Effectiveness of Dual Situated Learning Model in Improving High School Students' Conceptions of Chemistry Equilibrium and Preventing Their misconceptions

Muhammad Ali Kurniawan[1], Sri Rahayu[1]*, Fauziatul Fajaroh[1], Saeed Almuntasheri[2]

[1]Department of Chemistry, State University of Malang, Malang, Indonesia
[2]Department of Science Education, Albaha University, Al Bahah, Saudi Arabia

*Corresponding Author. sri.rahayu.fmipa@um.ac.id

ABSTRACT This study aims to compare the impact of the Dual Situated Learning Model (DSLM) and conventional instructions in improving High School Students' understanding of chemical equilibrium concepts and the prevention of possible misconceptions. The study utilized a quasi-pretest-posttest control and experimental group design with two classes of XI SMAN as the research sample (N=60 students). Pre-posttests consisting of 12 two-tier questions (r = 0.691) used to assess the learners' understanding of the chemical equilibrium. The results showed a significant difference in favor of the learners who taught using the DSLM model in comparison to those in the conventional approaches ($F_{ount} = 4.149$; $p = 0.003$). Students in the experimental class had a better understanding and fewer misconceptions about the concept of chemical equilibrium. Implications for science educators suggest that learning that is designed by considering students' misconceptions or preconceptions and anticipating them through appropriate learning steps will have a positive influence on the learners' conceptual understanding.

Keywords Conceptual change, Chemical equilibrium, Dual situated learning model (DSLM), Misconception

1. INTRODUCTION

Chemical equilibrium is one of the topics in chemistry that contains many abstract concepts such as the concept of dynamic balance, the difference between equilibrium and non-equilibrium, the Le Chatelier's principle of equilibrium shift, and the energy that accompanies chemical equilibrium reactions (Raviolo & Garritz, 2009). Studies have shown that characteristics of abstract concepts such as chemical equilibrium cause students to experience difficulties in learning (Johnstone, 1991; Şendur, Toprak, & Pekmez., 2011; Zarei, 2016).

The difficulty of students in understanding abstract concepts in chemical equilibrium can hinder students from establishing a conceptual understanding of those concepts. As a result, students can have different perceptions and misconceptions about the phenomenon of chemical stability. Scientific delusion can define as an understanding that is not following the view of the scientific community (Nakhleh, 1992). Students who experience misunderstandings convince that their knowledge is correct, and thus misconceptions are often challenging to alter or change.

Some students' misconceptions in chemical equilibrium identified by previous research; the concentration of all substances in the equilibrium state is the same (Bilim, 2003; Özmen, 2008). The rate of reaction towards the product increases until equilibrium reached (Hackling & Garnett, 1985), increasing the temperature will increase the product (Ozmen, 2007), the addition of catalysts will increase the concentration of reactants and products (Demircioğlu, Demircioğlu, & Yadigaroglu, 2013), the constant equilibrium price determined by all substances in the system (solid, liquid, gas, and solution) (Rosidah, 2012). The learning process in the classroom can cause student misconceptions that occur, for example, the approach, strategy, and the learning method (Barke, H. D., Hazari, A., & Yitbarek (2008).

Practise in the schools indicate that conventional instruction with the lecture method is the dominant learning approach used in both schools and colleges. Most of the laboratory tasks utilized the traditional type, that is,

to rely on 'step by step' scientific methods, which direct the students to the correct data, which then suits a predetermined outcome (McDonald, 2013). Another study reported that teachers thought the lecture method is more efficient compared to other ways so that all subject topics in the curriculum can convey (Lotter, Harwood, & Bonner, 2007). This study also supported by the results of PISA in 2012, which placed China, which in learning uses the chalk and talk method, in the top position in the categories of science, mathematics, and reading data (OECD, 2015). Furthermore, Miao, Reynolds, Harris, & Jones (2015) concluded that the average increase in metacognitive abilities and active learning of students in China was better than students in Britain who used a constructivist approach.

Despite the advantages of the conventional approach, some deficiencies, such as the lack of students' motivation and allowing opportunities for learners to solve problems, can deter educators from considering it as a preferred teaching-approach (Atasoy, Akkus, & Kadayifci, 2009). This approach has been criticized for its tendency to make students passive (Henikusniati, Andayani, & Savalas, 2015) and less effective in overcoming misconceptions (Demircioglu, Ayas, & Demircioglu, 2005; She & Lee, 2008).

