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Investigating Cognitive Structures in Some Basic Chemistry Concepts Via Word Association Test

Kelime İlişkilendirme Testi Aracılığıyla Bazı Temel Kimya Kavramları Konusundaki Bilişsel Yapının Araştırılması

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ABSTRACT. In this study it was aimed to investigate cognitive structures of pre-service science teachers in some basic chemistry terms via word association test. Data were analyzed according to the number of responses to each key word in the word association test and concept maps were drawn according to frequencies as well as relatedness coefficient. Results of this study showed that participants' strongest part of cognitive structures within the given keywords was "compound-molecule" relation and they have weaknesses/difficulties in "ion" concept. It can be said that the abstract feature of the given concepts and the difficulties on understanding of macro and micro relations were effective on these results. Besides, according to sentence analysis participants were most likely to "define" and "describe" the knowledge but have difficulties on "comparing" and "interpreting" the knowledge. This study was conducted at the beginning of the chapter and cognitive structures of the pre-service science teachers were explored. Therefore course can be designed according to the findings of the study.
Keywords. Cognitive Structure, Basic Chemistry Terms, Word Association Test

ÖZ. Bu çalışmada kelime ilişkilendirme testi kullanılarak fen bilgisi öğretmen adaylarının bazı temel kimya kavramları hakkındaki bilişsel yapılarının ortaya çıkarılması amaçlanmıştır. Veriler testteki her bir anahtar kelimeye verilen cevap kelime sayısına göre değerlendirilmiş ve hem frekans hem de ilişkililik katsayısına bağlı olarak çizilen kavram haritalarına göre analiz edilmiştir. Çalışmanın sonuçlarına göre katılımcıların verilen temel kavramlar ile ilgili bilişsel yapılarının en güçlü kısmının "bileşik-molekül" ilişkisi olduğu, en fazla ise "iyon" kavramı ile ilgili zayıflıklarının/eksikliklerinin bulunduğu belirlenmiştir. Bu sonuçlarda kavramların soyut oluşu ve öğrencilerin makro ve mikro ilişkileri iyi özümseyememelerinin etkili olduğu düşünülmektedir. Ayrıca katılımcıların yazdığı cümlelerin analizine göre katılımcılar bilgiyi en çok "tanımlayabilmekte" ve "betimleyebilmekte" iken, bilgiyi "kıyaslama" ve "yorumlama"da eksiklikleri vardır. Çalışma konunun başlangıcında uygulanmış ve kelime ilişkilendirme testi ile katılımcıların bilişsel yapıları ortaya konmuştur. Elde edilen verilere göre dersin tasarlanabileceği belirtilmiştir.
Anahtar Kelimeler. Bilişsel Yapı, Temel Kimya Kavramları, Kelime İlişkilendirme Testi

INTRODUCTION

One of the major concerns of science educators is to enlighten "how we learn?" All the students in a class may construct the new knowledge in different ways although the same teacher teaches them. This is because the students may have different backgrounds and experiences and knowledge about the topic. According to the constructivist approach students can only make sense of new situations in terms of their existing understanding and learning is an active process in which students link the new knowledge to their existing knowledge (Naylor & Keogh, 1999).

The hypothetical construct representing the organization and relationships of concepts in a learner's long-term memory can be defined as cognitive structure (Tsai, 2001; Tsai & Huang, 2002) and it is the dominant determinant for the reconstruction of incoming stimuli (Tsai, 2001). Cognitive structure provides a stable and organized framework to construct new knowledge (Anderson, Randle, & Covotsos, 2001). Therefore by exploring students' cognitive structures, educators can have an insight to "how learning occurs". Investigation of the organization and the relations between student's concepts

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can give information about their organization of knowledge. Therefore educators can get a chance to create better learning environments (Atabek-Yigit, 2015).

There are many methods, i.e., word associations, tree construction, concept map, flow map, structured grids, drawings and explanations (Tsai & Huang, 2002), mind map (Dhindsa, Kasim, & Anderson, 2011), open-ended questions, multiple-choice questions (Bishop & Anderson, 1990), to explore the cognitive structure of individuals. Among these, word association test (WAT) is one of the oldest, simplest and most used method. In this method it is assumed that there is a relation between the responses to any given keyword and the links in the cognitive structure of the students (Bahar & Özatlı, 2003). Word association tests have been used in many studies to investigate the cognitive structures of students (Kostova & Radoynovska, 2008; Kurt & Ekici, 2013; Aydın & Taşar, 2010; Bahar & Özatlı, 2003; Bahar, Johnstone, & Sutcliffe, 1999; Özata-Yücel & Özkan, 2015) as well as to determine the misconceptions (Ercan, Taşdere, & Ercan, 2010; Özata-Yücel & Özkan, 2015) and to evaluate the conceptual change (Hovardas & Korfiatis, 2006; Nakiboğlu, 2008; Ercan, Taşdere, & Ercan, 2010). Most of the studies using WAT were in the field of science (Kostova & Radoynovska, 2008; Hovardas & Korfiatis, 2006; Nakiboğlu, 2008; Bahar & Özatlı, 2003; Bahar, Johnstone, & Sutcliffe, 1999) but there are also studies using WAT in social sciences (Işıklı Taşdere & Goz, 2011). The studies in the literature using WAT have been mostly conducted to high school students (Bahar & Özatlı, 2003; Özatlı & Bahar, 2010), primary school students (Kostova & Radoynovska, 2008; Ercan, Taşdere, & Ercan, 2010; Özata-Yücel & Özkan, 2015), pre-service teachers (Hovardas & Korfiatis, 2006; Nakiboğlu, 2008; Aydın & Taşar, 2010; Bahar, Johnstone, & Sutcliffe, 1999; Kurt & Ekici, 2010) and teachers (Kostova & Radoynovska, 2008).

