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AN INVESTIGATION OF CHANGES IN THE COGNITIVE STRUCTURES OF 11TH GRADE STUDENTS USING THE WORD ASSOCIATION TEST: THE CASE OF CHEMICAL EQUILIBRIUM

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ABSTRACT

Cognitive structures offer an opportunity to assess what learners know with respect to a particular area of knowledge. It is therefore important to identify the cognitive structures that may also influence the structuring of new knowledge and examine how these change with instruction. This study used the word association test to reveal the cognitive structures of 11th grade students (ages 15-16) in the context of the basic concepts taught in the unit on chemical equilibrium and to understand how these changed after the instruction. In line with this goal, a study was conducted with 30 students enrolled in the 11th grade of a secondary school in the city of Izmir. In collecting data for the study, an association test consisting of ten stimulus words was implemented before and after the instruction. The stimulus words used in the test were, "equilibrium", "catalyzer", "endothermic reaction", "exothermic reaction", "pressure", "molar concentration", "reversible reaction", "maximum disorder", "rate of forward reaction" and "rate of reverse reaction". In the analysis, responses for each stimulus word is counted, a frequencies table is prepared, and mind maps with different cut-off points were drawn up. The results of the study indicated that students were most likely to associate the concept of equilibrium with physical equilibrium in their mind maps before the instruction, responding with words such as "weighing scale" or "balance". At the same time, it was found that the stimulus words "maximum disorder" and "reverse reaction" did not appear in their mind maps and that the responses given to the other concept stimuli revealed very few associations between them before the instruction. Following the instruction however, the students were able to associate the concept of equilibrium with chemical equilibrium; all the stimulus words on the mental map were defined and it was seen that the students were able to form substantially more

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associations between the stimulus words. These findings show that the cognitive structures of the 11th grade students with respect to "chemical equilibrium" changed positively after the instruction.

STRUCTURED ABSTRACT

Introduction

Learners' cognitive structures has important role in the field of science and chemistry education with the effects of the constructivist learning approach. According to constructivist approach, it is important to know what students know when they come into the classroom to design effective learning environments (Siegler, 1998). For this reason, identifing leaners' cognitive structures has great importance in the learning process. Thus, Nakiboğlu (2008) stated that cognive structures help educators to understand how the learners' knowledge change during the learning process.

There are many techniques have been used to identify learners' cognitive structures such as concept maps, flow maps, structured grids, mind maps, and word association test (Kinchin and Hay, 2005; Novak and Gowin, 1984; Anderson and Demetrius, 1993; Tsai, 2001; Tsai and Huang, 2002, Dhindsa, Kasim and Anderson, 2011). Within these techniques, word association test (WAT) has been used by many researchers over the years (Cachapuz and Maskill, 1987; Johnstone and Moynihan, 1985; Kaya and Akış, 2015) . According to these studies, WAT is very useful to identify concepts, and relationship between these concepts in learners' minds (Bahar, Johnstone and Sutcliffe, 1999; Bahar and Özatlı, 2003) .

In chemistry education, WAT was used in many studies, however, there is still a need for studies invesitigating how learners' cognitive stuctures change with the effects of the instruction.

The Purpose of The Study

The purpose of this study is to understand students' cognitive structures regarding the topic of chemical equilibrium by using word association test, and to identify how students' cognitive structures are affected by the instruction. In the line of this purpose, these questions were answered in the study:

- What concepts did the students have in their cognitive structures about the basic concepts related to the unit on chemical equilibrium before the instruction?
- Has there been a change in the students' cognitive structure regarding the basic concepts in the unit on chemical equilibrium after the instruction? If so, what kind of changes have there been.

Methodology

This research was based on one-group pre-test/post-test study. In this design, before instruction, the Word Association Test (WAT) was applied as a pre-test in the group, after the topic of chemical equilibrium began to be taught. The same test was employed as a post-test one week after the instruction.

Sample

The study sample included 30, 11th grade students who were studying in a secondary school in Izmir, Turkey. All students had volunteered to participate in the study, and they had similar backgrounds. The ages of the students ranged from 15 to 16 years.

Instrument

The data of this study was collected through a Word Association Test (WAT). WAT was administered as a pre-test and post-test to all groups. To conduct the WAT, ten key terms selected as cornerstones of chemical equilibrium were selected by the researchers. These key terms acted as stimuli. These were *"equilibrium", "rate of forward reaction", "rate of reverse reaction", "catalyzer", "pressure", "molar concentration", "maximum disorder", "endothermic reaction", "exothermic reaction", "reversible reaction"*

Analysis

In the analysis of WAT, three steps were followed. These are:

1. Analyzing the response words for each stimulus word
2. Counting the response words for each stimulus word and preparing a frequency table.
3. Drawing of mind maps.

In the first stage, the researchers independently examined the responses to each stimulus word/phrase to check whether they were meaningful or not. After that, the Miles and Huberman (1994) formula was used to calculate the percentage of agreement for the responses. These percentages were respectively: *equilibrium (93%), rate of forward reaction (90%), rate of reverse reaction (91%), catalyzer (91%), pressure (92%), molar concentration (92%), maximum disorder (94%), endothermic reaction (95%), exothermic reaction (92%), and reversible reaction (94%).*

In the second stage of the analysis, the responses included in the analysis for each stimulus word were counted and frequency tables were prepared.

The third stage of the analysis included of mind maps that were drawn with using the frequencies of the response words to each of the stimulus words.

Findings

First research question in the study aims to reveal students' cognitive structures regarding the basic concepts of chemical equilibrium before the instruction. With this aim, firstly, a frequency table was prepared for the responses to the stimulus words in the pre-test. After that, mind map with different cut-off point were drawn based on frequency table. According to first mind map displaying a cut-off point of 20 and above, students mostly associated the concept of equilibrium with a weighing scale and equality was based on their experiences in daily life. This result is striking in that it reveals the possible alternative conceptions that the students may have had. At the same time, in this mind map, some meaningful connections were determined. For example, molar concentration - mole, endothermic reaction - heat, endothermic reaction- enthalpy, exothermic reaction - heat, exothermic reaction and enthalpy are scientifically and correctly associated.

In the second mind map with a cut-off point at 15-19, it was determined that the stimulus words did not change but that the responses to these increased. For example, the stimulus word response "cerebellum" appeared in this mind map. That the students formed an association between the concept of "equilibrium" and "cerebellum" is significant in that this indicates meaningful associations that they had carried with them from their biology lessons. Also, molar concentration-ion, molar concentration –volume, pressure- volume and pressure- piston were evidence of the meaningful associations that the students could make.

When third mind map for the cut-off point 10-14 was examined, it can be seen that two new stimulus words (rate of forward reaction" and "catalyzer) have been added as compared to first and second mind map. This showed that the students were able to form a two-way association between these concepts. .

According to fourth mind map for the cut-off point 4-9, map, 8 of the 10 stimulus words have a place on this map. Differing from the other mind maps, the stimulus phrase "rate of reverse reaction" took its place on the map for the first time. When the students' responses to this stimulus phrase are examined, it can be seen that, just as in the responses to "rate of forward reaction," the same responses of "reaction" and "catalyzer" were given.

The aim of second research problem in the study is to determine changes in change in the students' cognitive structures regarding the basic concepts in the unit on chemical equilibrium after the instruction. Similary to before instruction, mind map with with different cut-off point were drawn based on frequency table. In the first mind map for cut-off point 20 and above after instudction, it was seen that 6 stimulus words have found their place on this map. According to this mind map, the responses given to the concept of equilibrium, that is, "reaction," "products" and "equilibrium constant," show that the students' cognitive structures have changed and that what was perceived as physical equilibrium has now been associated with chemical equilibrium.

When the mind map for a cut-off point at 15-19 after instruction was examined, it was seen that the number of stimulus words did not change compared to the mind map for the cut-off point 20 and above but that the responses given to the stimulus words have increased. For example, the responses given to the stimulus word "equilibrium" such as Kp, reactants, mole is an indication that the students were able to form meaningful relationships.

In the third mind map for cut-off point at 10-14 relating to post-instruction, it is observed that both the number of stimulus words and the responses to these have increased. In fact, the stimulus words "forward" and "reverse reaction rates" appear on this mind map for the first time.

The last mind map relating to post-instruction shows that all of the stimulus words given to the students are present in this mind map. In particular, it is striking to see that the two sets of stimulus words representing the concepts of "maximum disorder" and "reversible reaction" have found their way to this mind map for the first time.

