Train high order thinking skills at undergraduate students chemistry through concept map based learning

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Abstract-This study aims to determine the role of concept map learning in studying organic chemical especially the matter of isomer. The subjects of this study were 58 chemistry education students with details of 24 PKU 16 students and 34 PKA16 students. Data acquisition was done by initial test, final test, and retention test, student response questionnaire and interview. Data analysis used descriptive and inferential analysis (t-test) using SPSS version 16.
The results of the study were: (a) based on the gain score test (<g>) higher order thinking skills (analyzing, evaluating, and synthesizing) PKU16 and PKA16 students increased with moderate and high categories; (b) have retention in higher order thinking skills; (c) excellent collaborative work, discussion and motivation; and (d) facilitate educational students in compiling of teaching material.

Keyword-Concept map, Higher order thinking skills.

I. INTRODUCTION

The Indonesian government through the Minister of Education and Culture has now taken various policies to improve the excellence of human resources. One change in the field of education is the renewal of the curriculum known as the curriculum 2013 (K-13). In the K-13 curriculum, the need to formulate curriculum based on the learning process that prioritizes personal experiences through the process of observing, asking, reasoning, and trying [observation based learning] to enhance students' creativity. In addition, students are accustomed to working in networks through cooperatives and collaborative learning [1)].

The K-13 curriculum requires learning based on students: (a) must actively have to find out in constructing their knowledge in their cognitive; (b) learning should involve learners actively in finding and building knowledge through higher order thinking and inquiry, problem solving; (c) students must have the ability to think critically, be able to apply conceptual knowledge and procedural to solve problems, and explain the interrelationship between concepts in a subject matter that is effectively and creativelyy [2, 3].

The teacher is not the only source of information and the teacher acts as a facilitator. Learning must be centered on students and students must actively find out in constructing their cognitive knowledge. Learning should also practice higher-order thinking skills [1].

Based on the analysis of the K-13 curriculum, be have the results of almost around 80% demanded basic competence in higher-level thinking skills, wherein the minimum ability to analyze, for example in 10th grade (first grade of high school) basic competencies (BK) 3.4. Analyzing the similarity of the nature of the elements in their class and periodicity; 11th grade (2nd grade high school) BK 3.1. Analyzing the structure and properties of hydrocarbon compounds based on the peculiarities of carbon atoms and their class of compounds; and class 12 (class 3 in high school) BK 3.9. Analyzing the structure, nomenclature, properties, synthesis, and usefulness of carbon compounds.

Based on these strategy issues, then in studying science (chemistry), the chemistry teacher and candidates of teacher must have the ability to higher order thinking skills, inquiry, and understand the concepts of chemistry that will be taught in depth and strongly, which in turn they will be able to teach their students.

Numerous reports support the view that the interplay between studying the chemistry concepts with inquiry and higher order thinking is a source of difficulty for many chemistry learners: (a) chemical concepts (organic) are generally abstract for that higher order thinking skills are needed to get the right understanding. rote learning (recall) is a learning that is relatively difficult to use in learning abstract concepts of chemistry. The researchers found evidence that when students use rote learning, it will experience a misunderstanding understand chemistry concepts. so for that it is necessary to use meaningful learning because learning is suitable for studying chemistry (organic) [4]. Because content of chemistry (organic chemistry) generally have a lot of concepts that are abstract, organized hierarchically, and often between concepts are having relationship [5]; (c) Studying the chemistry concepts