In the application of a WAT, stimulus words, to act as stimuli, are chosen and participants are asked to respond to keyword within a specified time limit with the first word that come to their mind. In a word association test, the degree of overlap of response hierarchies is a measure of the semantic proximity of the stimulus words (Bahar & Hansell, 2000). Retrieval time for concepts depend on how closely they are related to each other. In other words if two concepts are closely related to each other they need less time to retrieve. Therefore the order of the responses to a given stimulus word is an important factor of the cognitive structure. The data obtained by WAT can be evaluated from different perspectives. First of all, the number of responses to any given keyword is an important parameter since it shows if the word is understood or not by the person (Bahar, Johnstone, & Sutcliffe, 1999). The more the meaning of a word is the more the responses i.e. more linkages to different words, in an individuals' cognitive structure. There may be matching responses between two different keywords and this shows the associations between the concepts in individuals' cognitive structure. Relatedness coefficient (RC), which is attempted to a formula by Garskoff and Hudson (Bahar, Johnstone, & Sutcliffe, 1999), is the relation between two concepts (Özata-Yücel & Özkan, 2015) or a measure of commonality (Bahar, Johnstone, & Sutcliffe, 1999). If responses to two keywords were the same words in the same order then the relatedness coefficient would have the value of 1, the perfect relatedness i.e., a synonym. At the opposite end if two keywords did not have any common responses, i.e. no overlapping between them, then the relatedness coefficient would have the value of 0 (Bahar, Johnstone, & Sutcliffe, 1999; Özata-Yücel & Özkan, 2015). Once the data obtained through a word association test, according to these data students' cognitive structure can be visualized by concept maps. Bahar, et al. (1999) have suggested a cut-off point technique to draw the concept map. According to this technique, a number that is 3-5 less than the most frequent response to any stimulus word is chosen as cut-off point and the frequencies bigger than that point is drawn in the map and then cut-off point is lowered step by step until all the stimulus words appear in the map. It is also possible to draw the map using RC values instead of frequencies.

There are studies in literature, which revealed that students have misconceptions and difficulties in learning some basic chemistry topics. For instance Taber (2001) stated that students have difficulty in learning about atomic structure and confusing the label of concepts such as atom, ion, molecule and element. According to Gabel (1999) students have difficulties learning basic chemistry subjects as they

are very abstract and are inexplicable without the use of analogies and models which should be resort the explanations.

The aim of this study is to investigate the cognitive structures of pre-service science teachers in some basic chemistry concepts through word association test. Basic chemistry concepts were chosen as study topic since most of the students have misconceptions and difficulties about the basic concepts and it is important to determine the cognitive structures of the students about that concepts in order to design a better educational setting for courses. The stimulus words in this study (atom, element, compound, ion and molecule) were chosen by examining the first chapters, since the rest of the chapters are constructed on these concepts, of some basic chemistry books, which are also the references for the course in which the participants were enrolled. In Turkey, basic chemistry concepts (as a part of "science class" where chemistry, physics and biology courses are integrated) are given to students in primary school by science teachers. Therefore participants of this study were chosen as pre-service science teachers as they will be teaching the basic concepts. This study was conducted before the instruction since it was aimed to determine the cognitive structures of the participants and design learning environment accordingly.

METHOD

Participants

This study was conducted in General Chemistry I course at a university located at northwest of Turkey. All the students in the class were informed about the study (aim, design and procedure) and 85 of them accepted to participate to the study voluntarily.

Instrument

Data of the study were obtained through word association test. For the development of the word association test, first chapters (with a name of "Introduction", "Getting Started" or "Basic Terms") of all three General Chemistry textbooks (Atkins & Jones, 1997; Hill & Petrucci, 1999; Brown, LeMay, & Bursten, 1991), which are also references for this course, were examined. Then, five basic chemistry terms namely atom, ion, element, compound and molecule were chosen as stimulus words to act as stimuli. These terms are the ones on which the chemistry science founded and students are supposed to learn them very well to understand the course. In order to establish the content validity of the instrument an instructor, other than the author, in the field of chemistry education has also reviewed the books and discussed for the stimulus words. After determination of stimulus words, word association test was formed. Stimulus words were written ten times down the side of the page since it was aimed to prevent the *chain effect* that is the distraction from the stimulus word (Nakiboğlu, 2008) or becoming each response rather than the stimulus word for the next response (Bahar, Johnstone, & Sutcliffe, 1999). There were blanks after each word on the paper for participants to respond. Each stimulus word was given on a separate page and each page was given to participants once at a time. At the end of each page there was space for participants to write a "related sentence" about the stimulus word. Since writing "a sentence" is more complex and requires higher order thinking skills in comparison to "a word", it would give better inside to the cognitive structure (Ercan, Taşdere, & Ercan, 2010).