Results and Discussion

The main aim of this study is t determine determining how the cognitive structures of 11th-grade students changed with respect to the topic of chemical equilibrium. With this aim, word association test twice as a data collection tool, was applied once before and once following the instruction.

According to the results of the analysis of the pre-instruction WAT, students regarded particularly the concept of equilibrium as a phenomenon referring to physical equilibrium. Thus, there are many studies in which it is reported that students have the tendency of conceptualizing chemical equilibrium in terms of a physical phenomenon, leading to the creation of alternative conceptions (Griffiths, 1994; Hackling and Garnett, 1985; Huddle and Pillay, 1996). On the other hand, after the instruction, the students offered responses that showed that their associations pertaining to the concept of equilibrium were no longer physical but chemical. The responses of "Kd", "reaction" and "products" for the concept of equilibrium indicate this. This mind map at the same time differs from the mind map belonging to before the instruction in that it has more stimulus words and more responses.

This result showes that, with regard to the basic concepts of chemical equilibrium, compared to before the instruction, the students were able to form new connections that were associated with each other instead of offering isolated structures. These findings indicate that the cognitive structures of the 11th grade students with respect to "chemical equilibrium" changed positively after the instruction. Similar results were observed in other studies (Cachapuz and Maskill, 1987; Nakiboğlu, 2008).

Keywords: Chemical equilibrium, cognitive structure, word association test

11. SINIF ÖĞRENCİLERİNİN BİLİŞSEL YAPILARINDAKİ DEĞİŞİMİN KELİME İLİŞKİLENDİRME TESTİ KULLANARAK İNCELENMESİ: KİMYASAL DENGE ÖRNEĞİ

ÖZET

Bilişsel yapılar, öğrenenlerin özel bir bilgi alanında ne bildiklerini değerlendirme fırsatı sunmaktadırlar. Bu yüzden, yeni bilginin yapılandırılmasını etkileyebilecek bilişsel yapıların tanımlanması ve öğretim ile bunların nasıl değiştiğinin incelenmesi önemlidir. Bu çalışmada 11. sınıf öğrencilerinin (15-16 yaş) kimyasal denge ünitesinin temel kavramlarına ilişkin bilişsel yapılarını ortaya çıkarmak ve bunların öğretim sonrası nasıl değiştiğini ortaya koymak amacıyla kelime ilişkilendirme testi kullanılmıştır. Bu amaç doğrultusunda, İzmir il merkezindeki bir ortaöğretim kurumundaki 11. sınıflardaki 30 öğrenci ile bir çalışma yürütülmüştür. Çalışmada veri toplama aracı olarak, 10 uyarıcı kelimeyi içeren kelime ilişkilendirme testi öğretim öncesi ve sonrası uygulanmıştır. Testte kullanılan uyarıcı kelimeler: "denge", "katalizör", "endotermik tepkime", "egzotermik tepkime", "basınç", "molar derişim", "tersinir tepkime", "maksimum düzensizlik", "ileri tepkime hızı", "geri tepkime hızı" dır. Verilerin analizinde, her bir uyarıcı kelimeye verilen cevaplar sayılmış, frekans tablosu hazırlanmış ve farklı kesme noktalarındaki zihin haritaları çizilmiştir. Çalışmanın sonuçları, öğrencilerin öğretim öncesi zihin haritalarında çoğunlukla denge kavramını terazi ve eşitlik gibi cevaplar ile fiziksel denge ile ilişkilendirme eğiliminde olduklarını göstermektedir. Aynı zamanda, öğretim öncesinde "maksimum düzensizlik" ve " tersinir tepkime" uyarıcı kelimelerinin zihin haritalarında yer almadığı, diğer uyarıcı kelimeler arasında da çok az bağlantının kurulabildiği saptanmıştır. Buna karşın öğretim sonrasında ise, öğrenciler denge kavramını kimyasal denge ile ilişkilendirebilmişler, tüm uyarıcı kelimler zihin haritalarında saptanabilmiş ve öğrencilerin uyarıcı kelimeler arasında daha fazla ilişki kurabildikleri saptanmıştır. Bu bulgular, 11. sınıf öğrencilerinin "kimyasal dengeye" yönelik bilişsel yapılarının öğretim sonrası olumlu yönde değiştiğini göstermektedir.

Anahtar Kelimeler: Bilişsel yapı, kelime ilişkilendirme testi, kimyasal denge

Introduction

Over the last two decades, exploring learners' cognitive structures has gained great important in the field of science and chemistry education. This is because, according to the constructivist learning approach, learners do not enter the classroom as empty vessels, they enter the classroom with half-formed ideas, prior knowledge and alternative conceptions (Jones and Araje, 2002; Sawyer, 2007). To design effective learning environments in the constructivist approach, teachers need a very good understanding of what students know when they come into the classroom (Siegler, 1998). This requires deep research into learners' cognitive structures.

Cognitive structure includes relationships between concepts that lie in the learner's long term memory (Bahar and Tongaç, 2009; Preece, 1976; Shavelson, 1974). Also, cognitive structures are known as learners' memorial structures or integrated bodies of knowledge that are made up of sets of concepts (Ausubel, 1968; Chang, 2005). Cognitive structure makes a significant contribution to learners' understanding of new concepts (Chambers and Andre, 1997; Thompson and Zamboanga, 2004). According to Ausubel (1968), students learn meaningfully by constructing new knowledge on the basis of what they already know. Accordingly, learners' cognitive structures have great effect on their subsequent learning. Thus, Atabek-Yiğit (2016) stated that investigating students' cognitive structures provides educators with some clues as to "how learning occurs."

As Tsai and Huang (2002) explain, determining learners' cognitive structures have important effects on the learning process. Specifically, before the teaching, exploring learners' cognitive structures could help teachers select appropriate teaching methods based on what has been determined as the learner's prior knowledge in this process. If students have some alternative conceptions in their cognitive structures and teachers determine these alternative conceptions before teaching, teachers can then capture the chance to remedy alternative conceptions and improve learners' understanding (Chin, 2001; Tsai, 1999). Also, it is essential to identify learners' cognitive structures because cognitive structure shows what learners know and how their knowledge modifies throughout the learning process (Nakiboğlu, 2008; Tsai and Huang, 2002.). Similarly, Atabek-Yigit (2015) expressed the view that an investigation into students' cognitive structures reveals knowledge about students' organization of knowledge, and as a result of this, teachers are then able to create better learning environments.

It is clearly understood from this perspective that it is of vital importance to determine students' cognitive structures during the teaching process. Towards this aim, many different techniques have been employed in the effort to identify students' cognitive structures, including tree construction (Jonassen, Beissner and Yacci, 1993), concept maps (Kinchin and Hay, 2005; Novak and Gowin, 1984), concept circles (Wandersee, 1987), flow maps (Anderson and Demetrius, 1993; Tsai, 2001), structured grids (Tsai and Huang, 2002), mind maps (Dhindsa, Kasim and Anderson, 2011), open-ended questions and multiple-choice questions (Bishop and Anderson, 1990). One of the techniques used to uncover the cognitive structure of individuals is the word association test (WAT), which has been employed by many researchers over the years (Cachapuz and Maskill, 1987; Johnstone and Moynihan, 1985; Kaya and Akış, 2015; Kaya and Taşdere, 2016; Kempa and Nicholls, 1983; Kurt and Ekici, 2013a; Kurt and Ekici, 2013b; Preece, 1978; Shavelson, 1974). Researchers have shown that WAT is a powerful technique that can be used to reveal concepts in learners' minds and the connections between these concepts (Bahar, Johnstone and Sutcliffe, 1999; Bahar and Özatlı, 2003). However, the use of WAT in chemistry education is not widespread as in other fields of science.

A general look into studies that have used the word association test in chemistry education reveals that these fall into two groups. The first group deals only with establishing students' cognitive structure and is used after a topic is taught in chemistry in the form of a one-off application of a word association test. This type of study has been carried out on chemistry topics such as acids-bases, solutions, Le Chatalier's principle and the particulate structure of matter (Derman and Eilks, 2016; Kempa and Nicholls, 1983, Şendur et al., 2011). The second group of studies has been designed to reveal how students' cognitive structures change with instruction and in this, the word association test is administered twice--once before and once after the instruction. For example, Nakiboğlu (2008) implemented a word association test before and after instruction in his effort to examine how students' cognitive structures changed during the teaching process. Similarly, Cachapuz and Maskill (1987) studied the change in students' cognitive structures regarding the collision theory by making use of a word association test. The results obtained in both groups revealed that the word association test is extremely helpful in studying students' cognitive structures and that the process also provides the opportunity to not only determine students' alternative conceptions but also to examine the process of conceptual change.

