ANALYSIS OF STUDENTS' COGNITIVE STRUCTURES USING FREE WORD-ASSOCIATION TEST IN CHEMISTRY LEARNING

Norma Muningsih[1], Nurjannah[1], Dinny Devi Triana[1], Nurbaity[2], Sondang N. Sihombing[2]

[1]Department of Research and Evaluation of Education, Universitas Negeri Jakarta, Jakarta, Indonesia
[2]Department of Chemistry Education, Universitas Negeri Jakarta, Jakarta, Indonesia
normamuningsih@gmail.com

ABSTRACT

This study aims to determine the cognitive structure of high school students of class XI with free word-association method in teaching chemistry at the material buffer solution. The research was conducted in the second semester with a sample of 37 students at SMAN 89 Jakarta. The method used is qualitative in interpretivism paradigm, focused on the analysis of cognitive structures using free word-association method in teaching chemistry. Data obtained by interview, documentation, observation and student assignments through free word-association. Instruments free word-association tests contain stimulus word of "buffer" to collect information about students' conceptual structure in the material buffer solution. The data were subject to content analysis and divided into categories through coding. Results of this study is there are five categories in the distribution of cognitive structures through free word-association test. These categories include the definition of a buffer solution, buffer solution properties, creation of buffer solution, pH buffer solution and calculate the buffer system in biological systems. The most dominant category is category nature buffer solution. The conclusion is that students have the cognitive structure of the most widely through recall or rote learning and there are learning difficulties experienced by students in learning material buffer solution.

Keywords: Cognitive Structure, Free Word-Association, Learning Chemistry

INTRODUCTION

Learning is an important thing for everyone because through learning then someone understands and master something so that person can improve his ability. The ability of a person to increase can be seen from the development of knowledge and activeness of the person in forming knowledge. Learning that happens to students is an interaction between what students learn and the concepts that already exist in the mind of the student (Posner, Strike, Hewson and Gertzog, 1982). The form of student learning outcomes that students can determine and express the concept that is in the minds of students as part of the cognitive structure.

Chemistry is not enough to be learned only through the process of memorization and remembering, but students must be able to make connections between concepts so that chemistry understood can thoroughly and not cause errors that can eventually lead to misconceptions. Misconceptions occur because of the lack of students' knowledge of the concepts being studied. The lack of student knowledge is due to the cognitive structure that students have not well developed and underused. Betty K Garner (2007) says cognitive structures compare data sets to process information in understanding things. Students whose cognitive structure has not developed well feel that learning is a burden and an unpleasant thing.

One of the important concepts that exist in Chemistry is the buffer solution. Students in understanding the concept not only learn about how to calculate buffer pH but also understand the nature and importance of buffer conditions in living systems. Based on interviews of Chemistry teacher grade XI SMAN 89 Jakarta and the author's experience during carrying out the activities of PKM (Teaching Practice Skills), students learn the concept of chemistry with a less well-structured understanding of concepts. This affects the students' learning outcomes in Chemistry subjects is still low. The low learning outcomes of students are associated with the inability of students in processing information during the learning process or cognitive processes of students who have not developed well. The teacher assumes the cognitive structure works automatically so that the teacher does not directly identify the cause of learning difficulties experienced by the students so that the students' learning outcomes are low because of the cognitive structure of the underdeveloped students (Betty K. Garner, 2007). Teachers should conduct a cognitive structure analysis because the cognitive structure gives effect to the student's learning process. The cognitive structure can be analyzed using several techniques or ways. Techniques such as through multiple choice test, free word-association test, drawing-writing, map concept, diagnostic tree, conceptual change text and analogy.