Data collection and procedure

Before the actual administration of word association test, a pre-administration procedure was followed in order the participants to understand the data collection instrument and the procedure. For this reason two pages with stimulus words (different from the actual test) were given to the participants one at a time and they were asked to respond to the stimulus words with the first word that come to their minds in 1 min. time period. After completing this period and all the participants were done, the

administration was accomplished. There were five pages of the test each having one stimulus word on it and each page was given at a time. Pre-service science teachers were given 1 min to complete each page and therefore a total of 5 min has spent for the administration of the instrument.

Analysis of data

Data obtained through word association test were analyzed as following. Firstly, the responses for each participant to each stimulus word were examined and a list of response words was formed. After that a frequency table was produced. Also, number of different responses to each stimulus word was counted and tabulated. Number of different responses to stimulus word is an important parameter since there is a positive relation between understanding a term and the number of response words that linked to that term.

Relatedness coefficient, which is the indicator of the commonality of two stimulus words, was calculated for each participant and for each pair of the stimulus words. Then overall relatedness coefficients were determined. For the calculation of relatedness coefficient the formula attempted by Garskoff and Houston (Bahar, Johnstone, & Sutcliffe, 1999) was used.

$$Relatedness\ Coefficient\ (RC) = \frac{\sum A.B}{\sum n^2 - 1}$$

where,

A is the rank order of occurrence of words under A which are in common with B

B is the rank order of words in B, which are shared in A.

n is the number of responses under A or B which has more responses.

An example to the calculation of relatedness coefficient is given below. The response words to stimulus words "element" and "molecule" for a participant were given in Table 1.

Table 1. *An example of a participant's responses and rank orders to stimulus words "Element" and "Molecule"*

Stimulus word: Element		*Stimulus word: Molecule*	
Response	Rank order	Response	Rank order
Pure substance	10	Atom**	7
Oxygen*	9	Compound	6
Hydrogen	8	Element	5
Atom**	7	Bond	4
Symbol	6	Water	3
Magnesium	5	Gas	2
Iron	4	Oxygen*	1
Chlorine	3		
Iodine	2		
Bromine	1		

/ Overlapping responses for two stimulus words*

Firstly, rank orders of responses were determined and the lower one was considered as 1. Then overlapping responses were found and rank orders of overlapping responses were multiplied and summed. After that the result was divided by the maximum number of responses under these stimulus words.

$$RC = \frac{(9x1) + (7x7)}{10^2 + 9^2 + 8^2 + 7^2 + 6^2 + 5^2 + 4^2 + 3^2 + 2^2 + 1^2 - 1} = 0.151$$

Once relatedness coefficients were obtained for each pair of stimulus words for each participant, overall relatedness coefficients were calculated and tabulated.

Participants' cognitive structure was visualized by concept map, which was drawn by using relatedness coefficients. Concept map was also drawn by using frequencies of the responses instead of relatedness coefficients.

Each participant was asked to write a related sentence for each stimulus word in word association test. The response sentences were analyzed as follows: firstly sentences were categorized into three classes, which are correct scientific knowledge, i.e., correct definition or use of the term; misconception, i.e., incorrect scientific explanation; and irrelevant or meaningless, i.e., sentences that are off-topic. Then, sentences were examined from the point of information processing modes, e.g., defining, describing, comparing, and inferring. If a sentence gives the definition of a concept it was thought in defining mode. A participants' response to the stimulus word "element", for instance, "an element is a substance that composed of same type of atoms" was categorized into defining mode. Description of a concept or term, for instance "when forming compounds elements combine in fixed proportions", was categorized into describing mode. If a sentence compares concepts it was putted into comparing mode. "Atoms are the smallest things in the world" is an example from this category. Sentences interpreting a phenomenon, "if there were thousands of billions of atoms in a piece of paper then atoms should be the smallest thing ever", for instance, were categorized into inferring mode. When examining the sentences irrelevant sentences were not further analyzed from the point of information processing modes.

Validity and Reliability

In the stage of determination of stimulus words, an instructor who is a chemistry educator was asked to review the textbooks of the course and select some basic chemistry terms. After the discussion with him, i.e., checking the content validity, final form of stimulus words was obtained.

In the calculation of relatedness coefficients, a researcher in the field of science education was asked to make calculations for randomly selected 20 participants' tests. An inter-coder reliability of 92% was calculated between his calculations of RC's and author's calculations. Besides, another researcher was asked to make examination for randomly selected 20 participants' "related sentences" and an inter-coder reliability of 90% was calculated between her and author's examinations. These are quite high values according to Miles and Hubermans' criterion (Miles, Huberman, & Saldana, 2014), which is a consistency value above 70%, is acceptable. Therefore the reliability of the calculations can be acceptable.

RESULTS

Number of responses to each stimulus word was counted and the results were given in Table 2.