These studies show that the word association test can readily be used to understand the connections in students' cognitive structures and to review their alternative conceptions, particularly in the context of subjects in chemistry that they find it hard to comprehend. In fact, in many studies conducted on students' conceptions, it has been shown that many students at different educational levels have difficulty understanding basic concepts in chemistry and harbor alternative conceptions about these topics (Demircioğlu, Ayas and Demircioğlu, 2005; Garnett et al, 1995; Nakhleh, 1992; Stieff and Wiliensky, 2003; Taber, 2002). It was particularly determined that students had difficulties in understanding some chemical concepts such as the mole concept, the atom, molecule, chemical equilibrium, chemical bonding, phase changing, acid-bases and electrochemistry (Bar and Travis, 1991; Griffiths and Preston, 1992; Novick and Nussbaum, 1981; Wheeler and Kass, 1978). Because chemical equilibrium forms a foundation for such topics as solubility, acids-bases and equilibrium, the subject of chemical equilibrium has acquired a central place in teaching chemistry. Accordingly, it is of vital importance that students' cognitive structures hold correct conceptions of chemical equilibrium and that they form meaningful associations between these.

Due to all of these reasons, it is apparent that there is a need to determine students' cognitive structures about chemical equilibrium prior to instruction and to further establish what in their cognitive structures may lead to alternative conceptions as well as to explore the change in this structure following the instruction.

The studies in the literature on chemistry education indicate that research on determining students' cognitive structures in the context of chemical equilibrium involve a limited number of concepts related to chemical equilibrium. For example, a study by Maskill and Cachapuz (1989) has focused on students' cognitive structures with respect to the concept of equilibrium but the word association test in this study was implemented only after the instruction. In another study, Cachapuz and Maskill (1989) used the word association test to determine students' cognitive structures with respect to Le Chatelier's principle.

When considered from this perspective, there is a need for studies that determine students' cognitive structures in the context of basic concepts related to chemical equilibrium and explore how changes are effected in these cognitive structures.

The Purpose of The Study

This study aims to employ the word association test to better understand students' cognitive structures regarding the topic of chemical equilibrium and to set forth how students' cognitive structures are affected by the teaching process. Toward this purpose, answers were sought to the following sub-problems:

- What concepts did the students have in their cognitive structures about the basic concepts related to the unit on chemical equilibrium before the instruction?
- Has there been a change in the students' cognitive structure regarding the basic concepts in the unit on chemical equilibrium after the instruction? If so, what kind of changes have there been?

Methodology

The research was designed as a one-group pre-test/post-test study. According to this design, before instruction, the Word Association Test (WAT) was applied as a pre-test in the group, after which the unit on equilibrium in chemical reactions began to be taught. Students in group were instructed based on Expository teaching strategy, The Word Association Test (WAT) was then repeated after the instruction as a post-test. The application stage in group was completed in 4 weeks (3 class hours a week)

Sample

The study sample included 30 eleventh-grade students who were studying in a secondary school in Izmir, Turkey. The research was approved by the ethics committee of the Institute of Educational Sciences at Dokuz Eylul University of Turkey. All students volunteered to participate in the study, and they had similar backgrounds. These students had attained similar scores on the national centralized exam and were also socioeconomically similar, coming from middle-class families. The ages of the participants were in the range of 15-16.

Instrument

In this study, the Word Association Test (WAT) was used as a measuring tool. WAT was administered as a pre-test and post-test to . To conduct the WAT, ten key terms considered as cornerstones of the conceptual framework of chemical equilibrium were selected by the researchers. These key terms acted as stimuli. These terms were *“equilibrium", "rate of forward reaction", "rate of reverse reaction", "catalyzer", "pressure", "molar concentration", "maximum disorder", "endothermic reaction", "exothermic reaction", "reversible reaction"*. Each stimulus term was placed at the top of the page and ten times down the side of the page. Students were asked to list the first 10 words that came to their mind for each key term in 30 seconds. The researchers kept track of the time allocated for each key term and students were told that they could pass onto the next key term after the end of 30 seconds, the limit for each key term. On average, pre- and post-WATs were completed in approximately 5 minutes.

To define the content validity of the WAT, the researchers analyzed the secondary school chemistry curriculum and the stimulus terms were determined. Afterwards, the stimulus terms that were chosen were shown to three chemistry educators for an expert's opinion; these experts stated that the terms that had been chosen were appropriate. Lastly, the WAT was piloted by the participation of 20 eleventh-grade students in order to determine whether there were any irregularities.

Analysis

The following consecutive steps were followed in the WAT analysis:

- Analyzing the response words for each stimulus word
- Counting the response words for each stimulus word and preparing a frequency table.
- Drawing of mind maps.

In the first stage of the data analysis, to ensure the reliability of the analysis, the first and second researchers independently reviewed the responses to each stimulus word/phrase to check whether they were meaningful. At this stage, responses that had no relation to the stimulus words were removed from the analysis. Later, the Miles and Huberman (1994) formula was used to calculate the percentage of agreement for the responses that the two researchers included in the analysis of the stimulus words. These percentages were respectively *equilibrium (93%), rate of forward reaction (90%), rate of reverse reaction (91%), catalyzer (91%), pressure (92%), molar concentration (92%), maximum disorder (94%), endothermic reaction (95%), exothermic reaction (92%), reversible reaction (94%).*

In the second stage of the analysis, the responses included in the analysis for each stimulus word were counted and frequency tables were drawn up. Some of the frequency tables prepared for the pre- and post-tests are shown in Table 1 and Table 2.

The last stage of the analysis consisted of mind maps that were drawn by using the frequencies of the response words to each of the stimulus words. Nakiboğlu (2008) particularly noted that the use of mind maps in WAT analysis was greatly useful in showing how students formed associations between their cognitive structures and concepts. While the mind maps were being constructed, firstly the highest frequency in the table was determined. The highest frequency interval cut-off point was taken as 20 and above in the first cell of the mind maps. Then the cut-off point was lowered step by step until all stimulus words appeared on the map (Bahar ve Tongaç, 2009; Nakiboğlu, 2008). As the mind maps were being constructed and the stimulus words were placed inside the frame, the response words were placed outside of the frame. Additionally, in order to show that the stimulus words and their responses had different frequencies, care was taken to make the thicknesses of the drawn arrows different. Similarly, the stimulus words with responses of higher frequencies were displayed in a thicker frame. If there were students' responses that could be interpreted as alternative conceptions, these were designated with dotted arrows. If a reciprocal relationship appeared in the stimulus word or in the responses on the mind map, this was shown with a two-way arrow.

Findings

The first research question was aimed at identifying students' cognitive structures about the basic concepts of chemical equilibrium before the instruction. Toward this aim, firstly, a frequency table was drawn up for the responses to the stimulus words in the pre-test. A summary of this table is presented in Table 1.

Table 1. A Sample Frequency Table from WAT Frequency Values Before Instruction

	Stimulus words									
Response words	Equilib.	Catalyz.	Pressure	Molar Concn.	Endothc React.	Exoth React.	Revers. React.	Max. Disorder	Rate of Forw. React.	Rate of Reve. React.
Weighing Scale	22	-	-	-	-	-	-	-	-	-
Equality	21	-	-	-	-	-	-	-	-	-
Cerebellum	17	-	-	-	-	-	-	-	-	-
Seesaw	6	-	-	-	-	-	-	-	-	-
Center of Weight	5	-	-	-	-	-	-	-	-	-
Activation Energy	-	13	-	-	-	-	-	-	-	-
Reaction	-	12	-	-	-	-	-	1	4	5
Rate	-	5	-	-	-	-	-	-	-	-
Piston	-	-	15	-	-	-	-	-	-	-
Gas	-	-	24	-	-	-	-	2	-	-
Manometer	-	-	22	-	-	-	-	-	-	-
	Stimulus words									
Response words	Equilib.	Catalyz.	Pressure	Molar Concn.	Endothc React.	Exoth React.	Revers. React.	Max. Disorder	Rate of Forw. React.	Rate of Reve. React.
Toricelli's Experiment	-	-	21	-	-	-	-	-	-	-
Volume	-	-	17	17	-	-	-	-	-	-
Air Pressure	-	-	12	-	-	-	-	-	-	-
Mercury	-	-	6	-	-	-	-	-	-	-
Turgor	-	-	4	-	-	-	-	-	-	-
Mole	-	-	-	21	-	-	-	-	-	-
Ion	-	-	-	15	-	-	-	-	-	-
Solution	-	-	-	5	-	-	-	-	-	-
Rate of Forward Reaction	-	11	-	-	-	-	-	-	-	-