One approach proposed to overcome the lack of the conventional method in engaging the students in the process of learning is the conceptual change approach. Conceptual change can define as an approach that involves the process of changing or correcting students' misconceptions (Sendur & Toprak, 2013). Changes in the concept itself interpreted as a process of turning ideas/thoughts from one concept to another (Hewson, 1992). Therefore, learning with the conceptual change approach involves the process of changing or refining old concepts into new ideas that are accepted by the scientific community (Vosniadou, Pnevmatikos, & Makris, 2018). Four conditions that must be met to change the concept: (1) students must be dissatisfied with the concepts they have (dissatisfaction), (2) new concepts must be clear and easily understood by students (can be understood), (3) new concepts must make sense, and (4) New concepts must be effective or beneficial (fruitful) (Posner, Strike, Hewson, & Gertzog, (198 2).To meet these conditions that create the state of cognitive conflict in the learners is required. (She, 2004b) mentions that cognitive conflict can raise in several ways, including practical activities, demonstrations, and visualization. The existence of cognitive conflict results in more meaningful learning so that understanding of the new concepts owned by students can last longer (Çalik, Kolomuç, & Karagölge, 2010; Atasoy, Akkus, & Kadayifci, 2009).

The implementation of the conceptual change approach to learning reflected in the learning model used. One learning model that fits the conceptual change approach is the Dual-Situated Learning Model (DSLM). This model considered having advantages because it combines three perspectives in conceptual change. Those perspectives involve epistemological, ontological, and motivational. This learning model has four duals as the principle of drafting DSLM learning, namely (1) conceptual change must be built following the characteristics of the concept and students' belief in the idea, (2) the process of conceptual change must cause dissonance of the students' initial knowledge/preconceptions and provide a new mental set either in the form of revision of old understandings or of the construction of the new agreement, (3) the process of making students' dissonance must foster student motivation and challenge their beliefs, (4) the process of conceptual change must challenge students' ontology and epistemological beliefs in a concept (She & Liao, 2010; She, 2004a). Based on these principles, this study developed the DSLM characteristics is developed into six stages of learning: (1) determining the attributes of the concept and mental setlist needed to create the idea, (2) identifying the students' misconceptions or preconceptions, (3) analyzing the mental set of students that are lacking, (4) design a dual-situated learning event, (5) implement a dual-situated learning event (DSL Event), and (6) provide a challenging situated learning event (CSL Event). The six stages of DSLM contained in 4 steps of learning, namely predicting, member reasons, dissonance confrontation, new mental set construction, and challenges. The step of DSLM expected to be able to prevent misconceptions among students or students' preconceptions that are similar to the misunderstandings found in the literature. In other words, DSLM learning expected to be able to improve students' understanding of concepts.

This study aims to compare the effectiveness of the Dual Situated Learning Model (DSLM) with conventional instruction in improving students 'understanding of the concept of chemical balance and comparing the effectiveness of the Dual Situated Learning (DSLM) model with conventional instruction in preventing students' misconceptions about chemical stability.

2. METHOD

This study used a quasi-experimental design with a pretest and posttest control group design. Pretest data use to test the normality and homogeneity of the sample as a prerequisite in determining the hypothesis test. The posttest examines the differences in students' understanding of the equilibrium and the possible misconceptions in the experimental and control groups. The research sample was grade XI high school students specializing in Mathematics and Natural Sciences. Two classes were selected by a cluster random sampling technique. An experimental class (N = 30 students) taught using the Dual-Situated Learning Model, and a control

class (N = 30 students) was taught conventionally (i.e., the class prepared by the lecture and discussion methods). The topic of chemical equilibrium taught for six meeting hours (@ 90 minutes) in both categories. The problem consists of four subtopics, namely the definition and characteristics of equilibrium, the state of equilibrium and its calculations, equilibrium shifts (Le Chatelier principles), and equilibrium in the industry. Data collected before treatment (pretest) and after treatment (posttest). The collected data were analyzed statistically with the help of the SPSS 17.0 for Windows program.

