceptions together were limited, so in this research it was aimed to highlight pre-service science teachers' images and misconceptions about chemical equilibrium together and in detail. The research question was determined as "What were the pre-service teachers' images and misconceptions about chemical equilibrium concept?"

Method

Research Design

In this research, qualitative research was employed. The pre-service teachers' images and misconceptions were determined on the basis of qualitative research. In qualitative researches, facts and states are researched in their natural domains on the basis of holistic perspectives via observations, interviews, and/or document analysis (Yıldırım & Şimşek, 2008, p. 39).

Case study was employed as being one of the qualitative researches in the current study. In case studies, the cases are people or situations. The cases are being studied in detail. The cases' stories are just wanted to hear in detail (Stake, 1995). So, in the current study the case being studied in depth was "the pre-service teachers' images and misconceptions."

The Participants of the Research

The research was conducted on 20 pre-service science teachers educating at a university in education faculty in middle Anatolia region. The research's academic year was also the pre-service teachers' first year at university. In other words, the pre-service teachers' class level was one and their age average was 19. The 16 of the participants were female and the four of the participants were male. The sample type was "convenience sample" which meant "easy-reachable, accessible subjects". The criteria for determining the participants, was their willingness for the study. The participants were told that they would have every right for the study so whenever they wanted, they would be able to leave the study. Also, they were told that codes would be used instead of their names in means of research ethics.

Data Collection Tools

Worksheets were utilized as data collecting tools. In worksheets there was a question about making pre-service teachers draw four different scenarios for a given equilibrium reaction at different times, but at a common temperature and then making them explain their drawings. The four different scenarios were about given times, which were at the beginning of the reaction, before the equilibrium, during the equilibrium, and after the equilibrium. The data collection tool's content validity was guaranteed by two different science educators. The data collection tool was given in Figure 1.

Suppose $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$ reaction comes to an equilibrium point at a common temperature in 30 seconds. Draw the reaction states at submicroscopic level for given times. Then do an explanation for your drawings.

Determine notation for the particles: ....

Draw your scenarios

0 second	**15 seconds**	**30 seconds**	**45 seconds**

Explanation:

...

...

...

Figure 1. Data collection tool

Data Analysis

Data was analysed through content analysis. Codes and categories were constructed according with pre-service teachers' drawings. Then frequencies and percentages were calculated. The cross-content analysis was done for determining whether the categories contained all the codes or not (Erickson, 2004). For the validity of the data collecting tool, two science educators checked the tool whether it provided the aim of the study or not. For the reliability of the data collecting tool, the two science educators coding and categorizing consistency was used. The science educators did the coding and categorizing individually but whenever they had a different coding, they argued with each other and came to a consensus which was only once that means the consistency between the researchers was 95 percentages. They came to a consensus that the pre-service teacher's drawing was "a scientifically wrong one."

It would be meaningful to explain the categories' meanings in this section. "Scientifically correct images" were based on current scientific explanations. "Partly scientifical images" were based on current scientific knowledge but with some missing parts. Also, "scientifically wrong images" were images not coherent with current scientific knowledge or just containing some misunderstandings.

Results

The Pre-service Teachers' Images About Chemical Equilibrium Concept

The pre-service teachers' drawings and explanations were coded, and then categories were constructed. At the end frequency and percentage calculations were made. The findings were shown in Table 1.

Table 1. The analysis of the pre-service teachers' images about chemical equilibrium

Categories	Codes	Frequencies and percentages
Scientifically correct images	-	-
Partly scientifical images	-	-
Scientifically wrong images	The code of not being able to show atomic/molecular sizes	19 – 95% T1, T2, T3, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, T16, T17, T18, T19, T20
	The code of not being able to show elastic collisions among particles and collisions with proper geometries, in other words not being able to show kinetic theory	20 – 100% T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, T16, T17, T18, T19, T20
	The code of not being able to picture the chemical equilibrium's stoichiometry	10 – 50% T2, T5, T7, T11, T13, T14, T16, T18, T19, T20
	The code of picturing no products before the chemical equilibrium	17 – 85% T1, T3, T4, T5, T6, T8, T9, T10, T12, T13, T14, T15, T16, T17, T18, T19, T20
	The code of picturing only the products or activated complexes at the chemical equilibrium and/or afterwards	15 – 75% T1, T3, T5, T6, T8, T9, T10, T11, T12, T13, T15, T16, T17, T18, T19
	The code of increasing/decreasing the product's concentration after the chemical equilibrium	7 – 35% T1, T2, T5, T7, T11, T12, T20