Rate of Reverse Reaction	-	8	-	-	-	-	-	-	-	-
Temperature	-	-	-	-	16	15	-	-	-	-
Heat	-	-	-	-	22	20	-	-	-	-
Heat-Absorbing	-	-	-	-	24	-	-	-	-	-
ΔH>O	-	-	-	-	8	-	-	-	-	-
Energy	-	-	-	-	7	4	-	-	-	-
Heat-Releasing	-	-	-	-	-	22	-	-	-	-
Enthalpy	-	-	-	-	22	20	-	-	-	-
ΔH<O	-	-	-	-	-	8	-	-	-	-
Phase Changing	-	-	-	-	-	-	1	-	-	-
Melting-Freezing	-	-	-	-	-	-	1	-	-	-
Catalyzer	-	-	-	-	-	-	-	-	12	7

When the responses to the stimulus words in Table 1 are reviewed, it can be seen that the responses of weighing scale and equality for the key concept equilibrium, the responses of gas, manometer and Torricelli's experiment for pressure, the responses of temperature, heat-absorbing and heat-releasing for endothermic and exothermic reactions, and the response of mole to the stimulus phrase molar concentration displayed frequencies of 20 and above. Therefore, the first mind map was constructed with the responses at the highest frequencies, in other words, displaying a cut-off point of 20 and above (Figure 1).

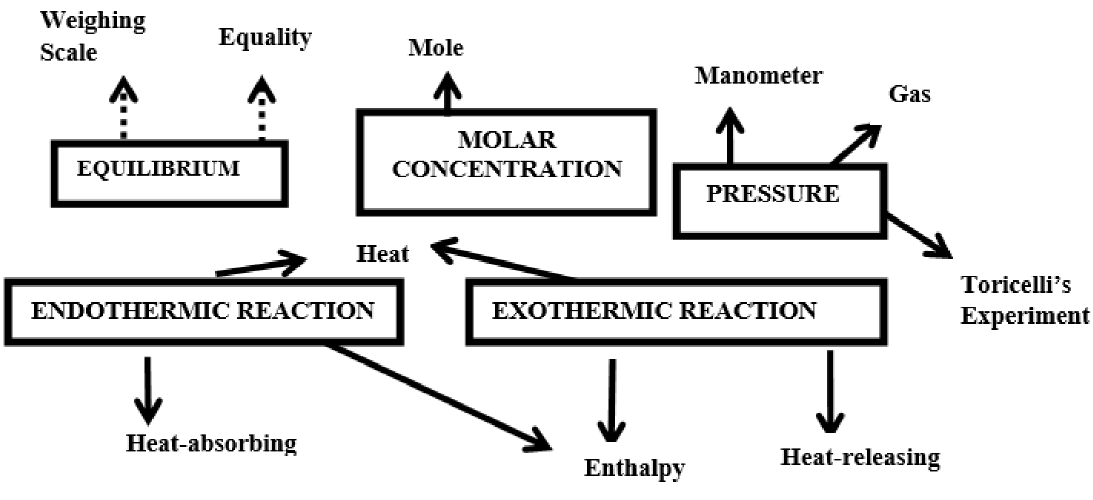

Figure 1. Cut-off Point 20 and Above Before Instruction

A review of the mind map in Figure 1 shows that the students' associating the concept of equilibrium with a weighing scale and equality was based on their experiences in daily life and how they associated the concept with physical phenomena. This association is particularly striking in that it reveals the possible alternative conceptions that the students may have had. Indeed, some research has shown that students perceive the point of chemical equilibrium as mass or mole/molarity equality in terms of reactants and products of a reaction, and that they do not sufficiently perceive the dynamic side of equilibrium (Hackling and Garnett, 1985; Huddle and Pillay, 1996). Furthermore, a study by Yıldırım et al. (2015) reports that students' perception of chemical equilibrium is "the kind of equilibrium that is found on a weighing scale in the process of weighing", which can lead to potential alternative conceptions In the mind map in Figure 1, alongside of the alternative concepts in the students' cognitive structures, there are also scientifically correct associations. Indeed, it can be seen that the relationships between molar concentration - mole, endothermic reaction - heat, endothermic reaction- enthalpy, exothermic reaction - heat, exothermic reaction and enthalpy are scientifically and correctly associated. Moreover, the associations students formed between "pressure-gas", "pressure-Toricelli" and "pressure-manometer" point to the meaningful connections that they have carried with them from the unit on gases. The reason that the associations had high frequencies may lie in the fact that the students had frequently encountered different types of manometers in their science classes since elementary school in their Toricelli’s experiment with air pressure and gas pressure during their were study of the topic of gases.

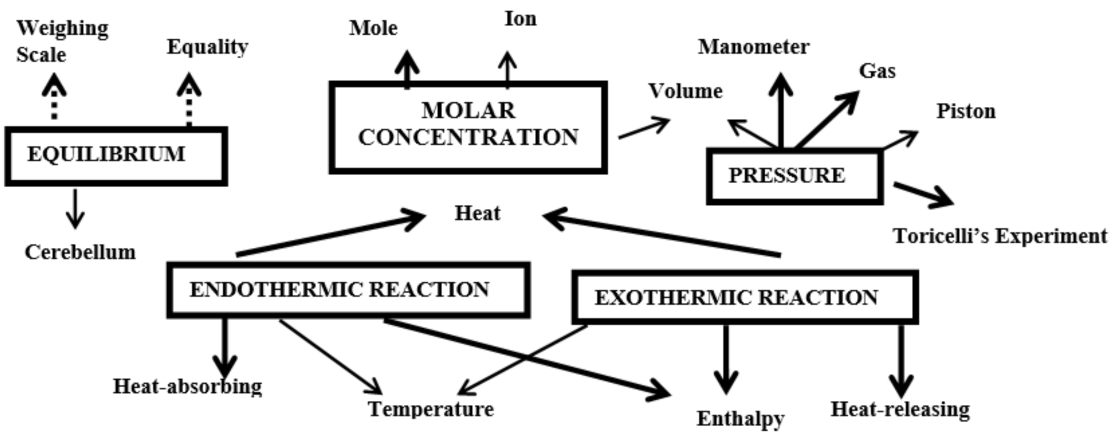

Figure 2. Cut-off Point 15-19 Before Instruction

The second mind map with a cut-off point at 15-19 is shown in Figure 2. The mind map in Figure 2, when compared with the mind map in Figure 1, shows that the stimulus words did not change but that the responses to these increased. For example, the stimulus word response "cerebellum" appeared in this mind map. That the students formed an association between the concept of "equilibrium" and "cerebellum" is significant in that this reveals meaningful associations that they had carried with them from their biology class. In the other stimulus words, it can be seen that the response "ion" was given to the stimulus phrase "molar concentration", which indicated that the students were able to form an association between the concept of "molar concentration" and "ion", a common and familiar element that they knew from the topic of solutions. Additionally, the students also provided the response "volume" to "molar concentration"; this was evidence that the students were able to make associations with their molar concentration calculations. A similar pattern was seen with the stimulus word "pressure"; the responses "piston" and "volume" were evidence of the meaningful associations that the students could make. Differing from the mind map in Figure 1, the students gave the response "heat" to both the stimulus phrases "endothermic reaction" and exothermic reaction". This may be considered a result of the students' associating these reactions with a change in temperature.