Based on the above description, the authors are interested in conducting research to determine the cognitive structure of students with free word-association method in chemistry learning on buffer solution which is the material of class XI even semester. Analysis of student cognitive structure can be used to know the description of students' understanding and knowledge in buffer solution material. If there is an incorrect student understanding of the buffer solution then the teacher can find the right solution to overcome it. The learning process of students on buffer solution matter can provide a learning experience for these students to develop cognitive structures. The development and absence of cognitive structure of students was analyzed using the free word-association method.This research was conducted under the title "Analysis of Students' Cognitive Structures using Free Word-Association Test in Chemistry Learning."

Based on the background that has been described, can be identified problems as follows:

1. How is the use of free word-association method in analyzing students' cognitive structure in chemistry learning?
2. How is the cognitive structure of high school students of class XI based on free word-association method on buffer solution matter?
3. What are the constraints or learning difficulties experienced by high school students of class XI on buffer solution matter?

The problem in this research is limited to cognitive structure analysis of high school students of class XI with free word-association method in chemistry learning on buffer solution matter.

METHOD

The purpose of this study was to analyze the cognitive structure of high school students of class XI with free word-association method in chemistry learning on buffer solution matter. This research was conducted at SMA Negeri 89 Jakarta in the even semester and sample of 37 students. This study focuses on a deep understanding of the subject of research so that the appropriate paradigm for use is Interpretivism Paradigm. The research method used is qualitative. Data collected in the research process in the form of words or drawings (Bogdan Robert C and Sari Knopp Biklen, 2007). Qualitative methods are used to obtain data that contain meaning or actual data (Sugiyono, 2008).

Preparation stage in this research through interviews to class XI chemistry teacher about the implementation of student learning on buffer solution matter, observation using free word-association test to know the understanding of high school students of class XII MIA about buffer solution and analyzing subject matter of buffer solution. Planning is done by creating a distribution for the categories and concepts that relate semantically to the categories of buffer solutions using free word-association and making lesson plan for the subject matter of Buffer Solution. Implementation stage include learning of buffer solution in accordance with lesson plan, students are introduced about free word-association test, learning evaluation and interview after students do free word-association test. During the learning evaluation, students do a free word-association test to find out the understanding (conceptual structure) of buffer solution. When the authors convey the word stilmulus "buffer solution" then the student was instructed to write the words (keywords) that exist in students' thinking based on the said stimulus. The time given for writing the words (keywords) is 5 minutes. Furthermore, students are required to write sentences within 10 minutes of the words (keywords) that have been written previously. The final stage is to process, analyze data and draw conclusions.

Instrument tests free word-association to collect information about the conceptual structure of students in the buffer solution matter. The free word-association test is a reliable technique used as a procedure for measuring numbers, directions and strengths in relationships (Novak and Govin, 1984; Mervis and Rosh, 1981). The free word-association test contains the word stimulus that is "buffer solution".

Data obtained from free word-association tests were analyzed using techniques of number of words, number of responses and semantic relationships or relationship of word meaning (Atasoy, 2004). Words are grouped by the same meaning or meaning and frequency of recurrence of the most words. Irregular words (not related to other words already written) are not included in the analysis. Words are categorized using word-of-mouth (semantic) and the frequency of words in each category are calculated (Daskolia, Flogaitis and Papageorgiou, 2006). The result of free word-association test in buffer solution matter is encoding. The encoding follows the following format: [" " (S1)].

RESULTS

This study obtained data through observation data, interviews, documentation and student tasks through free word-association test. Observational

data obtained from observers who make observations on the learning process of students about buffer solution. Interviews were conducted with the teacher prior to conducting the research. In addition, interviews are conducted on students after completion of a free word-association test to find out and confirm the results or answers to the test and to find out the constraints or learning difficulties that students experience when learning about the concept of buffer solution. Documentation is done by the observer during the learning process takes place. Student assignment through free word-association test done after the student finished carrying out the learning in the class about buffer solution.