The research instrument was a two-tier multiple-choice test of the chemical equilibrium concepts consisting of 6 pairs of two-tier of questions. It consisted of two subconcepts in which many misconceptions held by students, that were the definition and characteristics of equilibrium and the equilibrium shifts (Le Chatelier principles). The items developed by researchers based on literature (Hackling & Garnett, 1985; Rosidah, 2012; Şendur, Toprak, & Pekmez (2010); Özmen, 2008). The first tier contains a choice of answers to questions, while the second tier includes a selection of reasons for the chosen answers (Treagust, 1988). Student answers judged correctly only if the pair of explanations and reasons are correct (score 1). If the answer is correct, but the reason is wrong or vice versa, then the answer is considered incorrect (score 0). Therefore, in addition to being used to examine the students' understanding, a two-tier diagnostic test can also be utilized to identify misconceptions that were held by the learners. Students are considered to experience misconceptions if students held misconception responses in paired items.

The scoring guideline for the second research objective differed from the scoring instruction for the first research objective. The score for misconception can gain when a student chooses the paired choices for mistakes in the two-tier test. For example, item tests no 10 and 11 (see figure 1) were the matched items to examine students' misconception "an increase in temperature will shift the equilibrium toward the exothermic reaction, and vice versa." The bold choice was the correct answer, and (*) sign was the paired misconception choice. If a student chose B (first tier) and (iii) (second tier) in the item no 10, and the same student wanted A (first tier) and (v) (second tier) for detail no 11, then the student was considered holding misconception, and he/she got to score one (1). Conversely, If a student chose the correct answer or wrong answer either in the first or second tier, the student got score 0.

---

10. The reaction of nitrogen dioxide (NO_2) to dinitrogen tetraoxide (N_2O_4) which takes place is exothermic, follows the reaction equation

$2NO_2 (g) \rightleftharpoons N_2O_4 (g)$

At constant pressure, after equilibrium is reached, if the temperature is raised then equilibrium will....
(A) shift left (C) not shift (B) shift to the right

Reason:
(i) the rise in temperature does not affect the equilibrium constant (K) and does not shift the equilibrium
(ii) the temperature rise will shift the equilibrium in the direction of the reaction which absorbs the energy and the equilibrium constant (K) will rise
(iii) an increase in temperature will shift the equilibrium in the direction of the reaction which releases energy and the equilibrium constant (K) will rise
(iv) an increase in temperature will shift the equilibrium in the direction of the reaction which absorbs energy **and the equilibrium constant (K) will decrease**
(v) the rise in temperature shifts the equilibrium in the direction of the reaction which releases energy and the equilibrium constant (K) decreases

11. The reaction between C and CO_2 to form CO is endothermic according to the reaction equation

$C (g) + CO_2 (g) \rightleftharpoons 2CO (g)$

At constant pressure, after equilibrium is reached, if the temperature is raised the equilibrium will ....
(A) shift to left (C) not shift **(B) shift to the right**

Reason:
(i)   the rise in temperature does not affect the equilibrium constant (K) and does not shift the equilibrium
(ii)   the temperature rise will shift the equilibrium in the direction of the reaction which absorbs the energy and the equilibrium constant (K) will rise
(iii) an increase in temperature will shift the equilibrium in the direction of the reaction which releases energy and the equilibrium constant (K) will rise
(iv) an increase in temperature will shift the equilibrium in the direction of the reaction which absorbs energy and the equilibrium constant (K) will decrease
(v) the rise in temperature shifts the equilibrium in the direction of the reaction which releases energy and the equilibrium constant (K) decreases

Figure 1 Paired items to examine misconception *(Bold font is a correct answer, (*) sign is misconception choice)*

Table 1 Statistics analyses of improvement in students' conceptions of equilibrium

Group	N	Mean	Std DEviation	Std Error Mean	df	T	Sig. (2-tailed)
Experimental	30	26.867	1.621	0.295	58	-3.137	0.003
Control	30	24.833	3.159	0.576			

Table 2 Statistics analyses of prevention of students' misconception of equilibrium

Group	N	Mean	Std DEviation	Std Error Mean	df	T	Sig. (2-tailed)
Experimental	30	1.00	1.083	0.198	58	-2.980	0.004
Control	30	2.00	1.486	0.271			

Figure 1. Paired items to examine misconception (Bold font is a correct answer, (*) sign is misconception choice). One hundred five students who had received equilibrium material participated in the trial tests. The reliability check of the experiment was 0.691. The scoring guide used is a score of 1 given only to students who choose the correct combination of answers and reasons. While the wrong combination gets a score of 0.