	The code of picturing only the products at the beginning of the reaction	1 – 5% T2
	The code of picturing only the reactants through all the chemical equilibrium reaction	2 – 10% T4, T14
	The code of drawing activated complexes at the chemical equilibrium	2 – 10% T5, T18
	The code of drawing wrong products	6 – 30% T2, T5, T15, T16, T18, T20
	The code of drawing atoms instead of molecules	11 – 55% T1, T2, T8, T9, T10, T12, T15, T16, T17, T18, T20
	The code of disappearing/reappearing of the atoms	14 - %70 T1, T2, T4, T5, T7, T10, T11, T12, T13, T14, T16, T18, T19, T20
	The code of not being able to draw the gas particles at a homogeneous state at the tank	2 – 10% T7, T19

As could be seen in Table 1, the whole pre-service science teachers' images about chemical equilibrium concept were under the category of "scientifically wrong images" which's total frequency was 20 that meant 100 percentages. The main codes made up this category were "not being able to show atomic and molecular sizes" (f:19, 95%), "not being able to show elastic collisions among particles and collisions with proper geometries, in other words not being able to show kinetic theory" (f:20, 100%), "not being able to picture the chemical equilibrium's stoichiometry" (f:10, 50%), "picturing no products before the chemical equilibrium" (f:17, 85%), "picturing only the products or activated complexes at the chemical equilibrium and/or afterwards" (f:15, 75%), "increasing/decreasing the product's concentration after the chemical equilibrium" (f:7, 35%), "drawing atoms instead of molecules" (f:11, 55%), and "disappearing/reappearing of the atoms" (f:14, 70%). The other codes were such as "picturing only the products at the beginning of the reaction" (f:1, 5%), "picturing only the reactants through all the chemical equilibrium reaction" (f:2, 10%), "drawing activated complexes at the chemical equilibrium" (f:2, 10%), "drawing wrong products" (f:6, 30%), and "not being able to draw the gas particles at a homogeneous state at the tank" (f:2, 10%). From all these findings it could be said that the participant pre-service teachers' images about the chemical equilibrium concept were inadequate.

In figure 2, 3, and 4, the examples from pre-service teachers' drawings were given for making roots for the findings.