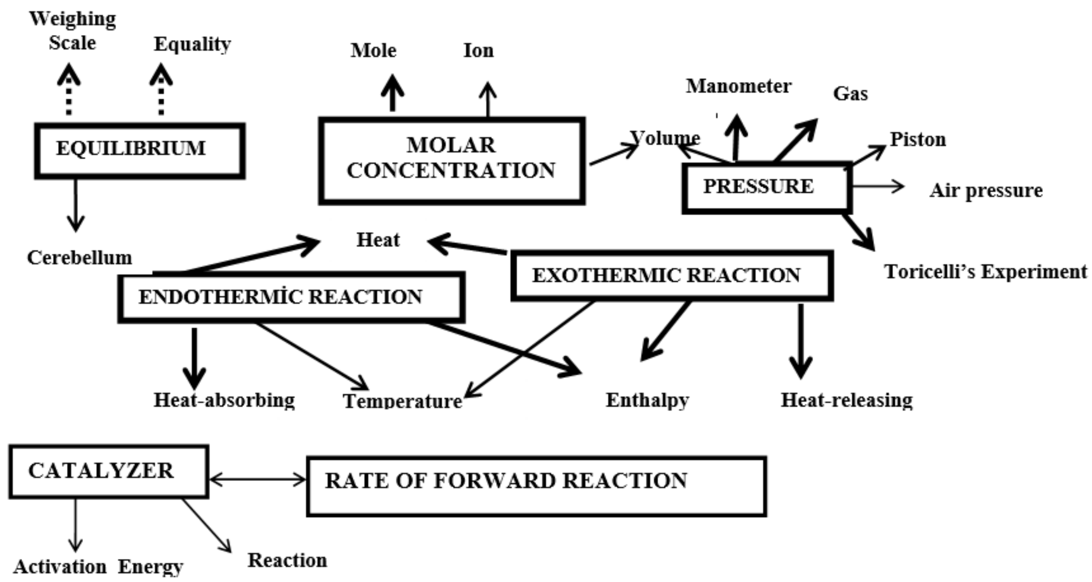

Figure 3. Cut-off Point 10-14 Before Instruction

In Figure 3, which shows the mind map for the cut-off point 10-14, it can be seen that two new stimulus words have been added as compared to Figures 1 and 2. One of these new stimulus words is "catalyzer"; the responses of "reaction" and "activation energy" given here indicate that the students have formed associations with the concepts taught in the context of the rates of chemical reactions. At the same time, another response to the stimulus word "catalyzer" was "rate of forward reaction". At this point, although the students have formed an association between "catalyzer" and "rate of forward reaction", it was interesting to see that they could not form a similar association with "rate of reverse reaction". This may be because the students considered the accelerating effect of catalyzers on the rate of forward reactions but did not give thought to the idea that the same effect held true as well for the rate of reverse reactions. In fact, some studies point to the fact that students think that catalyzers increase the rate of forward reactions but have the alternative conceptions that the same effect is not true of the rate of reverse reactions (Hackling and Garnett, 1985; Pedrosa and Dias, 2000). A mutual association was seen for the first time between two stimulus words in Figure 3. These two stimulus words were "rate of forward reaction" and "catalyzer". This showed that the students were able to form a two-way association between these concepts. When the other stimulus words in the mind map were reviewed, it was seen that with the exception of the stimulus word "pressure", there were no changes in the responses given to the other words. In the case of the stimulus word "pressure", the response of "atmospheric pressure" indicated that, as in the response of Toricelli's experiment, the students tended to form associations on the basis of their prior knowledge of atmospheric pressure.

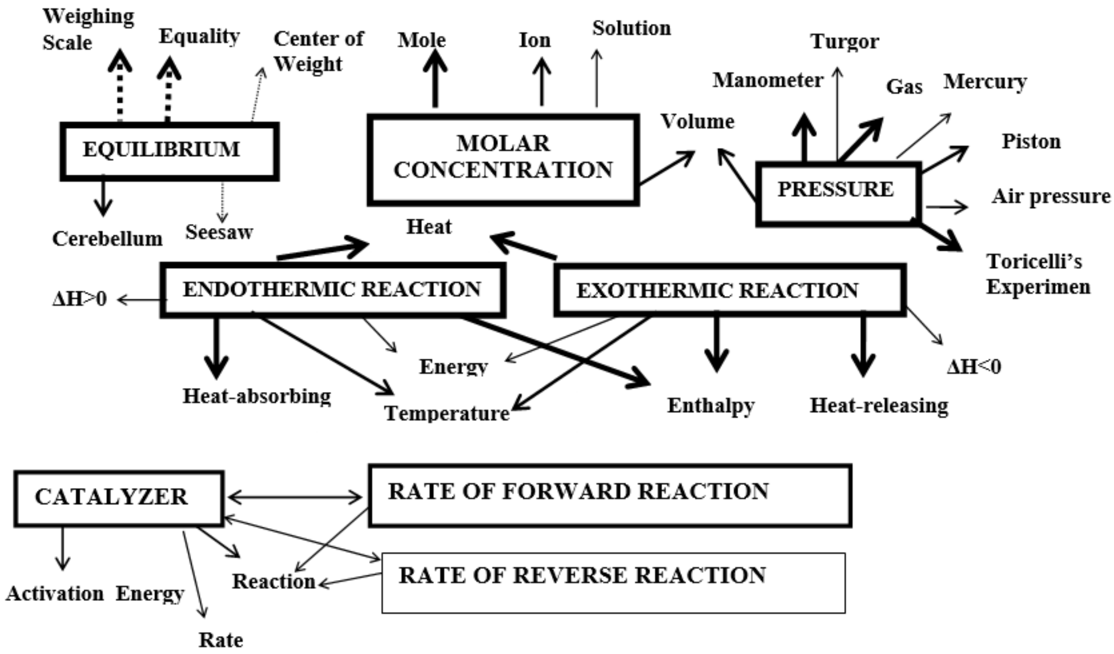

Figure 4. Cut-off Point 4-9 Before Instruction

Figure 4 displays the mind map for the cut-off point 4-9. According to this mind map, 8 of the 10 stimulus words have a place on this map. Differing from the other mind maps, the stimulus phrase "rate of reverse reaction" took its place on the map for the first time. When the students' responses to the stimulus phrase "rate of reverse reaction" are examined, it can be seen that, just as in the responses to "rate of forward reaction," the same responses of "reaction" and "catalyzer" were given. At the same time, again as in the "rate of forward reaction," two-way associations could be formed between the stimulus words "rate of reverse reaction" and "catalyzer". However, the cut-off point of this association was lower on the map, which may be an indication that the students found it easier to form an association between "catalyzer" and "rate of forward reaction" as compared to associating "catalyzer" and "rate of reverse reaction". Looking at the responses on the mind map given to the other stimulus words, it is observed that the responses are varied. For example, responses that showed that the students were able to form meaningful associations were the responses of "rate" for the stimulus word "catalyzer", "$\Delta H>0$" for "endothermic reaction", "$\Delta H<0$" for "exothermic reaction" and "solution" for "molar concentration". Furthermore, the responses of "center of weight" and "seesaw" for the stimulus word equilibrium showed once more that they treated the concept of equilibrium as a physical phenomenon. Another striking response the students gave was "turgor" for the stimulus word "pressure." This response shows that the students were familiar with and could make an association with the term "turgor pressure" which they knew from their biology classes.

To find an answer to the study's second sub-problem, "Has there been a change in the students' cognitive structures regarding the basic concepts in the unit on chemical equilibrium after the instruction? If so, what kind of changes have there been?" as in the analysis of the word association test administered before the instruction, a table containing the responses given to the stimulus words and their frequencies was drawn up; a section of this table is presented in Table 2.

Table 2. A Sample Frequency Table from WAT Frequency Values After Instruction

	Stimulus words									
Response words	Equilib.	Catalyz.	Pressure	Molar Concn.	Endothc React.	Exoth React.	Revers. React.	Max. Disorder	Rate of Forw.. React.	Rate of Reve. React.
Weighing Scale	4	-	-	-	-	-	-	-	-	-
K_c	21	-	-	-	-	-	-	-	-	-
Cerebellum	4	-	-	-	-	-	-	-	-	-
Equality	5	-	-	-	-	-	-	-	-	-
Reaction	20	15	-	-	-	-	-	-	-	-
Reactants	15	-	-	-	-	-	-	-	-	-
Products	20	-	-	-	-	-	-	-	-	-
K_p	15	-	5	-	-	-	-	-	-	-
Rate	-	22	-	-	-	-	-	-	-	-
Le Chatelier's Principle	7	-	-	-	-	-	-	-	-	-
Minimum energy	6	-	-	-	-	-	-	-	-	-
Forward Activation Energy	-	17	-	-	18	16	-	-	-	-
Reverse Activation Energy	-	16	-	-	16	15	-	-	-	-
Intermediate	-	5	-	-	-	-	-	-	-	-
Inhibitor	-	4	-	-	-	-	-	-	-	-
Air	-	-	17	-	-	-	-	-	-	-
Gases	-	-	22	-	-	-	-	6	-	-
Manometer	-	-	20	-	-	-	-	-	-	-
Toricelli’s Experiment	-	-	5	-	-	-	-	-	-	-
Volume	-	-	22	20	-	-	-	-	-	-
Piston	-	-	23	-	-	-	-	-	-	-
Mercury	-	-	5	-	-	-	-	-	-	-
Turgor	-	-	5	-	-	-	-	-	-	-
Air pressure	-	-	8	-	-	-	-	-	-	-
Osmotic	-	-	4	-	-	-	-	-	-	-
Mole	16	-	-	22	-	-	-	-	-	-
Rate of forward reaction	12	12	-	13	-	-	5	-	-	-
Rate of reverse reaction	5	10	-	11	-	-	4	-	-	-
Temperature	6	-	-	-	23	21	-	-	-	-
Heat-absorbing	-	-	-	-	24	-	-	-	-	-