3. RESULT AND DISCUSSION

3.1 The effectiveness of DSLM in improving the high school students' understanding of the chemical equilibrium concepts.

Before conducting the research, a pretest is undertaken to check the normality and homogeneity between the experimental and control groups. The significance values showed that the normality test in the pretest for the trial and control classes were 0.052 and 0.155, respectively, and they showed that the two types were usually distributed ($\alpha >$ 0.05). Homogeneity prerequisite tests in both groups showed that both classes were homogeneous, with a significance value of 0.460 ($\alpha >$ 0.05).

The first research objective tested using a T-Test. The post-test results showed that there was a significant difference between the experimental and the control groups. That can see from the F_{count} value of 4.149 and the significance of 0.003 (<0.05). Based on this analysis, it can conclude that there were differences in students' understanding that are taught by the Dual-Situated Learning Model (DSLM) and conventional instruction. The average score of the experimental class posttest was 26.86, while the control class was 24.83. That means that the implementation of DSLM was better in improving students' understanding of chemical equilibrium concepts compared to conventional instruction.

Table 1. Statistics Analyses of Improvement in Students' Conceptions of Equilibrium. The result of the analysis showed that DSLM was effective in improving students' understanding of the chemical equilibrium concepts compared to conventional instruction. That can explain from one perspective, such as teaching strategy/model. Learning with a DSLM invites students to

prepare the mindset needed to understand a concept before gaining new knowledge by considering students' perceptions of an idea and the nature of scientific concepts (She, 2002). The existence of a cognitive conflict in this learning approach aims to create a state of disequilibrium for students who have incompatible understanding/preconception. After students' dissatisfaction with the concept, the teacher presents a new idea that is more acceptable. The cognitive conflict results in more meaningful learning so that understanding of the latest concepts in students can last longer (Çalik, Kolomuç, & Karagölge, 2010; Atasoy, Akkus, & Kadayifci, 2009). That is evident in the five stages of DSLM, namely prediction, giving reasons (explanations), confrontation of dissonance, and the construction of a new mindset and provide challenges to students (She, 2002).

Besides, the differences in students' active learning may also be reasons for differences in students' understandings in the experimental and control classes. Learning with DSLM requires students to play an active role in the learning process by following instructions written in worksheets. Some of the procedures students must follow are contained in the worksheet, while the rest are instructions from the teacher. The existence of worksheet instruction makes students active and cannot just wait for an explanation by the teacher. Giving a challenge is formed separately from the worksheets so that students can answer with the correct knowledge confidently.

The learning process with a conceptual change approach to DSLM begins by asking students to make predictions of a given phenomenon. The students are also asked to provide reasons to strengthen their answers. Each student uses their fundamental knowledge to solve the given problem. This stage will attract students' curiosity so that it motivates students to look for more information. From various predictions and reasons given, it appears that several predictions that lead to misconception.

The next stage is the dissonance confrontation, where students give facts about the concept being studied. This fact will cause cognitive conflict for students who have incompatible initial knowledge so that students experience dissatisfaction with their education. This condition results in accommodation in the cognitive structure of students so

Table 3 High school students' misconceptions in both experiment and control groups

Concept	Misconception	Item Number	Exp. group (%)	Control group (%)
Equilibrium definitions & characteristics	• Equilibrium is reached when the concentration of the product is the same as the reactants.	1 & 2	13.33	40.00
	• Equilibrium is reached when the reaction rate of product formation and reactant formation are constant	1 & 2	10.00	23.33
	• During the reaction, the concentration of reactant decreases and the concentration of the product increases until both concentrations are equal (equilibrium)	3 & 4	0	6.67
Le Chatelier Principal	• The addition of reactants will cause the equilibrium to shift to the reactants	5 & 12	16.33	26.67
	• Adding solids to the equilibrium system will shift the equilibrium	6 & 9	10.00	23.33
	• Adding pressure will shift the equilibrium in the direction of a large number of molecules	7 & 8	13.33	20.00
	• An increase in temperature will shift the equilibrium toward the exothermic reaction, and vice versa	10 & 11	26.67	33.33

that the process of conceptual change can occur. Submission of facts can be made in several ways, such as providing data, videos, pictures, or practice directly. For illustration, the dissonance confrontation that carried out on the concept of shifting equilibrium is to practice directly. The training is a reaction between the copper metal and concentrated sulfuric acid. In addition to practice, students also asked to answer questions in the dissonance confrontation section. That intended to direct students while increasing the likelihood of dissatisfaction of students. In other concepts such as the concept of definition and equilibrium, dissonance confrontation carried out by providing several videos to provoke conflict in students.