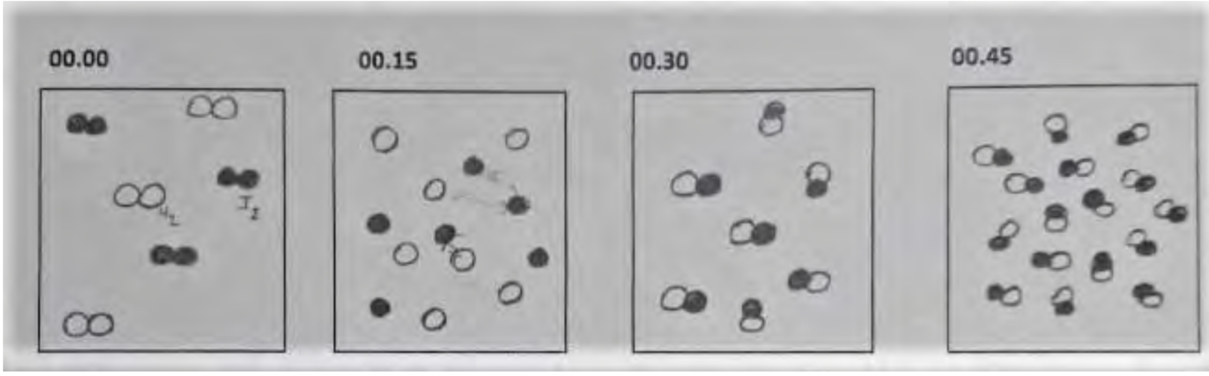

Figure 2. T1 coded pre-service science teacher's drawing

In Figure 2, it could be seen that the pre-service science teacher (T1) could not show the molecular sizes properly at the first scenario, also T1 did not have a proper kinetic theory image which could be seen from all scenarios especially at the second scenario. Because there were no kinetic movements showed by arrays. First the pre-service teacher tried to something but then erased, also kinetic movements must be according to molecular movements in the first and second scenarios not for atomic movements. The second and third scenarios also told the reader that T1 thought that first the diatomic molecules formed atoms and then these atoms formed the products which of both were not scientifically true. Before the chemical equilibrium which was the second scenario, there were no formed products, and during and after the chemical equilibrium which were third and fourth scenarios there were no reactants, which of whole were also scientifically incorrect. In the third scenario the atoms total number was incoherent with the previous one that meant of reappearing new atoms which was not a scientifically proper status. In the fourth scenario, one could see that the products' concentration increased that meant reappearing of new atoms which was not also a scientifically proper status, on the other hand increasing the products' concentration after the chemical equilibrium was not likely.

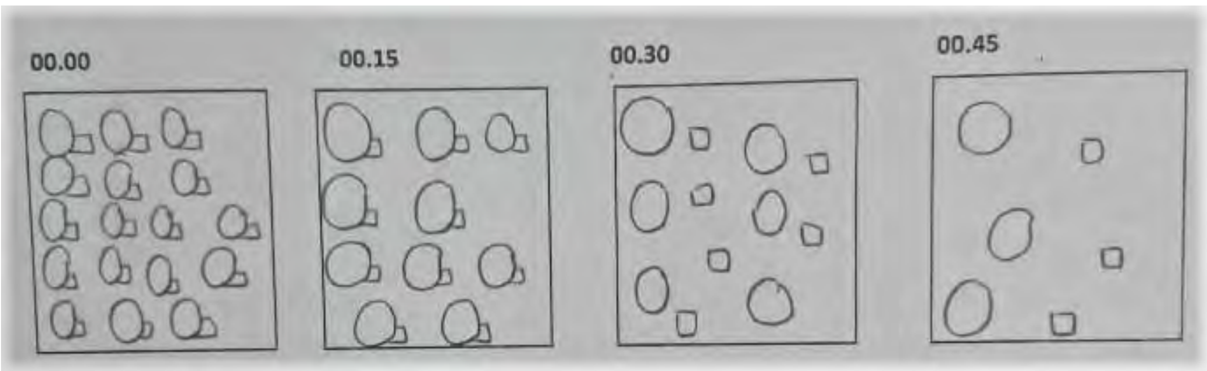

Figure 3. T2 coded pre-service science teacher's drawing

In Figure 3, it could be understood that the whole of the scenarios was scientifically wrong since the pre-service science teacher (T2) thought that at the beginning of the chemical equilibrium reaction, there were products at the tank. The products decreased in the second scenario but there were no other chemicals in the tank. So where were the other particles? According to T2's mental scheme, the disappearing of the atoms was not a scientifically proper situation. In the third and fourth scenarios, decreasing the atom numbers continued which was not a scientifically proper situation too. Also, the atomic sizes were not proper, whereas hydrogen was represented with big sphere and iodine was represented by small sphere on the basis of pre-service science teacher's explanations. And also, in the third scenario molecules formed new chemicals but without collisions which was not also scientifically likely on the basis of kinetic theory. There were atoms instead of molecules in the third and fourth scenarios which were not scientific. The whole scenario also told nothing to reader about the stoichiometry.