Student cognitive structure was analyzed based on free word-association test result. An example of free word-association results of S19 and S33 students regarding the following buffer solutions.
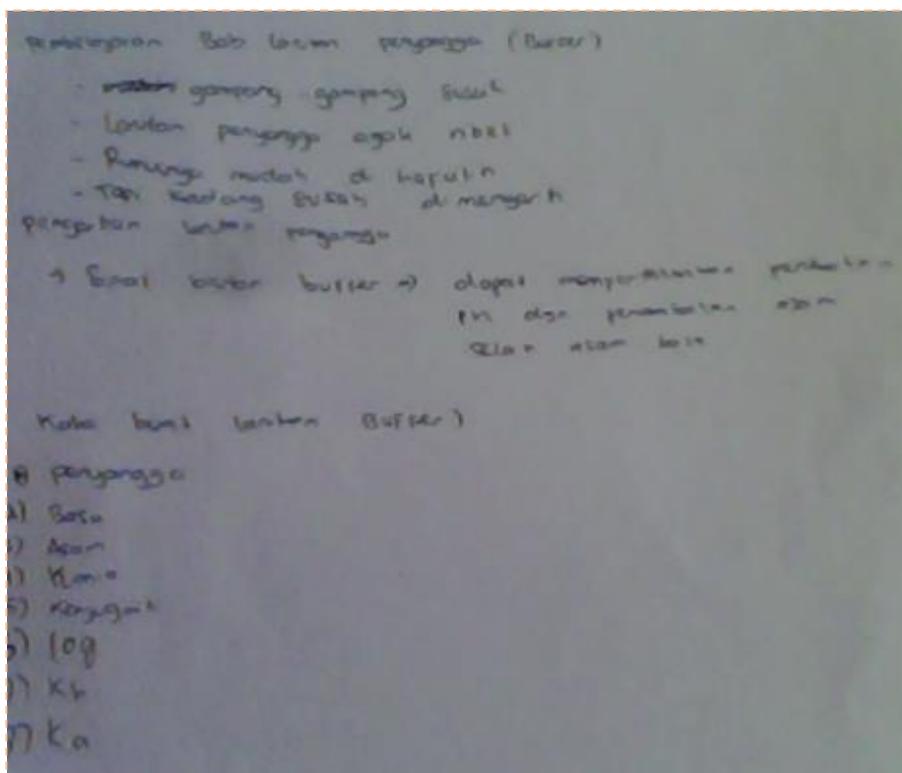
Figure 1. Results of Free Word-Association of Students S19 Concerning Buffer Solution

Students with S19 code (Figure 1), categories written among others: the nature of the buffer solution (based on the written keyword that is base, acid and based on the sentence written), calculating the pH of the buffer solution (based on the written keywords such as log, Kb and Ka). Students with code S33 (Figure 2), categories written among others: definition of buffer solution (based on written keyword ie weak acid, weak base, strong acid, strong base, conjugate acid, conjugate base), creation of buffer solutions (based on written keywords ie weak

acids, weak bases, strong acids, strong bases and based on written sentences), calculates the pH of the buffer solution (based on the written keyword that is mole, concentration, volume, acid determination, base determination, pH, pOH and based on written sentence). The test results are coded first so that categorization can be done in accordance with the concept in buffer solution.