(concept in organic chemistry) is often perceived as a difficult subject, because the concept of abstract and require higher order thinking skills [5. 6]; (d) Learning of Chemistry (organic chemistry), requires much of inquiry, higher order thinking skills, and comprehension of concept, because teaching material in chemistry is many contains of abstract concepts, the concepts are arranged hierarchically, and generally between concept - concept have relationships [7]; (e) the acquisition of knowledge isomers (structural and stereo chemical) is very difficult and concepts confuse learners [8]; (f) The understanding of the teaching material of isomer especially of stereochemistry, learners are often difficult to understanding and confusing [9,10]; (g) The learning process should be able to engage students actively in building of knowledge through activities to identify, analyze, synthesize, and evaluate learning materials studied, and simulate or explain back to the audience and onshore apply knowledge in other situations. Teaching strategies that can be used may be learning and work collaboratively in both the investigation and discussions, brainstorming, simulation, and implementation [11, 12]; (h) The presentation of knowledge of concepts of students with concept mapping strategy can be enhances their performance and academic achievement in organic chemistry and retention of the knowledge [13]; (j) by introducing students of instruction based on concept with to use concept map to universal themes and engaging of students in active learning: (1) creates connections new knowledge with students' prior knowledge; (2) facilitates deeper understanding of content knowledge; (3) facilitates for students to respond of problems to use higher order thinking; (4) will be able to improve the ability to learning outcomes, higher order thinking skills of Bloom's taxonomy, and the ability to communicate [14]; (j) The concept maps (Cmaps) are valuable tools for assessing the effectiveness of the conceptual changes provoked by engagement activities of students and inquiry done of teaching materials at the classroom [15]; (k) the strategy of inquiry is one way to achieve conceptual understanding for students [16]; (m) Angelo and Cross (1993) indicate that the use of concept maps develop students' abilities to draw inferences from observations, analyze, evaluate, synthesize and integrate information. Concept mapping also enables students to make meaning out of information, make judgments and develop informed opinions [17].

Based on the opinion of several experts at above, then to study teaching materials chemistry which is rich with abstract concepts, arranged in a hierarchy, and often a relationship between concepts, it is necessary to meaningful learning with the strategy of inquiry and the ability to higher order thinking skills. The learning process should use the strategy of inquiry with collaborative learning to engage students actively in the activities of observing, analyzing, synthesizing and evaluating key concepts teaching materials, discussing, and brainstorming, so it will be able to provide concrete and meaningful experiences for students. The learning outcomes of concept map with strategy of inquiry are can expected to improve learning achievement, higher order thinking skills, communicate, and can have a retention time longer retain of concepts in cognitive long-term memory.

According to some experts, the concept is: (1) a process of mental functions and is used as a tool to facilitate communication and express ideas, (2) an order or relationship in a group of objects or events indicated by the word or words, signs or symbol. The concept has five essential elements: (a) the name of the concept, (b) the definition of the concept, (c) attributes determinants such as the attributes of critical and attributes variables, (d) the value, and (e) examples [18, 19, 20]. The process the find of concept is often referred to the concept of assimilation concept or acquisition concepts [21]. Alice and Glenda (2009), in detail found based learning acquisition and understanding of the concept of a multi step process including: (1) specifies the name of the critical (main) feature concept; (2) mentions some additional features of the concept of (critical attributes and attribute variables); (3) the type of concept, (4) provide an example or non-sample or prototype or non-prototype concept (5) identify and hierarchy of concepts (main concept, super ordinate, ordinate, subordinate, sub-subordinate).Teachers can help by alerting students when a key concept is being introduced, and identifying the explicit characteristics of the concept [22]. Students need to understand whether the concept is concrete, abstract, verbal, nonverbal, or process. In any subject area, students should be aware of the key concepts they must learn. The students must be able to identify, analyze, synthesize, and evaluate key concepts and they must be practice them [23].

Learning theory of learning that can be used in learning concept that has characteristics that are abstract concepts, organized hierarchically, and the relationship between the concepts of having a theory of meaningful learning [24. (25]. Meaningful learning theory has three principles: (1) when the learner can visualize these concepts and classifying it in the cognitive structure of learners; (2) classification of the concept starts from the concept of the most general to the most specific; (3) the readiness of learners that includes the knowledge that learners have today and receive knowledge/new concepts and linking with prior of knowledge [20].

Based on the theory of meaningful learning that the concepts are arranged hierarchically and inter-concept has can be used in learning concept map (CM). CM is the visualization of relationships between concepts in the form of two-dimensional graphical representations and concepts are represented by rectangles or circles. The linkage between two or more concepts will be connected with the line of arrows (→ labeled conjunctive) called with a

proposition that meaningful relationships between concepts [26]. Learning of concept map suitable for use on the knowledge they have the characteristics of a declarative (conceptual) and procedural. Declarative knowledge is knowledge that requires explanation; whereas procedural knowledge is organized procedures such steps hierarchically organize concepts. The steps in preparing a concept map requires investigation (inquiry) capabilities, the invention of the concept contained in teaching materials and higher order thinking skills [27]. The higher order thinking skills include of analyzing, evaluating and synthesizing [28]. Vygotsky (1978) states there are four principles of constructivist learning theory underlying concept mapping, namely: (1) students to actively construct knowledge through relationships between concepts/ideas and experienc/ prior knowledge; (2) learners will personally create meaning through analyzing and synthesizing the experience so that new understanding can be constructed; (3) learning activities should foster the integration of thoughts, feelings and activities (actions) that help learners in the development process of meaning; (4) learning is a social activity that can be enhanced through learning and collaborative investigation between facilitators and learners or between learners with other learners. [29].