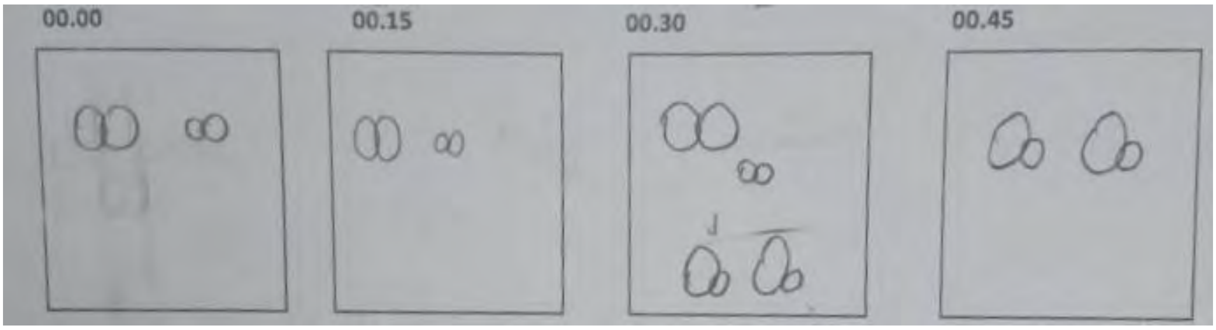

Figure 4. T3 coded pre-service science teacher's drawing

In Figure 4, it could be understood that the whole of the scenarios was scientifically wrong since the pre-service science teacher (T3) thought that only in the equilibrium point the products formed. According to T3's scheme, before the chemical equilibrium point, there were no products, and after the chemical equilibrium point there were no reactants which of both were not scientifically logical. Then the molecular sizes were not proper too whereas hydrogen molecule was represented much bigger than the iodine molecules on the basis of pre-service science teacher's explanations. Also, in the third scenario molecules formed new chemicals but without collisions which was not also scientifically likely on the basis of kinetic theory.

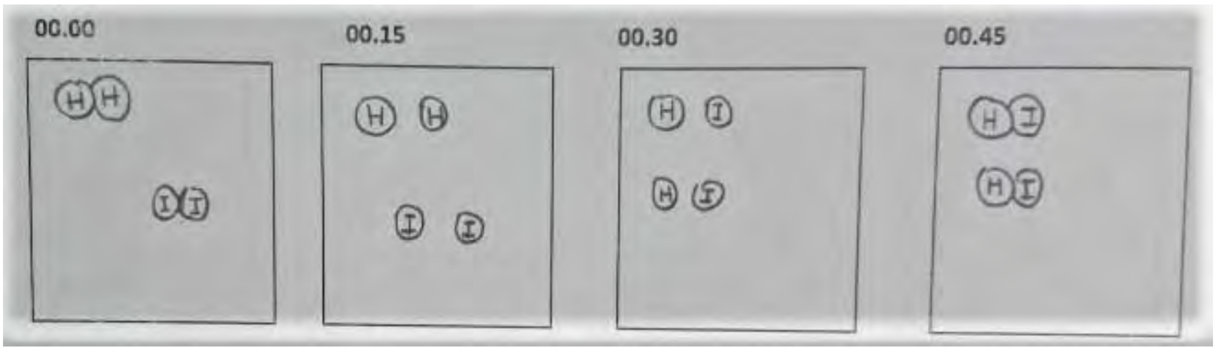

Figure 5. T8 coded pre-service science teacher's drawing

In Figure 5, the pre-service teacher (T8) had not also a scientifically proper image about chemical equilibrium concept like the previous examples. T8 drew the molecular sizes incoherent. The molecule numbers also were inadequate for modelling a chemical equilibrium in the first scenario. In the first, second, third and fourth scenarios there were no collisions, so it was meaningless according to kinetic theory. T8 also had a mental scheme supporting the scientifically wrong situation that "The diatomic molecules could form first atoms then molecules." Which could be said by looking at the second, third, and fourth scenarios. Before the chemical equilibrium there must be some formed products, at the chemical equilibrium and after the chemical equilibrium the concentration of the products must be same, also at the chemical equilibrium and after the chemical equilibrium there must be reactants too, which of whole could not be seen above.

The Pre-service Teachers' Misconceptions About Chemical Equilibrium Concept

The pre-service teachers' drawings and explanations were coded on the basis of scientifically wrong explanations. At the end frequency and percentage calculations were made. The findings were shown in Table 2.