The result of free word-association of students regarding buffer solution is categorizing. Categorization is done based on the meaning (type of semantic relationship or the relationship of the word meaning). The frequency of words in each category is also calculated. Based on the result of free word-association test of class XI MIA students about buffer solution, there are 5 categories in the distribution of cognitive structure. These categories include buffer solution definition, buffer solution properties, buffer solution creation, buffer buffer pH counting, and buffer systems in biological systems. In addition, of the 5 categories there are 43 total keywords.
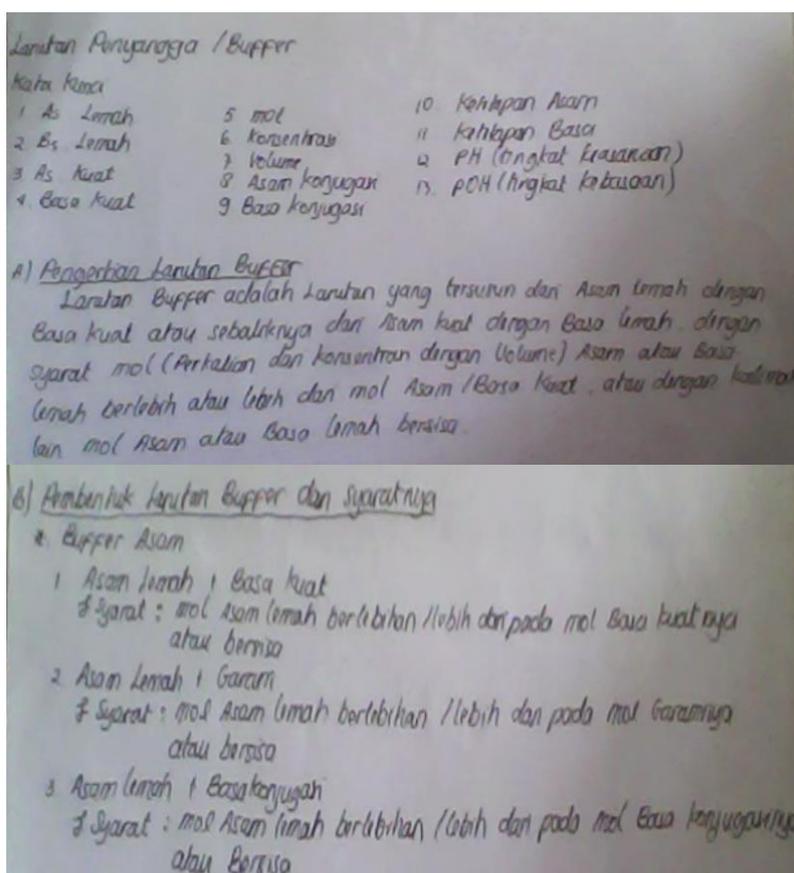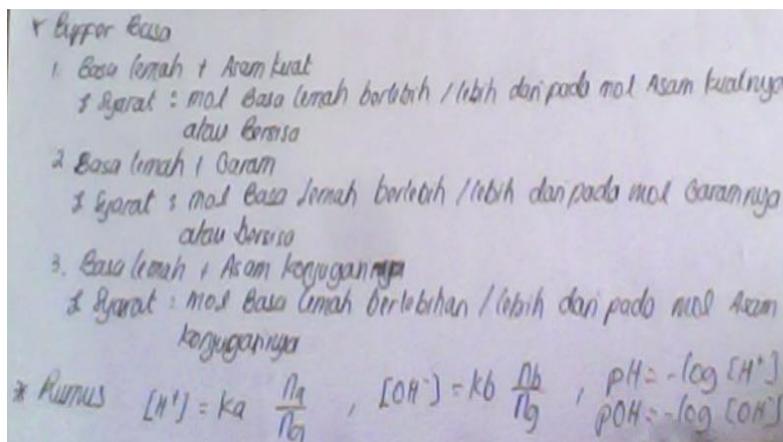
Figure 2. Results Free Word-Association S33 Students Regarding Buffer Solution

The following is the result of the distribution of students' cognitive structure of class XI MIA regarding buffer solution.

Table 1. Distribution of Cognitive Structure of MIA Class XI Students Regarding Buffer Solution

Categories	Concepts Related to Semantics with Categories	Total Frequencies of Categories
1. Properties of Buffer Solution	"pH" "acid" "base" "buffer" "acid pH" "base pH" "stability buffer" "maintain pH"	27
2. Calculate the pH of Buffer Solution	"pH" "Ka" "Kb" "$[H^+]$" "$[OH^-]$" "formula of $[H^+]$" "formula of $[OH^-]$" "pOH" "concentration" "salt" "pKa" "pKb"	25