Table 2. *Number of responses to the stimulus words*

Stimulus word	Number of different responses
Atom	136
Element	125
Ion	113
Compound	161
Molecule	130
Total number of responses	355

From Table 2 it can be said that participants responded to stimulus word "compound" with more words than to the other stimulus words. Since the number of responses to a stimulus word indicates the linkages e.g., interpretation of that word/term (Bahar, Johnstone, & Sutcliffe, 1999), one can state that the participants would structure "compound" better. On the contrary side the number of responses to the stimulus word "ion" was the less indicating that the participants' structure on "ion" would not be formed so strong.

Calculated relatedness coefficients to the stimulus words were given in Table 3.

Table 3. *Relatedness coefficients of stimulus words*

	Compound	Ion	Element	Molecule
Atom	0.094	0.094	0.099	0.126
Compound	-	0.110	0.196	0.229
Ion	-	-	0.081	0.111
Element	-	-	-	0.181

From Table 3, it can be said that participants related the stimulus words "compound-molecule" most (RC= 0.229). In other words "compound" and "molecule" were related most closely to each other in participants' cognitive structure. Then "compound-element" relation (RC= 0.196) and "element-molecule" relation (RC= 0.181) were observed. The weakest relation was detected between "ion" and "element" (RC= 0.081). According to these results one can conclude that participants' cognitive structures do not cover so strong relations.

In order to visualize the data gathered through word association test, concept maps were drawn according to relatedness coefficients (Figure 1) as well as frequency of response words (Figure 2). In both figures the darker the lines between stimuli or respond words show the stronger interrelations between them.

The first cut-off point was chosen as RC≥0.225 by taking into consideration the strongest value of RC, and the last cut-off point was chosen as RC≥0.075 in order to cover all the stimuli. From Figure 1, it can be said that "compound-molecule" interaction was the most strong interaction of the cognitive structures of the participants', since it has the biggest RC value. When RC was lowered (or "relaxed") to 0.225≥RC≥0.175, another stimulus word "element" joins to the structure. A further relaxation of RC to 0.175≥RC≥0.125 range reveals "atom-molecule" interaction by adding "atom" to the structure. RC needed to be lowered to RC≥0.075 in order "ion" to join to the structure where "atom-compound" and "atom-element" interactions also revealed.

A more complex but informative map was drawn by using frequencies instead of RC values, and given in Figure 2. The first cut-off point was chosen as f≥60, since the biggest value of f was 67. According to Figure 2, the strongest relation was observed between "molecule and compound"(f ≥60, meaning that more than 60 of the participants responded to stimulus word "molecule" with "compound"). At this point only two of the stimulus words were connected to each other. When cut-off point was relaxed to 60≥f≥50, "atom" and "element" were joined to the structure. Participants also responded to "atom" with "Dalton" at this stage. The last stimulus word "ion" confronted at 50≥f≥40 level. But at this stage it was like an isolated island i.e., there were no interconnections between "ion" and the rest of the stimulus words, and "anion", "cation" and "negative" response words appeared to be connected to "ion". The subatomic particles (electron, proton and neutron) responses to "atom" and response word "pure" to "element" also showed up at this stage. Although all stimuli were covered at this stage further relaxations were made in order to get a deeper inside to the participants' cognitive structure. When cut-off point was relaxed to 40≥f≥30, the two separate islands came together via various connections between "ion" and "element", "ion" and "compound" and "ion" and "atom" through "electron". Many response words also joined to the structure. The last relaxation of cut-off point was made to f≥20, and a more complete structure was obtained. The salient features of this stage can be the addition of "water" linkage between "molecule and compound", and "oxygen" to "element".

Strong

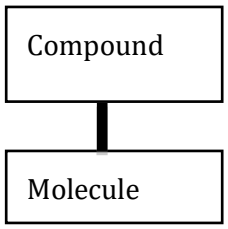
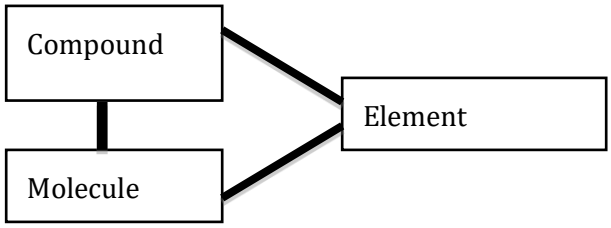
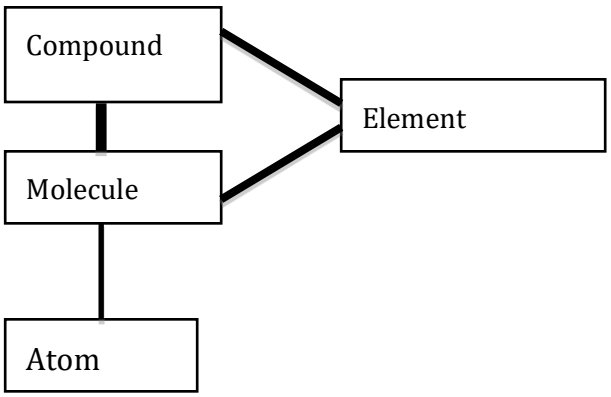
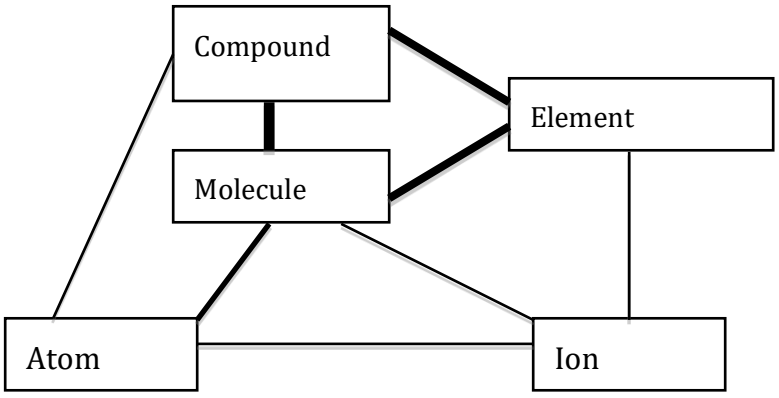
Cut-off point	Graph
0.225	
0.175	
0.125	
0.075	