	Stimulus words									
Response words	Equilib.	Catalyz.	Pressure	Molar Concn.	Endothc React.	Exoth React.	Revers. React.	Max. Disorder	Rate of Forw. React.	Rate of Reve. React.
Heat-releasing	-	-	-	-	-	22	-	-	-	-
Heat	-	-	-	-	22	21	-	-	-	-
Enthalpy	-	-	-	-	16	15	-	-	-	-
ΔH<0	-	-	-	-	-	22	-	-	-	-
ΔH>0	-	-	-	-	21		-	-	-	-
Energy	-	-	-	-	6	7	-	-	-	-
Combustion	-	-	-	-	-	4	-	-	-	-
Melting	-	-	-	-	5	-	-	-	-	-
Ion	-	-	-	4	-	-	-	-	-	-
Solution	-	-	-	4	-	-	-	-	-	-
Equilibrium	-	-	-	6	-	-	6	5	11	5
MW	-	-	-	5	-	-		-	-	-
Mass	-	-	-	4	-	-		-	-	-
Phase Changing	-	-	-	-	-	-	7	-	-	-
Reversible Reaction	4	-	-	-	-	-	-	-	6	4
Molar Concentration	7	-	-	-	-	-	-	-	12	10
Maximum Disorder	7	-	-	-	-	-	-	-	-	-
Minimum Energy	-	-	-	-	-	-	-	8	-	-
Catalyzer	-	-	-	-	-	-	-	-	13	12

A review of Table 2 shows that the responses to the six stimulus words (equilibrium, pressure, molar concentration, catalyzer, endothermic and exothermic reaction) with the highest frequencies were those with frequencies of 20 and above. Because of this, as in the mind maps for before the instruction, the cut-off point on the first mind map was taken to be 20 and above to accommodate the highest frequency values (Figure 5).

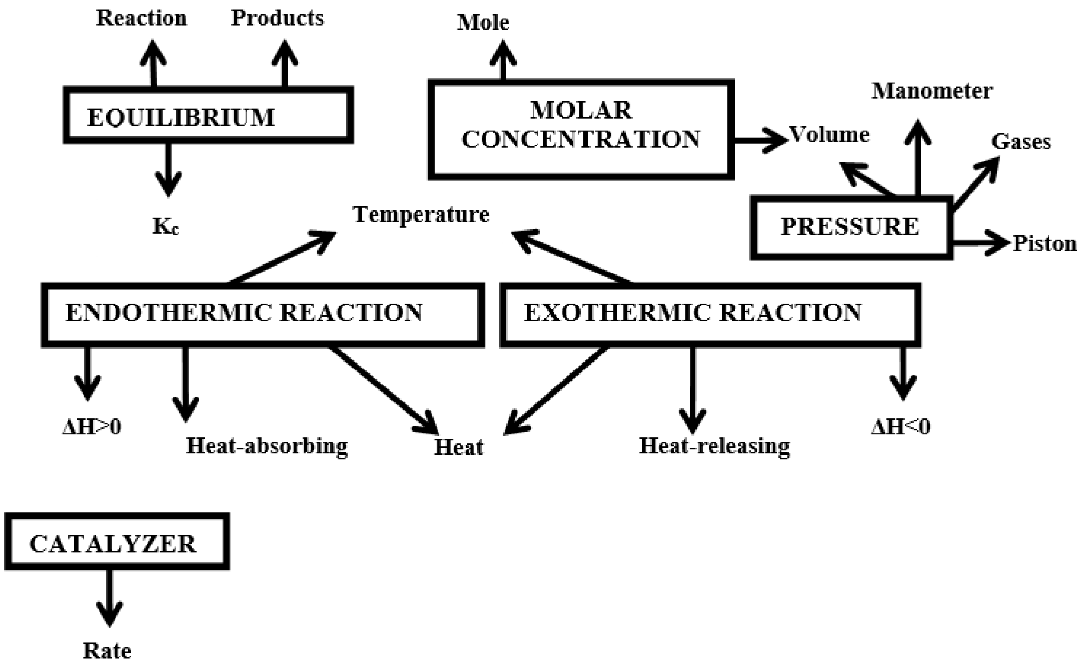

Figure 5. Cut-off Point 20 and Above After Instruction

Examining the mind map in Figure 5 containing the strongest associations between the concepts, it can be seen that 6 stimulus words have found their place on this map. Among the stimulus words, the responses given to the concept of equilibrium, that is, "reaction," "products" and "equilibrium constant," show that the students' cognitive structures have changed and that what was perceived as physical equilibrium has now been associated with chemical equilibrium. This result shows that the most conspicuous change that occurred in the students' cognitive structures took place with respect to the concept of equilibrium. When the other stimulus words on the mind map are reviewed, it can be seen that the responses given were almost exactly the same as the pre-instruction mind map. The only difference is that the responses for some stimulus words have a higher frequency on this mind map. For example, the responses of "volume" for "molar change", "piston" and "volume" for "pressure", "ΔH>0", "ΔH<0", "heat" for "endothermic" and "exothermic reactions" had higher frequencies. Another pronounced difference in the mind map in Figure 5 as compared to the pre-instruction mind map in Figure 1 is that the stimulus word "catalyzer" has taken its place on this mind map. The fact that the students responded to the stimulus word "catalyzer "with "rate" is indicative of how the students were able in their cognitive structures to form a strong association between "catalyzer" and its impact on the rate of reaction.

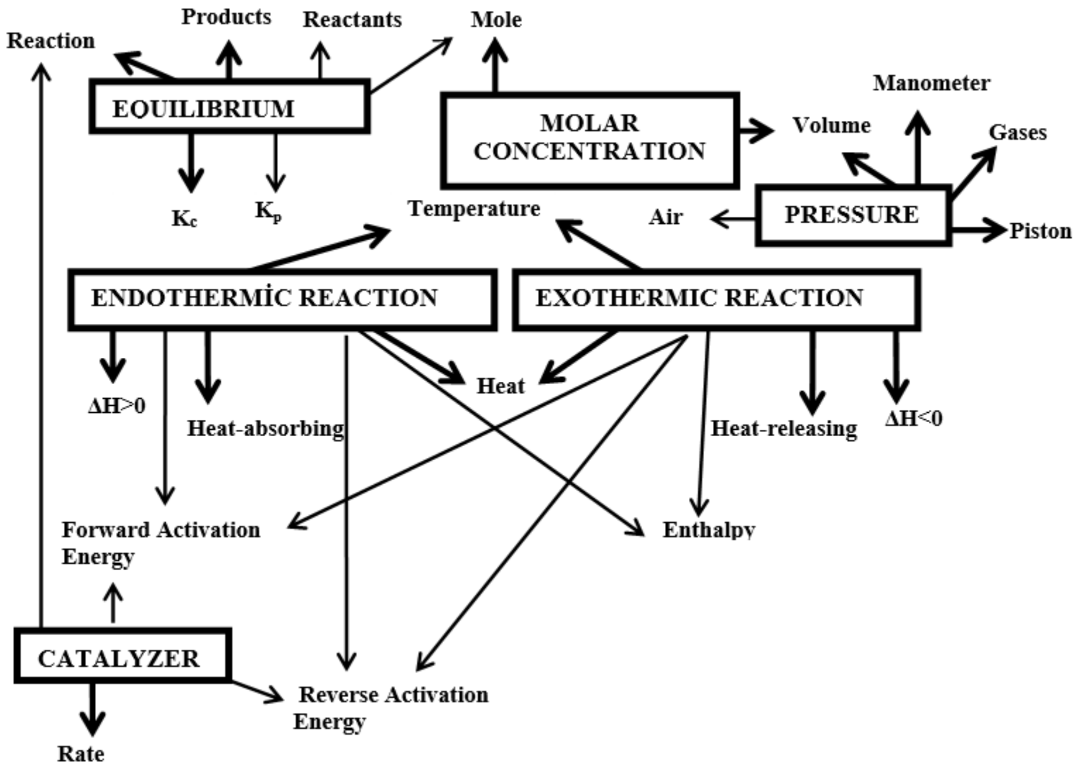

Figure 6. Cut-off Point 15-19 After Instruction

Figure 6 displays the mind map for the cut-off point interval of 15-19. When examined, the mind map indicates that the number of stimulus words did not change compared to the mind map for the cut-off point 20 and above but that the responses given to the stimulus words have increased. The fact that the responses given to the stimulus word "equilibrium" are basic concepts that are frequently encountered in the unit on chemical equilibrium (Kp, reactants, mole) is an indication that the students were able to form meaningful relationships. At the same time, when compared with the pre-instruction mind map in Figure 2, this mind map shows that the students are now considering the concept of equilibrium not as a physical phenomenon but as a chemical one. Looking at the other responses to the stimulus words on the mind map, it can be seen that the responses are diverse. In particular, the appearance of the responses "forward" and "reverse activation energy" to the stimulus word "catalyzer" shows that the students were able to draw an association between catalyzer and both types of activation energy.