The next stage is the construction of new mental sets. This stage asks students to carry out instructions in the worksheet with the guidance of the teacher. Instructions and questions in the worksheet are made in such a way as to be able to guide students to find the correct concepts. The new idea that built must be easier to understand (intelligible), more plausible, and can apply to other problems (fruitful) that are similar so that the new concept that built produces inherent changes in ideas. To see the concept change is by comparing the answers at the prediction stage and the metal construction set.

The final stage in learning with the DSLM conceptual change approach is the challenge stage. At this stage, students are allowed to use new concepts in solving other problems (She, 2002).

3.2 The effectiveness of DSLM in preventing high school students' misconceptions of chemical equilibrium

To examine the second research aim t-test analysis was performed. The results of the analysis showed a F_{count} value of 1.675 and a significance level of 0.004 (<0.05), meaning

that there were significant differences between students' misconceptions taught with DSLM and conventional instruction. The misconceptions held by students from the two groups showed that the experimental group (mean score = 1) held fewer misunderstandings in comparison to the control group (mean score= 2) so that it can conclude that DSLM was more effective in preventing students' misconceptions compared to conventional instruction (see Table 2)

Table 2. Statistics Analyses of Prevention of Students' Misconception of Equilibrium, further analysis carried out to find out what misconceptions were held by students. Misconception experienced by students was obtained from the results of the consistency of wrong answers to each concept in chemical equilibrium. Inconsistent mistakes cannot consider as misconceptions, but it can be considered as random errors. The following misconceptions record on chemical equilibrium using a two-tier test instrument (see Table 3).

Table 3. High school students' misconceptions in both experiment and control groups, based on Table 3, it can be noticed that there are differences in the number of students' misconceptions between the experimental group and the control group. Students who studied with Dual-Situated Learning Model (DSLM) in the experimental group have a smaller number of mistakes compared to the conventional group. That shows that learning chemical equilibrium concepts using DSLM was more effective in preventing students' misconceptions comparing with conventional instruction. From seven misconceptions held by students after instruction in both groups, the DSLM was found to be effective instruction in preventing misconception no 1 'Equilibrium is reached when the concentration of the product is the same as the reactants' with 13.3 % of the experimental group compared with 40%

of the learners in the control group. It followed by misconceptions no 2 'Equilibrium reached when the reaction rate of product formation and reactant formation are constant' in which the control group had more misconceptions by almost 13%. Similarly, misconception no 5 'Adding solids to the equilibrium system will shift equilibrium'', 23% of the students in the control group held misconceptions about it, in comparison with only 10% for the learners in the control group. Finally, the learners in the experimental group held less misconception by almost 10% about no 4 'The addition of reactants will cause the equilibrium to shift in the direction of the reactants.

The first concept in equilibrium is the definitions and characteristics of equilibrium. In this concept, students expect to be able to understand equilibrium in terms of macroscopic and submicroscopic aspects. Students often have no difficulty in understanding the macroscopic aspects of equilibrium because the human senses can capture them. Conversely, the sub-microcosmic aspects of equilibrium cannot capture by the thoughts and required student's deep understanding. As a result, students have difficulty in understanding the definition and characteristics of equilibrium. This difficulty triggers misconceptions within this concept group. The first misconception found in this concept group is that balance reached when the product concentration is the same as the reactants. This misconception also found by Üce & Ceyhan (2019), Hackling & Garnett (1985), and Demircioğlu, Demircioğlu, & Yadigaroglu, (2013) where the students assume that equilibrium occurs when the concentration is the same. Another misconception found that the equilibrium is reached when the rate of formation of the product and the rate of formation of the reactants is fixed, and during the reaction, the reactant concentration decreases the concentration of the product increases to the same concentration. These three misconceptions may occur because students have difficulty in understanding the conditions of equilibrium as a whole. As expressed by Bilim (2003), students do not understand equilibrium conditions because they do not understand alternating reactions, two-way reaction rates, and the relationship between reactant and product concentrations to time. The correct concept is that equilibrium reached when the rate of product formation is equal to the rate of reactant formation so that the concentration of reactants and products remains constant (Silberberg & Amateis, 2018).