Figure 1. *Cognitive structure of the participants using relatedness coefficients*

Weak

Strong

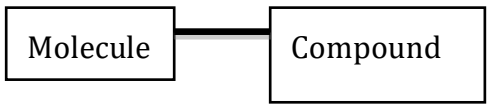
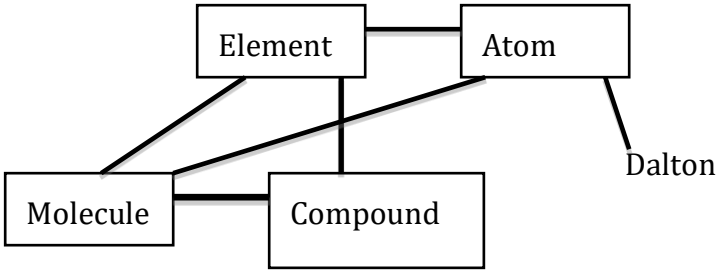
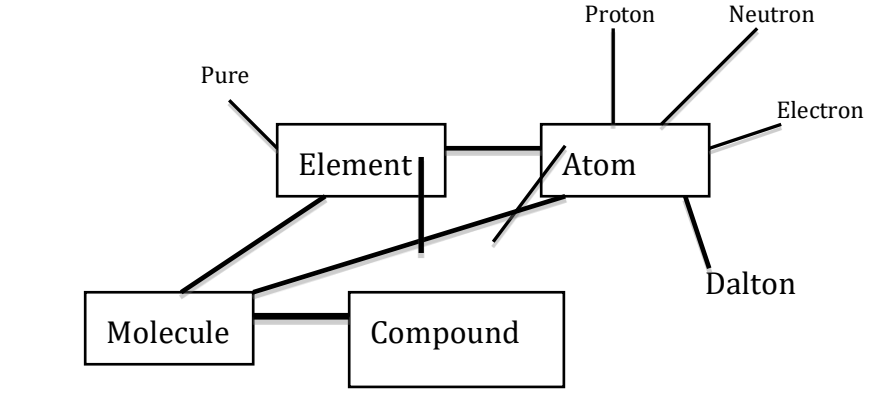
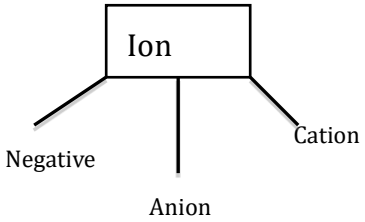
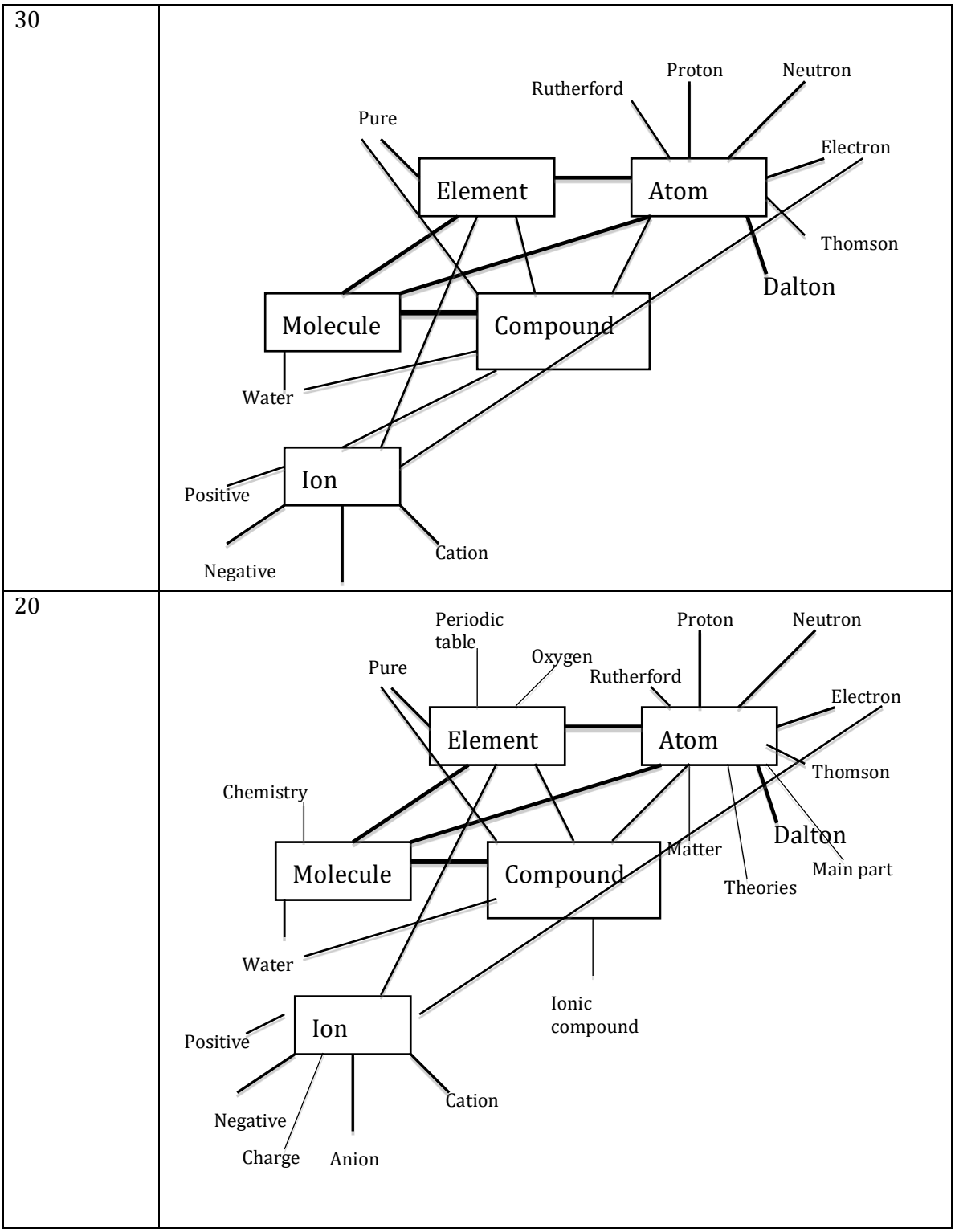
Cut-off point	Graph
60	
50	
40	 