	"acid or base buffers" "formula of pH" "formula of pOH" "mole" "volume" "conjugate acid" "conjugate base" "mixture of mole" "base" "log" " The Henderson-Hasselbalch equation"	
3. Definition of Buffer Solution	"weak acid" "strong acid" "weak base" "strong base" "acid buffer" "base buffer" "conjugate base" "conjugate acid" "salt" "solution" "component" "a weak acid mixture with a conjugate base"	20
4. Preparation of Buffer Solution	"salt" "acid" "base" "strong acid" "strong base" "weak acid" "weak base" "excess" "react" "weak acid + strong base" "acids or weak bases + salt" "strong" "weak"	13
5. Buffer System on Biological System	(written in the form of a sentence not in the form of a keyword)	1
Total	43 words	86

The "properties of buffer solution" category is the most dominant category among the other four categories. Based on the result of distribution of cognitive structure of XI MIA class students about buffer solution, the most students response is in "buffer solution" category. The total frequencies in that category are

27 (n = 27). Only 5 students (S8, S13, S23, S25, S29) out of a total of 27 students who answered the "how" question when writing free word-association about buffer solution properties. The average student only writes the buffer's buffer properties, which can maintain the pH value, but how the process to maintain the pH price is not written in the students' free word-association. Students mostly emphasize the concept of buffer solution properties using the word "pH", "acid" and "base". Other words students write in the "properties of buffer solution" category include "buffer", "acid pH", "base pH", "buffer stability" and "maintain pH".

The second dominant category is "calculating the pH of the buffer solution". The total frequencies in that category are 25 (n = 25). Students write "pH", "Ka", "Kb", "$[H^+]$", "$[OH^-]$", "formula of $[H^+]$" and "$[OH^-]$", "pOH" and "concentration". The word "pH" is written by students who have codes including S1, S4, S7, S8, S10, S12, S15, S16, S17, S18, S20, S22, S24, S25, S26, S32 and S33 (total 17 students) . The words "Ka" and "Kb" are each written by 6 students who have codes including S1, S2, S19, S20, S22 and S33. The words "$[H^+]$", "$[OH^-]$", "formula $[H^+]$", "formula $[OH^-]$", "pOH" are each written by 4 students. The words "$[H^+]$" and "$[OH^-]$" are written by students with the same code such as S16, S20, S22 and S29. Likewise for the words "formula $[H^+]$" and "formula $[OH^-]$" written by students with the same code such as S28, S30, S31 and S35. While the word "pOH" written by students who have code S20, S22, S24 and S33. Three other students with code S26, S32, S33 write the word "concentration". Other words written bythe students include "salt", "pKa", "pKb", "acid or base buffer", "pH formula" and "pOH formula". Other words written by the students in the category of "calculating the pH of a buffer solution" include "mol", "volume", "conjugate acid", "conjugate base", "mol", "base", "log" and "Henderson-Hasselbalch ". The words are only written once.

The third dominant category is the "definition of buffer solution". The total frequencies in that category are 20 (n = 20). Most students write the words "weak acid", "strong acid", "weak base", "strong base", "acid buffer", "base buffer" and "conjugate base". The word "weak acid" is written by students who have code such as S8, S15, S16, S26, S32, S33, S34, S36 and S37 (total 9 students). The words "strong acid", "weak base" and "strong base" are each written by students with the same code ie S8, S16, S32, S33, S34, S36 and S37 (total 7 students). The words "acid buffer", "base buffer" and "conjugate base" are each written by 6 students. Other words in the category "definition of buffer solution" include "conjugate acid", "salt" and "solution". While the word "component" and "mixture of weak acids with conjugate bases" are only written once.