The concept group of chemical shifts (Le Chatelier's principle) also gives rise to misconceptions about students. Based on Table 1, misconceptions in bullets, 4 through 7, are still widely experienced by students. The first misconception in this concept group is that the addition of reactants will shift the equilibrium towards the reactants. The same misconception discovered by Demircioğlu, Demircioğlu, & Yadigaroglu (2013) and Özmen (2008), where students assume that when a substance added to the equilibrium system, equilibrium will shift to the side of the addition. The correct concept is the addition of substances to equilibrium will shift the equilibrium from the direction of addition (Silberberg & Amateis, 2018). The second misconception in this group is the addition of solids to equilibrium will shift equilibrium. The addition of solids should not affect equilibrium (Silberberg & Amateis, 2018). Misconceptions were also found by Özmen (2008), Demircioğlu, Demircioğlu, & Yadigaroglu (2013), Şendur, Toprak, & Pekmez (2010) and Banerjee (1991) because students lack understanding of the equilibrium concept and the nature of the substance itself. As a result, students assume that the principle of Le Chatelier can be used on a variety of systems, including heterogeneous equilibrium systems. The next misconception in this concept group is that the addition of pressure will shift the equilibrium toward the number of large molecules, and an increase in temperature will shift the balance toward the exothermic. Both of these misconceptions also discovered by Özmen (2008) and Demircioğlu, Demircioğlu, & Yadigaroglu (2013). Based on the findings of other researchers, it was found that the two misconceptions were caused by a lack of understanding of the equilibrium and the principle of Le Chatelier itself.

4. CONCLUSION

The results of this study show that Dual-Situated Learning Model (DLSM) is more effective in improving students' understandings of equilibrium concepts compared to their understanding when using conventional instruction. Besides, DSLM is also more effective in preventing misconceptions on the same topic compared to conventional instruction. This research implies that in designing classroom instruction, a teacher should firstly identify the students' initial concepts (preconceptions) or alternative concepts that are similar to misconceptions found in the literature. The students' pre-concepts or initial concepts are then included explicitly in learning so that the new topics taught will be aligned with the students' initial concepts so that the potency of misconceptions could avoid,.

REFERENCES

Atasoy, B., Akkus, H., & Kadayifci, H. (2009). The effect of a conceptual change approach on understanding of students' chemical equilibrium concepts. *Research in Science & Technological Education*, *27*(3), 267–282.

Banerjee, A. C. (1991). Misconceptions of students and teachers in chemical equilibrium. *International Journal of Science Education*, *13*(4), 487–494.

Bilim, E. (2003). Student's Misconceptions on the Concept of Chemical Equilibrium Öğrencilerin Kimyasal Denge Konusundaki Kavram Yanılgıları. *Education*, *28*(127), 10-17.

Çalik, M., Kolomuç, A., & Karagölge, Z. (2010). The effect of conceptual change pedagogy on students' conceptions of rate of reaction. *Journal of Science Education and Technology*, *19*(5), 422–433.

OECD. (2015). *OECD family database*. OECD Paris. http://www.oecd.org/social/family/database.htm

Demircioglu, G., Ayas, A., & Demircioglu, H. (2005). Conceptual change achieved through a new teaching program on acids and bases. *Chemistry Education Research and Practice*, *6*(1), 36–51.

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

Hackling, M. W., & Garnett, P. J. (1985). Misconceptions of chemical equilibrium. *The European Journal of Science Education*, *7*(2), 205-214.

Henikusniati -, Andayani, Y., & Savalas, L. R. T. (2015). Implementation of instruction using science process skills approaches for improving learning outcomes of Public Vocational School 3 Mataram. *Jurnal Penelitian Pendidikan IPA*, *1*(2), 52-58.

Hewson, P. W. (1992). Conceptual change in science teaching and teacher education. *A Meeting on "Research and Curriculum Development in Science Teaching," under the Auspices of the National Center for Educational Research, Documentation, and Assessment, Ministry for Education and Science, Madrid, Spain.* Retrieved from https://www.researchgate.net/profile/Peter_Hewson2/publication/253300170_Conceptual_change_in_science_teaching_and_teacher_education/links/571fe01308aeaced788acc6b/Conceptual-change-in-science-teaching-and-teacher-education.pdf.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*(2), 75–83.