Figure 2. *Cognitive structure of the participants using frequencies*

Weak

Strong



Weak

Figure 2 (cont). *Cognitive structure of the participants using frequencies*

Results from the analysis of "related sentences" were given in Table 4.

Table 4. *Findings from "related sentences" analysis*

	Atom				Element				Compound				Molecule				Ion			
	Correct scientific knowledge	Misconception	Irrelevant	Total	Correct scientific knowledge	Misconception	Irrelevant	Total	Correct scientific knowledge	Misconception	Irrelevant	Total	Correct scientific knowledge	Misconception	Irrelevant	Total	Correct scientific knowledge	Misconception	Irrelevant	Total
Defining	40 (52)	4 (5)	5 (7)	44 (57)	8 (15)	4 (7)	5 (9)	12 (22)	18 (23)	10 (13)	5 (6)	28 (35)	12 (18)	7 (10)	6 (9)	19 (28)	9 (13)	16 (23)	7 (10)	25 (36)
Describing	14 (18)	7 (9)		21 (27)	25 (46)	12 (23)		37 (69)	33 (42)	13 (16)		46 (58)	22 (32)	20 (30)		42 (62)	14 (20)	20 (29)		34 (49)
Comparing	6 (8)	-		6 (8)	-	-		-	-	-		-	1 (1)	-		1 (1)	-	-		-
Inferring	1 (1)	-		1 (1)	-	-		-	-	-		-	-	-		-	1 (2)	2 (3)		3 (5)
Total	61 (79)	11 (14)		77 (100)	33 (61)	16 (30)		54 (100)	51 (65)	23 (29)		79 (100)	35 (51)	27 (40)		68 (100)	24 (35)	38 (55)		69 (100)

** Numbers in brackets are the percentages.*

Participants were able to write 77 sentences for the stimulus word "atom", 54 sentences for "element", 79 sentences for "compound", 68 sentences for "molecule" and 69 sentences for "ion", according to Table 4. When sentences were analyzed from scientifically correct point of view, participants wrote most scientifically correct knowledge for "atom" and less for "ion". The opposite is also true i.e., most sentences including misconceptions were for the stimulus word "ion" and less for "atom". Besides most irrelevant sentences were written for "ion". From information processing modes of view, it can be said that participants responded mostly with sentences in "describing mode" and, "comparing" and "inferring" modes were almost not included. Participants mostly "define" "atom" and "describe" the other stimuli. Interestingly participants used "inferring" mode mostly for "ion" which was the stimulus word that they have had most misconceptions.