Piaget (1964) sees cognitive development as.... while at the formal operational stage (12 years and above), they can engage in formal thinking as well as abstraction. Piaget believed that the process of thinking and the intellectual development has also two on-going processes: assimilation and accommodation. There is assimilation when a child responds to a new event in a way that is consistent with an existing schema. There is accommodation when a child either modifies an existing schema or forms an entirely new schema to deal with a new object or event [30]. Ormrod, J.E. (2012) in the model Piaget developed in stage three, he argued that intelligence develops in a series of stages that are related to age and are progressive because one stage must be accomplished before the next can occur. For each stage of development the child forms a view of reality for that age period. At the next stage, the child must keep up with earlier level of mental abilities to reconstruct concepts. Piaget conceived intellectual development as an upward expanding spiral in which children must constantly reconstruct the ideas formed at earlier levels with new, higher order concepts acquired at the next level [31].

Based on the theory of Piaget, the teaching learning based on concept map is an appropriate learning in developing the ability to construct and relate the concept of linkages between concepts has a hierarchical structure. Piaget believed that learners who have over 12 years of age have been able to be invited to formal thinking to understand concepts such abstract concepts contained in the science of learning materials, such as concept isomer of organic chemistry.

A concept map is used to help students organize and represent knowledge of a subject. Concept maps begin with a main idea (or concept) and then branch out to show how that main idea can be broken down into specific topics. Concept mapping used as learning and teaching technique, concept mapping visually illustrates the relationships between concepts. Often represented in circles or boxes, concepts are linked by words and phrases that explain the connection between the concepts, helping students organize and structure their thoughts to further understand information and discover new relationships. Most concept maps represent a hierarchical structure, with the overall, broad concept first with connected sub-topics, more specific concepts.

Concept mapping is a powerful way for students to train of higher order thinking skills and to reach high levels of cognitive performance. A concept map is also not just a learning tool, but an ideal evaluation tool for educators measuring the growth of and assessing student learning. As students create concept maps, they reiterate ideas using their own words and help identify incorrect ideas and concepts; educators are able to see what students do not understand, providing an accurate, objective way to evaluate areas in which students do not yet grasp concepts fully. Concept mapping serves several purposes for learners: (1) helping students brainstorm and generate new ideas; (b) encouraging students to discover new concepts and the propositions that connect them; (c) allowing students to more clearly communicate ideas, thoughts and information; (d) helping students integrate new concepts with older concepts; (e) enabling students to gain enhanced knowledge of any topic and evaluate the information. Learning of concept map with inquiry strategies can be done at level 3 [32], in which learners must investigate and find their own concepts (No condition) in teaching materials or topics under the guidance of educators. This level is suitable for a given learners who "experienced" or students in the second year and above (Figure 1).

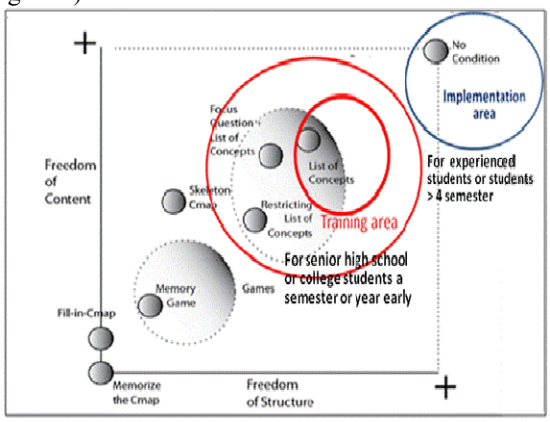

Fig 1. The method used to implement learning model (adoption and adaptation from Strautmane (2012).

Whereas developed of learning based on concept map for the training of higher order thinking skills used concept maps level 3 “no conditions”. Students in the learned process of concept map “no conditional” will be identify of the key concepts, analyze, evaluate from handout and synthesis to create/building of hierarchy concept map. Evaluation at concept map level 3 (no condition) is used way of Markham, et.al, 1994 [33] as a result of the development of the rubric developed by Novak and Gowin [34], with a scoring rubric as follows: concept (1); preposition (1); linked (1); cross linked (10); level (5), and example of concept (1).