The fourth category is "preparation of buffer solution". The total frequencies in that category are 13 (n = 13). Most students write the word "salt". The word is written by students who have code such as S1, S12 and S16 (total 3 students). Other words written in the category of "buffer solution" include "acid", "base", "strong acid", "strong base", "weak acid" and "weak base". Each of these words was written by 2 students. The words "acid" and "base" are each written by students with the same code that is S1 and S16. Then, the words "strong acid" and "strong base" are also written by students with the same code S12 and S33. The same is true of the words "weak acid" and "weak base", both words are also written by students with the same code S29 and S33. In addition, words such as "excess",
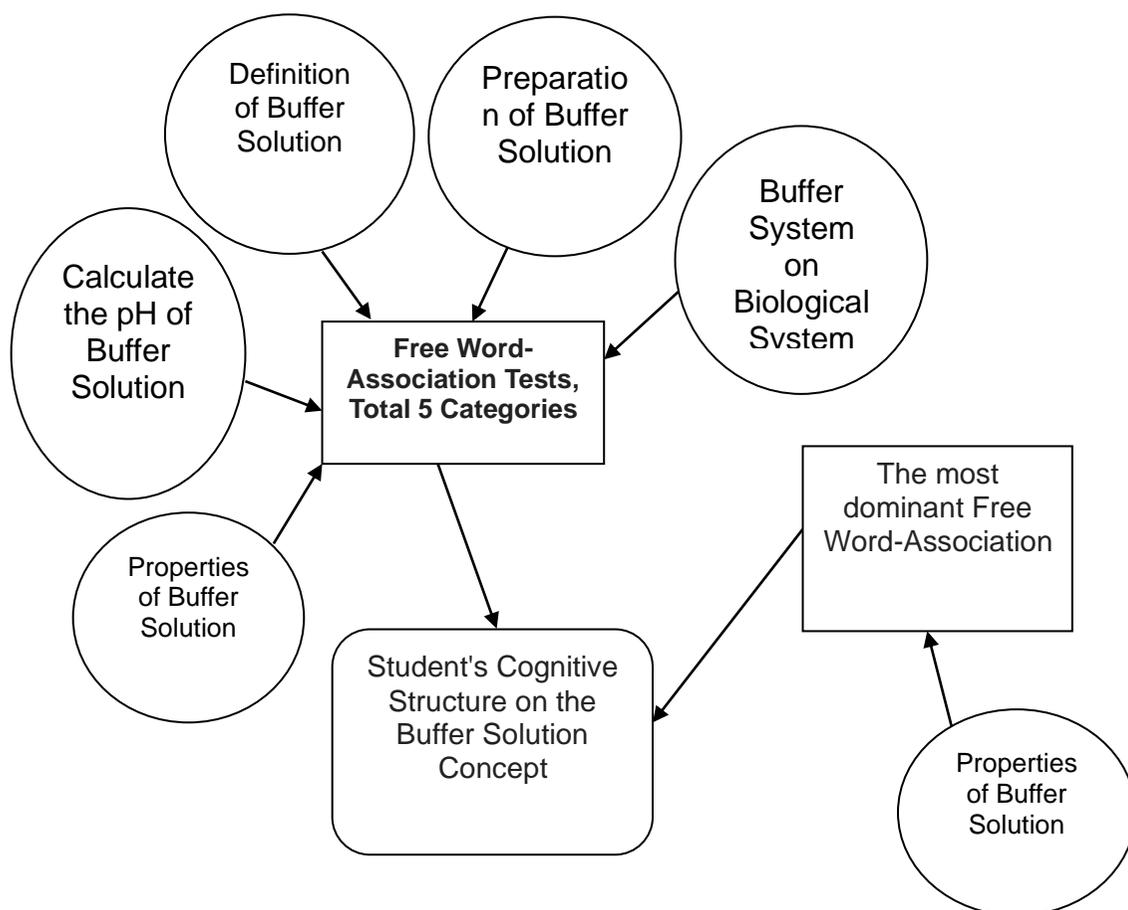
"react", "weak acid + strong base", "acid or base weakness + salt", "strong" and "weak" are only written once.