DISCUSSION and CONCLUSIONS

Research on how students think or learn has been the major topic for educational researchers in many years. Determination of cognitive structure, which can simply be defined as the organization of information in individuals' long-term memory, is one of the most studied topics of educational researchers. According to Tsai and Huang (2002), by exploring one's cognitive structure, educators can obtain benefits on prior knowledge, assessment and metacognition. From the point of constructivist approach, it is crucial to obtain students' prior knowledge since it would be the basis for the new information. Also by revealing the misconceptions in students' cognitive structures, educators can design better learning settings and conceptual changes. Word association test, which is a simple but informative method to gather information about cognitive structure, was used in this study. Research topic was chosen as some basic chemistry concepts, which are fundamental for the chemistry science, as well as the ones that the students have most misconceptions. Participants were pre-service science teachers as they will teach the basic science terms to their students and therefore it is important to explore their cognitive structure on the basic terms.

In this study, word association test was successfully revealed the organization of terms and concepts in participants' minds. In their studies Bahar, Johnstone and Sutcliffe (1999), Aydın & Taşar, (2010), Nakiboğlu (2008), Özata-Yücel & Özkan, (2015) have also claimed that the benefits of word association tests on determining the cognitive structures of the participants. Number of responses to a stimulus word is an indicator since if a term were understood i.e., constructed very well, it would be linked to many terms in the memory. According to results of this study, participants were able to give most response (161 different responses) to the stimulus word "compound" and less response (113 different responses) to the stimulus word "ion". From this result, it can be concluded that "compound"

was the term that the participants constructed most strongly, and "ion" was the term that the participants have less knowledge about that. Analysis of relatedness coefficient, which is an indicator of commonality of stimulus words, also showed that participants related "compound-molecule" most closely (RC=0.229) in their minds. "Ion-element" relation on the other hand, has the less relation (RC=0.081) for the participants.

When it comes to visual representation of cognitive structure, concept maps can be drawn by using either relatedness coefficients or frequencies. Both graphs were drawn in this study. It can be said that the strongest part of the cognitive structures of the participants was "compound-molecule" relation (the first cells in figure 1 and 2). According to Figure 1, "element" and "atom" joined to the picture next and the last term joining to the picture was "ion". Concept map drawn by using frequencies was a little bit complex but informative. According to that concept map (Figure 2) "compound-molecule" relation appeared strongly in participants' minds and then "element" and "atom" were added to the structure. "Ion" was first appeared in the concept map as a separate island (for frequency>40) with "anion", "cation" and "negative" relations attaching it. Then it joined to the structure via "ion-element", "ion-compound" and "ion-atom (thorough "electron")" relations. In the analysis of word association test results, relaxation of frequencies continues until all the stimuli appear. In this study it was continued two steps further after all the stimuli joined to the map in order to see a bigger picture. It is an interesting finding from the map that participants related all three atomic theories (Dalton, Thomson, and Rutherford) but not Bohr' atomic theory to "atom". Also "oxygen" was the most related element in participants' cognitive structure.

Participants "related sentences" analysis yield to the result that they were able to write most sentences for "compound" (79 sentences). From the point of misconceptions, participants had most misconceptions on "ion" (55%). Also they wrote most irrelevant sentences for "ion". Participants were able to use "describing" and "defining" information processing modes more frequently (Table 4). Describing and defining modes are viewed as lower-level modes of information processing while comparing and inferring are viewed as higher-level modes of information processing (Wu & Tsai, 2011). From this result, it can be stated that participants do not have higher-order strategies for organizing information during recall.

The overall results of the study can be summarized, as participants' cognitive structure is strong on "compound" and weak on "ion". Gabel (1999) stated that learner' difficulties in learning chemistry is the relationship between the molecular and macroscopic. According to Taber (2001) learner experiences chemistry at a molar level. But a major part of the theoretical structure of chemistry relies on entities like ions and electrons etc. that are on a molecular state. When the stimulus words in this study were thought it could be said that "compound" was the one that participants thought more macroscopic comparing to other stimuli. In other words participants related, "compound" in their macroscopic worlds better. "Ion" on the other hand, was thought more molecular level.

This study was conducted before the instruction in order to probe participants' prior knowledge and to design better learning settings (Nakiboğlu, 2008; Atabek-Yigit, 2015) according to the findings of the study. Therefore, instruction should be more address to weak connections, i.e., between "ion" and other stimuli for these participants. Overall, word association test method is an easy to apply, time-saving (takes only a few minutes to administer) and effective method to examine the cognitive structure of the participants and should be used more frequently in classes before instruction in order to determine the prior knowledge as well as after the instruction in order to control and detect conceptual change of the participants. It can be proposed to the researchers who try to enlighten the understanding of participants in any topic to use word association method as they provide a detailed picture.