Table 2. The analysis of the pre-service teachers' misconceptions about chemical equilibrium

Misconception	Frequencies and percentages
1.Diatomic molecules form atoms and then these atoms form new chemicals.	10 – 50% T1, T8, T9, T10, T12, T15, T16, T17, T18, T20
2.The atoms adjust during the chemical reactions.	5 – 25% T1, T5, T15, T16, T18
3.There are only products or activated complexes in the tank during and/or afterwards of the chemical equilibrium.	15 – 75% T1, T3, T5, T6, T8, T9, T10, T11, T12, T13, T15, T16, T17, T18, T19
4.After the chemical equilibrium, the products' concentration increases.	4 – 20% T1, T5, T7, T20
5.After the chemical equilibrium, the products' concentration decreases.	3 – 15% T2, T11, T12
6.Atoms could disappear and/or reappear.	14 – 70% T1, T2, T4, T5, T7, T10, T11, T12, T13, T14, T16, T18, T19, T20
7.The reactants and products' concentrations were equal during the chemical equilibrium.	1 – 5% T7
8.Products are formed at the chemical equilibrium.	17 – 85% T1, T3, T4, T5, T6, T8, T9, T10, T12, T13, T14, T15, T16, T17, T18, T19, T20

In Table 2, it was seen that the pre-service science teachers had misconceptions about chemical equilibrium concept. “There are only products or activated complexes in the tank during and/or afterwards of the chemical equilibrium.” (f:15, 75%), “Products are formed at the chemical equilibrium.” (f:17, 85%), “Atoms could disappear and/or reappear.” (f:14, 70%), and “Diatomic molecules form atoms and then these atoms form new chemicals.” (f:10, 50%) were the most common misconceptions among the participants. On the other hand, “The atoms adjust during the chemical reactions.” (f:5, 25%), “After the chemical equilibrium, the products’ concentration increases.” (f:4, 20%), “After the chemical equilibrium, the products’ concentration decreases.” (f:3, 15%), and “The reactants and products’ concentrations were equal during the chemical equilibrium.” (f.1, 5%) were much more rare misconceptions among the participants.

The quotations from pre-service science teacher’s explanations could be given for illustrating the misconceptions.

T1: “The diatomic molecules form elements (1st misconception), these elements concentrations would increase, then during the chemical equilibrium point these elements would adjust with each other (2nd misconception, 3rd misconception, 8th misconception) so would be able to form equilibrium constant, after the equilibrium point the products concentration would increase much more (4th misconception, 6th misconception)”.

T7: “The reactants and products’ concentrations were equal during the chemical equilibrium (7th misconception).”

T8: “Hydrogen and iodine molecules’ atoms depart from each other (1st misconception). Hydrogen and iodine atoms form hydrogen iodide at the chemical equilibrium (3rd misconception, 8th misconceptions).”

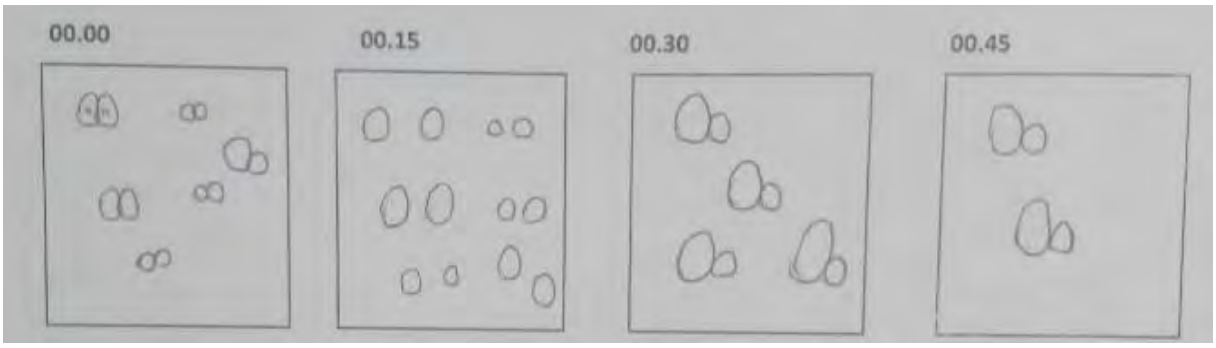

Figure 6. T12 coded pre-service science teacher’s chemical equilibrium image

In Figure 6, as could be seen 1st misconception (Diatomic molecules form atoms and then these atoms form new chemicals), 3rd misconception (There are only products or activated complexes in the tank during and/or afterwards of the chemical equilibrium), 5th misconception (After the chemical equilibrium, the products’ concentration decreases), 6th (Atoms could disappear and/or reappear), and 8th misconception (Products are formed at the chemical equilibrium), were available.