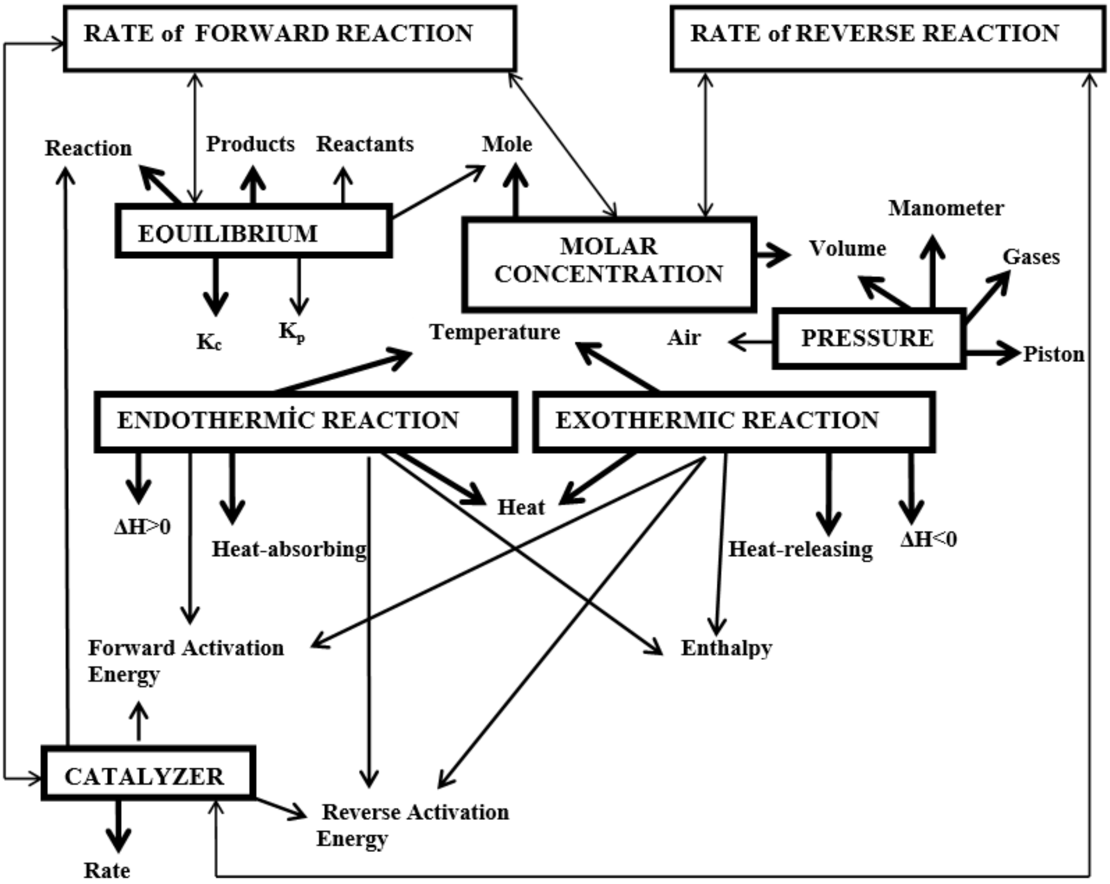

Figure 7. Cut-off Point 10-14 After Instruction

In the third mind map relating to post-instruction, shown in Figure 7, the cut-off point was determined as 10-14. In this mind map, which differs from the mind map in Figure 6, it is observed that both the number of stimulus words and the responses to these have increased. In fact, the stimulus words "forward" and "reverse reaction rates" appear on this mind map for the first time. While from these stimulus words, an association has been drawn between "forward reaction rate" and the concept of" equilibrium", it is interesting that a similar relationship could not be established for "reverse reaction rate". On the other hand, a reciprocal relationship has been set up between the stimulus words "mole" and "catalyzer" and both "rate of forward" and "rate of reverse reaction". Comparing the mind map in Figure 7 with the mind map in Figure 3, which represents the same cut-off point as at pre-instruction, we can see that the responses given to the stimulus words contain more instances of the dimension of chemical equilibrium and also differences in cognitive structures about the concept of "rate". For example, only the stimulus words "rate of forward reaction" appears in the mind map in Figure 3 and the response to this is "catalyzer". After the instruction however, the stimulus phrase "rate of reverse reaction" appears alongside of "rate of forward reaction" and a two-way association is formed for these with both "catalyzer" and "molar concentration". This may have resulted from the fact that during the teaching of the topic of equilibrium in chemical reactions, the topics of rates of forward and reverse reactions had been taken up again.