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Kelime İlişkilendirme Testi Aracılığıyla Bazı Temel Kimya Kavramları Konusundaki Bilişsel Yapının Araştırılması

ÖZ

Amaç ve Önem: Bireylerin nasıl öğrendiğinin anlaşılmasıyla daha etkili öğrenme ortamları tasarlanabilir, daha yeni teknikler geliştirilebilir ve nasıl daha iyi "öğretilebileceği" anlaşılabilir. Bireylerin hafızasında bilgileri düzenleme şekli "bilişsel yapı" olarak tanımlanmaktadır ve bilişsel yapının belirlenmesi "öğrenmenin nasıl gerçekleştiği" sorusuna aranan cevapta kilit bir nokta oluşturmaktadır. Kelime ilişkilendirme testi bilişsel yapının belirlenmesinde kullanılabilecek basit ama etkili yöntemlerden biridir. Bu çalışmada kelime ilişkilendirme testi aracılığıyla, fen bilgisi öğretmen adaylarının bazı temel kimya kavramları konusundaki bilişsel yapılarının incelenmesi amaçlanmıştır.
Yöntem: Bir eğitim fakültesinin ilköğretim bölümü fen bilgisi eğitimi programı 1. sınıflarında öğrenimlerini devam ettiren ve Genel Kimya I dersini alan seksen beş fen bilgisi öğretmeni adayı bu çalışmanın katılımcılarını oluşturmaktadır. Konu olarak ise katılımcıların meslek hayatlarında sıklıkla kullanacakları ve kimya dersinin üzerine kurulduğu temel kavramlar (atom, molekül, element, bileşik ve iyon) seçilmiştir. Bu kavramlar anahtar kelimeler olarak kullanılarak kelime ilişkilendirme testi hazırlanmış ve çalışmanın verileri elde edilmiştir. Çalışmanın verileri hem cevap kelime sayısına göre hem de kavram haritaları ile analiz edilmiştir. Kavram haritaları cevap kelimelerin frekansına ve aynı zamanda ilişkililik katsayısına göre de çizilmiştir. İlişkililik katsayısı iki kavramın ortak noktalarının bir göstergesi olarak tanımlanır. Kavram haritalarının değerlendirilmesinde kesme noktası tekniği kullanılmıştır. Ayrıca katılımcılardan her bir anahtar kavram ile ilgili cümleler yazmaları istenmiş ve bu cümleler de incelenmiştir.

Bulgular: Çalışmadan elde edilen bulgulara göre katılımcılar en fazla cevap kelimeyi (161 kelime) "bileşik" en az cevap kelimeyi (113 kelime) ise "iyon" anahtar kelimelerine karşılık olarak yazmışlardır. Bir kavramın anlaşılıp anlaşılmadığına yönelik önemli bir gösterge olan cevap kelime sayısına göre katılımcıların "bileşik" kavramını zihinlerinde diğer kavramlara göre daha iyi yapılandırdıkları düşünülebilir. İlişkililik katsayısına göre çizilen kavram haritalarından katılımcıların bilişsel yapılarının "bileşik-molekül" (RC=0.229) ilişkisinde en güçlü olduğu, yapıya en son "iyon" kavramının katıldığı belirlenmiştir. Anahtar kelimelere verilen cevap kelimelerin frekanslarına göre çizilen kavram haritalarından da "bileşik-molekül" ilişkisinin ($f \geq 60$) katılımcıların bilişsel yapısının en güçlü noktası olduğu, "iyon" kavramının öncelikle bağımsız bir adacık şeklinde ortaya çıktığı ($50 \geq f \geq 40$) ve daha sonra "element", bileşik" ve "atom" kavramlarına bağlantılarının kurulduğu ($40 \geq f \geq 30$) tespit edilmiştir. Katılımcıların anahtar kelimelere karşılık yazdıkları cümleler incelendiğinde, en fazla cümleyi (79 cümle) atom için en az cümleyi ise (54 cümle) element için yazabildikleri görülmüştür. Cümleler bilimsel açıdan doğru olup olmamalarına göre incelendiğinde en fazla doğru cümlenin "atom" için (%79) yazıldığı, en fazla kavram yanılgısının ise "iyon" kavramına ilişkin (%35) olduğu bulunmuştur. Bilgi işleme modlarına göre yapılan değerlendirme sonuçlarına göre, katılımcıların bilgiyi en fazla "tanımlayabildikleri" ve "betimleyebildikleri", en az ise "kıyaslayabildikleri" ve "yorumlayabildikleri" tespit edilmiştir.

Tartışma, Sonuç ve Öneriler: Kimya pek çok soyut kavramı içeren bir derstir ve öğrenilmesindeki temel güçlükler de bu soyut kavramlardan kaynaklanmaktadır. Öğrenciler makro ve mikro ilişkileri anlamakta güçlük çekmekte ve bu durum bu araştırma da dahil pek çok araştırma ile tespit edilmektedir. Bu çalışmanın sonucunda, katılımcıların verilen temel kavramlar ile ilgili bilişsel yapılarında "bileşik" kavramını daha sağlam şekilde yerleştirdikleri ve "iyon" kavramı ile ilgili zayıflıklar/eksiklikler olduğu belirlenmiştir. Elde edilen bu sonuçların, "bileşik" kavramının katılımcıların makro dünya ile daha fazla ilişkilendirebildikleri bir kavram olması sebebiyle olduğu düşünülmektedir. Bu çalışmada kelime ilişkilendirme testi konu öncesinde katılımcıların bilişsel yapılarının belirlenmesinde kullanılmıştır. Çalışmanın sonuçlarından hareketle katılımcıların bilişsel yapısındaki zayıf/eksik noktalar göz önünde bulundurularak derslerin tasarlanması önerilebilir.