Discussion, Conclusion and Recommendations

In this study pre-service science teachers' images and misconceptions about chemical equilibrium were researched together and in detail since Mai et al. (2021) stated that determining the misconceptions especially in the topic of chemical equilibrium was very important. The current study results showed that pre-service science teachers' images about chemical equilibrium concept were insufficient since their mental images about the concept were scientifically wrong. On the other hand, the pre-service science teachers had different misconceptions. The most common misconceptions of the participants were such as

"There are only products in the tank during and afterwards of the chemical equilibrium."

"Products are formed at the chemical equilibrium."

"Atoms could disappear and/or reappear."

"Diatomic molecules form atoms and then these atoms form new chemicals."

The reasons for pre-service science teacher wrong images, unproper metal schemes, and misconceptions could be reasoned because of the pre-service science teachers' previous inadequate chemistry learning experiences.

In literature the studies investigating pre-service teachers or in-service teachers' chemical equilibrium concept images or chemical equilibrium misconceptions were about equilibrium shift (Ekiz-Kıran et al., 2018; Andriani et al., 2020). There was also a study determining university students' cognitive structures about chemical equilibrium (Şen et al., 2019). But in this study being different from these studies, the pre-service science teachers' images and misconceptions about the chemical equilibrium process; the particular nature of the chemical equilibrium reaction on the basis of kinetic theory at the beginning of the reaction, after a time, at the chemical equilibrium and afterwards, was researched together and in detail and was found some misconceptions about the "conceptualization of chemical equilibrium". Being alike with the current study Betancourt (2021) found alternative conceptions about "conceptualization of chemical equilibrium" in the research that was conducted with 15 university students who were in the first academic semester of their teaching career in Chemistry.

As academicians or educators or candidate teachers, being aware of in-service teachers, pre-service teachers or students' concept images and misconceptions was so important. But then what? Designing educating environments removing these misconceptions with scientifically true ones or preventing further misconceptions were needed. For example, in this research as a complex concept chemical equilibrium concept images and misconceptions of pre-service teachers, were studied in detail. Then constructivist or innovative or student-based learning domains or the whole of them together could be offered to remove the current misconceptions or prevent the future ones. For an illustration, Akkuş (2004) designed an innovative and specific game with marbles for teaching the participants chemical equilibrium concept by making them play with marbles for representing the particles' situations for a chemical equilibrium reaction; at the beginning of the reaction, after a time, at the chemical equilibrium, and afterwards. There were some rules. Each time a common percentage of reactants formed products and also a common percentage of products reformed the reactants. When the both reactants and products concentrations came to a stability but with different concentrations, the participants would understand the chemical equilibrium and afterwards. The illustration could prevent this study's misconceptions of

"There are only products in the tank during and afterwards of the chemical equilibrium."

"Products are formed at the chemical equilibrium."

"Atoms could disappear and/or reappear."

"After the chemical equilibrium, the products' concentration increases."

"After the chemical equilibrium, the products' concentration decreases." And

"The reactants and products' concentrations were equal during the chemical equilibrium."

The limitation of the current study was the participant number which was 20 since the student number educating at this university were limited. So, for further studies, big participant numbers for searching pre-service teachers or in-service teachers or students' images and misconceptions about chemical equilibrium concept could be offered, in the same time for further chemistry concepts the same suggestion could be offered too.

In literature there was a study of teacher education for enhancing teachers' visual literacy skills via visual images (Özsoy & Saribaş, 2021). So, for further studies it could be suggested that these study's illustrated images with codes could be given to pre-service teachers for making them being aware of what was wrong for the images so gain scientific literacy knowledge. Also, in literature candidate teachers' metaphorical perceptions about education system was not positive (Tekel & Öztekin-Bayır, 2021). So as academicians, maybe being aware of the pre-service teachers' probable misconceptions, so then arranging them much more qualified teaching domains could cause them to have much stronger positive metaphorical perceptions in means of education for their future without bias.

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