The fifth category is "buffer system in biological system". Students in that category only write in sentence form instead of in keyword form. Students who write about "buffer systems in biological systems" are students who have codes S36. The student writes the buffer system in human blood and also the application of buffer solution in everyday life.

Based on the result of free word-association data of XI MIA 1 and XI MIA 2 students on buffer solution, there are 5 categories in buffer solution concept (category "buffer solution character" is the most dominant category among the other four categories). Here is the cognitive structure of students of class XI MIA based on free word-association method on buffer solution matter.

Figure 3. Cognitive Structure of High School Student Class XI on Buffer Solution

Other data obtained from this study about the constraints or difficulty of learning experienced by students while learning about the concept of buffer

solution. The data obtained from the interviews conducted on students after completion of the test free word-association. Based on the results of interviews, learning difficulties experienced by students, among others, students feel difficulty in calculating the pH of buffer solution, especially when there is addition of acid or base to buffer solution. In addition students are still confused in the use of formulas because there is a formula of calculating pH for acid buffer solution and there is a formula of calculating the pH of an alkaline buffer solution. This is expressed by students with code S3, S9 and S19 as follows.

"Memorizing theories is hard but curious. I'm lazy if item not clear "(S3).

"Sometimes it's hard to make and count. Confused to use which formula "(S9).

"Learning chapter of buffer solution is easy, hard to use, complicated, the formula easy to memories but sometime difficult to understand" (S19).

Constraints faced by students are also caused because they can not follow the learning process at the initial meeting (the cause of pain) so it takes time to adjust. Students often lack concentration while studying. This makes it difficult for students to understand the concept of buffer solution. Students say that if concentrating while learning the concept of buffer solution will be easy to understand.

Another thing that becomes a student constraint when learning about buffer solution is the understanding of acid-base concept (chapter 1/ chapter before buffer solution) is less perfect, making it difficult for students to understand the components of the buffer solution. For example, when students identify which is a buffer solution, students must understand the term strong acid, weak acid, strong base, weak base, conjugate acid, conjugate base and salt. Students find it difficult to distinguish between compounds belonging to strong acids, weak acids, strong bases and weak bases. In addition, some students forget about the Bronstead-Lowry acid-base theory so as to confuse the conjugate acid or base of acid or base compounds.

CONCLUSION

Based on research conducted at SMA Negeri 89 Jakarta to class XI MIA students amounting to 37 students about buffer solution matter, obtained 5 categories in the distribution of cognitive structure through free word-association test. These categories include "definition of buffer solution", "buffer solution properties", "buffer solution creation (preparation of buffer solution)", "calculate buffer solution pH" and "buffer system in biological system". The most dominant category based on the result of free word-association of students is the category of "buffer solution properties". Based on these results can be stated that students have the most cognitive structure through learning "remember" or memorization. This is due to only 5 students who answered the "how" question when writing free word-association about the nature (properties) of the buffer solution.

Based on the research that has been implemented, it is recommended to conducting cognitive structure analysis using more than one way (not only using free word-association method) but can be combined with other ways such as using conceptual change text, drawing-writing technique, analogies, mapping concepts and other ways so that the result of structural analysis cognitive students more complete and accurate. But the combination must also take into account and adjusted to the matter or topic being studied. The cognitive structure analysis is performed not only in the buffer solution matter but can be done for other chemical materials (topic) so that the results of the analysis can be used for the improvement of the learning system and the students' inadequate understanding (minimizing the occurrence of misconception). Free word-association method can be used to train and develop students' cognitive thinking and cognitive structure.

REFERENCES

Atasoy, B. "Science Learning and Teaching." Ankara:Asil Publisher, 2004.

Bogdan, Robert C dan Sari Knopp Biklen. "Qualitative Research For Education An Introduction To Theories And Methods Fifth Edition." New York:Pearson Education, 2007.