Lotter, C., Harwood, W. S., & Bonner, J. J. (2007). The influence of core teaching conceptions on teachers' use of inquiry teaching practices. *Journal of Research in Science Teaching*, *44*(9), 1318–1347.

McDonald, C. V. (2013). An examination of preservice primary teachers' written arguments in an open inquiry laboratory task. *Science Education International*, *24*(3), 254–281.

Miao, Z., Reynolds, D., Harris, A., & Jones, M. (2015). Comparing performance: A cross-national investigation into the teaching of mathematics in primary classrooms in England and China. *Asia Pacific Journal of Education*, *35*(3), 392–403.

Barke, H. D., Hazari, A., & Yitbarek, S. (2008). *Misconceptions in chemistry: Addressing perceptions in chemical education.* Springer Science & Business Media.

Nakhleh, M. B. (1992). Why some students don't learn chemistry: Chemical misconceptions. *Journal of Chemical Education*, *69*(3), 191.

Özmen, H. (2007). The effectiveness of conceptual change texts in remediating high school students' alternative conceptions concerning chemical equilibrium. *Asia Pacific Education Review*, *8*(3), 413–425.

Özmen, H. (2008). Determination of students' alternative conceptions about chemical equilibrium: A review of research and the case of Turkey. *Chem. Educ. Res. Pract.*, *9*(3), 225–233.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227.

Raviolo, A., & Garritz, A. (2009). Analogies in the teaching of chemical equilibrium: A synthesis/analysis of the literature. *Chemistry Education Research and Practice*, *10*(1), 5–13.

Rosidah, Y. A. (2012). *The use of the "Two-tier Test" to evaluate Grade 11 High School Students' understanding of chemical equilibrium in Batu.* Retrieved from http://karya-ilmiah.um.ac.id/index.php/kimia/article/view/18349.

Sendur, G., & Toprak, M. (2013). The role of conceptual change texts to improve students' understanding of alkenes. *Chemistry Education Research and Practice*, *14*(4), 431–449.

Şendur, G., Toprak, M., & Pekmez, E. Ş. (2010). Analyzing of Students' Misconceptions About Chemical Equilibrium. *International Conference on New Trends in Education and Their Implications*, 1-7.

Şendur, G., Toprak, M., & Pekmez, E. Ş. (2011). How Can Secondary School Students Perceive Chemical Equilibrium? *Education Sciences*, *6*(2), 1512–1531.

She, H.-C. (2002). Concepts of a higher hierarchical level require more dual situated learning events for conceptual change: A study of air pressure and buoyancy. *International Journal of Science Education*, *24*(9), 981–996.

She, H.-C. (2004a). Facilitating changes in ninth grade students' understanding of dissolution and diffusion through DSLM instruction. *Research in Science Education*, *34*(4), 503–525.

She, H.-C. (2004b). Fostering radical conceptual change through dual-situated learning model. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *41*(2), 142–164.

She, H.-C., & Lee, C.-Q. (2008). SCCR digital learning system for scientific conceptual change and scientific reasoning. *Computers & Education*, *51*(2), 724–742.

She, H.-C., & Liao, Y.-W. (2010). Bridging scientific reasoning and conceptual change through adaptive web-based learning. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *47*(1), 91–119.

Silberberg, M. S., & Amateis, P. (2018). *Chemistry: The molecular nature of matter and change: with advanced topics* (8e [8th edition, revised]). McGraw-Hill Education.

Treagust, D. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education - INT J SCI EDUC*, *10*, 159–169.

Üce, M., & Ceyhan, I. (2019). Misconception in Chemistry Education and Practices to Eliminate Them: Literature Analysis. *Journal of Education and Training Studies*, *7*(3), 202–208.

Vosniadou, S., Pnevmatikos, D., & Makris, N. (2018). The role of executive function in the construction and employment of scientific and mathematical concepts that require conceptual change learning. *Neuroeducation Journal*, *5*(2), 58–68.

Zarei, E. (2016). Misconception about Chemical Equilibrium and Some Suggestions for Their Reduction. *Iranian Physical Chemistry Conference*, *19*, 77-80.