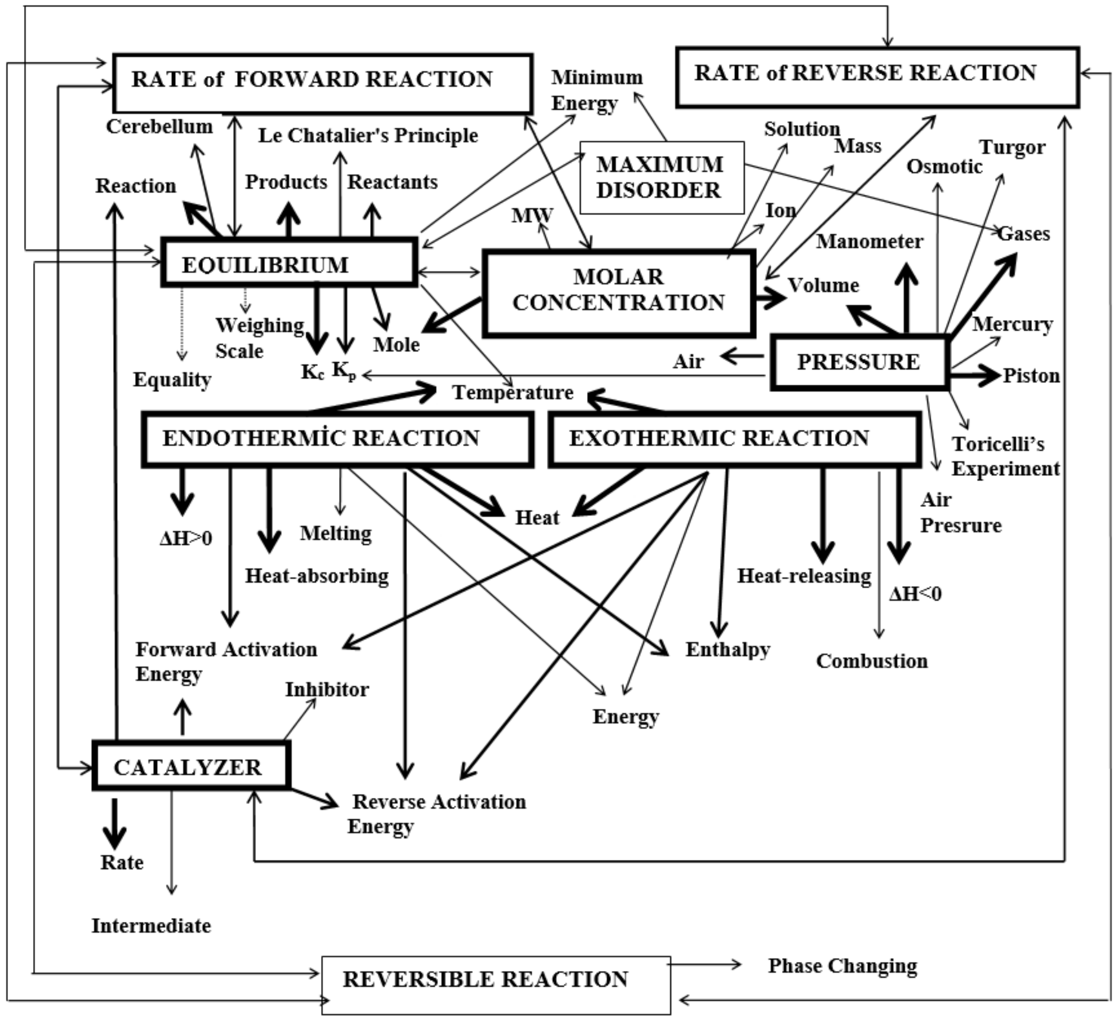

Figure 8. Cut-off Point 4-9 After Instruction

The last mind map pertaining to post-instruction is given in Figure 8. A review of Figure 8 shows that all of the stimulus words given to the students are present in this mind map. In particular, it is striking to see that the two sets of stimulus words representing the concepts of "maximum disorder" and "reversible reaction" have found their way to this mind map for the first time. The responses of "minimum energy" and "equilibrium" given to the stimulus words "maximum disorder" indicates that the students were able to form the mutual relationship between "maximum disorder" and "minimum energy" tendencies at the point of equilibrium. The students at the same time associated the gaseous state of a substance with its state of disorder. The students were also able to form a reciprocal relationship between the other stimulus words, the concept "reversible reaction", and both the "rates of forward and reverse reactions". This points to the fact that students are aware of the relationship between the equal forward and reverse reaction rates at the point of equilibrium. One of the responses the students gave for the "reversible reaction" concept was “phase changing". Looking at the responses given to the stimulus phrases "rate of forward" and "rate of reverse reaction", contrary to the mind map in Figure 8, it can be seen that an association has been formed between the concept of equilibrium and the rate of reverse reaction. The responses given to the stimulus word equilibrium include not only Le Chatelier's principle, molar concentration, heat and other concepts related to chemical equilibrium but also indicate that the students have treated equilibrium as a physical phenomenon. For example, the response of "scale" and "equality" that appeared on the mind maps pertaining to before the instruction also appeared on this mind map. This indicates that the structures in a student's cognitive structure are not easy to change (Nakhleh, 1992). Another response to the concept of equilibrium was "cerebellum". This response had been given before the instruction as well, which shows that the tendency to connect the concept of equilibrium to biological systems still continues. Examining the response given to the stimulus word "pressure", we can see that while the response Kp has been given in connection with equilibrium, the other responses appear to be concepts that the students are familiar with from both their biology course (osmotic pressure) and from the topic of gases (atmospheric pressure, mercury). The responses given to the stimulus words "molar concentration" (solution, ion, mole, volume, MW, etc.) shows that the students were able to form a relationship with their calculations of molar concentration. Another stimulus word that produced different responses compared to the other mind maps was the stimulus word "catalyzer". The students responded to this word with "inhibitor" and "intermediate" In answer to the words "endothermic" and "exothermic", however, differing from the other mind maps, the responses "melting" and "combustion" were given. In short, the mind map in Figure 9 displayed a greater number of responses to stimulus words compared to the mind maps belonging to the period after the instruction, and it was seen that there were more connections formed between the stimulus words. When compared with the mind map with the same cut-off points belonging to the period before the instruction (Figure 4), the mind map in Figure 9 showed in particular that the concept of equilibrium was more commonly associated with chemical equilibrium and that concepts such as maximum disorder, minimum energy took their places on this mind map.

Results and Discussion

This study, which aimed at determining how the cognitive structures of 11th-grade students changed with respect to the topic of chemical equilibrium, applied the word association test twice as a data collection tool, once before and once following the instruction.

In line with the first sub-problem of the study, WAT was first of all implemented 3 weeks prior to the instruction in order to ascertain the students' cognitive structures with regard to basic concepts. According to the results of the analysis of the pre-instruction WAT, the mind maps with the different cut-off points determined in line with the results showed that the students regarded particularly the concept of equilibrium as a phenomenon referring to physical equilibrium. This is supported by the fact that in the mind map in Figure 1, which features the strongest connections (cut-off point>20), the concept of equilibrium received the responses of "weighing scale" and "equality." In fact, there are many studies in which it is reported that students have the tendency of conceptualizing chemical equilibrium in terms of a physical phenomenon, leading to the creation of alternative conceptions (Griffiths, 1994; Hackling and Garnett, 1985; Huddle and Pillay, 1996). For this reason, the responses on the mind map have been indicated in dotted arrows to differentiate their potential of causing alternative conceptions. A review of the other mind maps where there are weaker connections shows that the new responses given to the concept of equilibrium also have been associated with physical equilibrium. For example, in the mind map where the cut-off point is 4-9, the responses of "seesaw" and "center of weight" to the concept of equilibrium are indicative of this.

These findings point to the need for assessing students' prior knowledge before instruction. Indeed, Ausubel (1968) asserts that determining the extent of prior knowledge students have before an instruction is of vital importance for the teaching process. Similarly, Nakiboğlu (2008) has pointed to the fact that becoming aware of students' cognitive structures before instruction will lead to meaningful learning and help in planning the teaching process. It can be seen from the mind maps pertaining to before the instruction that even the mind map in Figure 4, where the cut-off point 4-9 indicates the weakest associations, does not contain all of the stimulus words. The fact that the stimulus phrases "maximum disorder" and "reversible reaction" cannot be found on the mind maps pertaining to before the instruction may be an indication that these concepts are still abstract for the students or they do not find it as easy to make connections compared with the other concepts. The results of many other studies show that students find it hard to understand the concept of disorder and that they have alternative concepts for this and for the concept of entropy (Sözbilir and Bennett, 2007). A point that is striking in the mind maps pertaining to before the instruction is that the responses the students gave to the stimulus words show their tendency to link these words to their biology course. The response of "cerebellum" for the concept of equilibrium, the answer "turgor" for "pressure" are examples of this.

By implementing WAT after the instruction in the light of the second sub-problem, this study sought to compare the students' cognitive structures concerning chemical equilibrium with their cognitive structures before the instruction. In keeping with this objective, mind maps were prepared with the same cut-off points as before the instruction. An examination of the first of these maps in Figure 5, the one with the strongest associations, reveals that the students offered responses that showed that their associations pertaining to the concept of equilibrium were no longer physical but chemical. The responses of "Kd", "reaction" and "products" for the concept of equilibrium indicate this. This mind map at the same time differs from the mind map belonging to before the instruction in that it has more stimulus words and more responses. Looking at the other mind maps in Figure 6 and Figure 7 respectively, we can see that the responses to the stimulus word equilibrium were "reactants", "Kp", "rate of forward reaction", "mole" and the responses to the stimulus phrase "rates of forward and reverse reactions" were "molar concentration" and "catalyzer" among others; this was evidence of the change in the students' cognitive structures. In addition, these mind maps also indicate that more reciprocal relationships were formed with the stimulus words compared to before the instruction. It can be seen that the last mind map pertaining to after the instruction (Figure 8), contains all of the stimulus words given in WAT. The stimulus concepts that did not appear in the mind maps pertaining to before the instruction, "reversible reaction" and "maximum disorder" received the response "equilibrium"; the fact that an association could be formed between these concepts shows that the associations had been formed, albeit weakly, in the students' cognitive structures. At the same time, the responses of "Le Chatelier's principle" and "minimum energy" for the stimulus concept "equilibrium" shows how the students made the association with chemical equilibrium in their cognitive structures. In addition, the responses to the other stimulus words were decidedly more that before the instruction and it was seen that more reciprocal relationships could be formed.

This result indicates that, with regard to the basic concepts of chemical equilibrium, compared to before the instruction, the students were able to form new connections that were associated with each other instead of offering independent and isolated structures. These findings reveal that the instruction helped to create a positive effect on the students' cognitive structures. Similar results were reported in other studies (Cachapuz and Maskill, 1987; Nakiboğlu, 2008).

Although it was determined through the mind mapping analysis of the students' cognitive structures that they had formed more scientific associations after the instruction compared to before the instruction, the associations recorded before the instruction which had the potential of causing alternative conceptions were not encountered after the instruction. For example, the responses of "scale" and "equality" to the stimulus word "equilibrium" appeared in the mind map in Figure 8, which contained the weakest associations. This result showed that the tendency of the students to treat the concept of equilibrium as a physical phenomenon continued after the instruction but that the association formed then was not as strong as before. At the same time, the results showed, as Nakhleh (1992) also reported, that students resisted making a change in their prior knowledge.

All of these findings may be enlightening and helpful to both teachers and curriculum developers in terms of understanding how the word association test affects the cognitive structures of 11th-grade students regarding the basic concepts taught in the unit on chemical equilibrium. It would however be more useful to implement the word association test together with other techniques in order to more clearly set forth possible alternative conceptions that students may have. In this context, for example, asking students to compose sentences containing the stimulus words and the responses they give to these words, conducting interviews with students or using the technique of thinking aloud may be beneficial in this process.

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