Bradley, JD. "The Chemist's Triangle And A General Systemic Approach To Teaching, Learning And Research In Chemistry Education." African Journal Of Chemical Education, Vol. 4(2), 2014:67-82.

Chang, Raymond. Kimia Dasar Konsep-Konsep Inti Edisi Ketiga Jilid 2. Jakarta:Erlangga, 2004.

Daskolia M, Flogaitis E dan Papageorgiou E. "Kindergarten Teachers' Conceptual Framework on the Ozone Layer Depletion Exploring the Associative Meanings of a Global Environmental Issue." Journal of Science Education and Technology, Vol.15(2), 2006:168-178.

Effendy. A-Level Chemistry For Senior High School Students Based on KTSP and Cambridge Curriculum Volume 2B. Malang:Bayumedia Publishing, 2008.

Fajemidagba, O. "Piaget's Construct of Equilibrium: Its role in Cognitive Development and its implications for mathematics/science instruction in Nigerian Secondary Schools." Journal of STAN 21(2), 1983:56 – 65.

Field, John. Psycholinguistics: A Resource Book for Students. London:Routledge, 2003.

Garner, Betty K. "Cognitive Structures Help Students Learn How to Learn." Vol. 8(6), 2007.

Given, K. Barbara. Brain-Based Teaching: Merancang Kegiatan Belajar-Mengajar yang Melibatkan Otak Emosional, Sosial, Kognitif, Kinestetis, dan Reflektif. Diterjemahkan oleh Lala Herawati Dharma.Bandung:Kaifa PT Mizan Pustaka, 2002.

Kostova, Zdravka dan Blagovesta Radoynovska. "Word Association Test for Studying Conceptual Structures of Teachers and Students." Bulgarian Journal of Science and Education Policy, Vol. 2(2), 2008.

Kurt, Hakan dkk.2013."Determining Biology Student Teachers' Cognitive Structure on the Concept of Diffusion Through the Free Word-Association

Test and the Drawing-Writing Technique." Canadian Center of Science and Education, Vol. 6(9), 2013:187-206.

─────────────. "On the concept of Respiration: Biology Student Teachers' Cognitive Structures and Alternative Conceptions." Canadian Center of Science and Education. Vol. 8(21), 2013:2101-2121.

Mervis dan Rosh.1981. *Categorization of Natural Objects*. Annual Rev. Psychology, 32, 89-115.

Mulyasa, E. Kurikulum Berbasis Kompetensi. Bandung:Remaja Rosdakarya, 2007.

Novak dan Govin. Learning how lo learn. New York: Cambridge University Press, 1984.

Permendikbud Nomor 81A Tahun 2013. "Implementasi Kurikulum, Lampiran V. Konsep dan Strategi Pembelajaran." Jakarta.

Posner, G dkk. "Accomodation of a Scientific Conception. Toward a Theory of Conceptual Change." Science Education, No.66, 1982:211-227.

Pribadi, Benny A. Model Desain Sistem Pembelajaran. Jakarta:Dian Rakyat, 2009.

Sanjaya, Wina. Strategi Pembelajaran Berorientasi Standar Proses Pendidikan. Jakarta:Kencana Prenadamedia, 2006.

Shenton, Andrew K. "Strategies for Ensuring Trustworthiness in Qualitative Research Projects." Journal of Education for Information, Vol. 22(1), 2004:63-75.

Slameto. Belajar dan Faktor-Faktor yang Mempengaruhiny*a*. Jakarta:Rineka Cipta, 2003.

Spiteri, Louise F. "Word Association Testing and Thesaurus Construction." Canada:Dalhousie University.

Sugiyono. Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan R&D. Bandung:Alfabeta, 2008.

Suryani, Nunuk dan Leo Agung. Strategi Belajar Mengajar. Yogyakarta:Ombak, 2012.

Willis, J. W. Foundations of qualitative research: Interpretive and critical approaches. Thousand Oaks, CA: Sage Publications, 2007.