Based on strategic issues currently of developing learning and learning theory developed meaningful learning (Ausubel), theory of cognitive development and constructivist (Piaget and Vygostky), information processing theory, and the concept map (Novak and Canas) above, it is necessary to develop innovative learning models. Learning to engage learners actively in the investigation, identification, analysis, synthesis, evaluation, discussion, brainstorming, communication, collaboration to understand, construction concepts, and has the ability to maintain an understanding of concepts (retention) is relatively long in structure learners cognitive learning model offered by the ”concept map” with the following five syntax; (Engagement, Assimilation-accommodation, Collaboration, Simulation, implementation).

Teaching materials based on concept map (containing are an outline plan of lectures, student handbook, student activity sheets, student activity observation sheet, and an evaluation sheet) to be developed that are organic chemical material (isomers), because teaching materials of isomers are materials that are rich in abstract concepts organized, the concept is generally arranged hierarchically, and there is often a relationship between concepts that require higher order thinking skills and inquiry of learners [35].

Prospective teacher or a chemistry teacher who studied chemistry must have the ability in inquiry, higher order thinking skills, and understand the concepts of chemistry (organic chemistry) correctly, because they will be taught to students. In connection with the foregoing, this study aims to determine Based on the above study, this study aims to determine: (a) the effect of concept map based learning on the ability to think at the high order thinking skills of chemistry education undergraduage students; (b) students' ability to maintain (retention) ability to think at a high level in the period of 5 months after the posttest; (c) collaborative and motivational work skills; and (d) student responses to teaching material.

II. METHODS

This research is a quasi-experimental research involving two classes of subjects consisting of PKU classes (28 students) and PKA (32 students). PKU and PKA classes prior to treatment, initial ability testing is done first. The aim is to find out: (a) the student's initial ability, (b) homogeneity test, and (c) normality test. his research design is.

O1 (PKU) X O2 (PKU) -> O3 (PKU)
O2 (PKA) X O2 (PKA) -> O3 (PKA)
Where
O1 = initial ability test (pretest)
X = treatment
O2 = final ability test (posttest)
O3 = retention test

to analyze homogeneity test results, normality, differences in posttest results and retention tests were analyzed using a Statistical test using SPSS 16.0

A. *Materials*

The materials used in this research among others: (1) handbook of isomer developed based on concept map; (2) student worksheet, (3) syllabus and lesson plan; (4) learning outcomes assessment rubric and; (5) learning of media.

B. *Instrumentation*

Instruments used at this research are: (1) observation sheets of learning process; (2) observation sheet of student activity during the learning process; (3) questionnaire sheet for student response; (3) instrument for academic test (objective and subjective test) for pretest, posttest, and retention test.

III. RESULT OF RESEARCH AND DISCUSSION

a. *The Results*

Data on the results of the pretest, posttest, test retention, and n-gains scores (analysis, evaluation, and synthesis) on PKU and PKA classes are shown in the following table I.

TABLE I. PRETEST, POSTTEST, TEST RETENTION, AND N-GAINS SCORES PKU AND PKA CLASSES

catagories	Analysis		evaluation		synthesis	
	PKU	PKA	PKU	PKA	PKU	PKA
pretest	20.0	20.1	11.9	11.9	12	11.9
posttest	63.4	64.1	53.9	53.9	54.5	53.9
Retention	63.3	64.1	54.5	55	55	54.4
n-gains	0.54	0.55	0.47	0.47	0.48	0.47

The graph of the pretest, posttest, retention test, and average score of n-gains increase can be illustrated as shown in Figure 2.

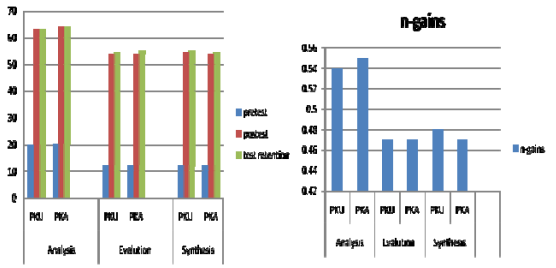

Fig 2. Graph of pretest, posttest, retention and average n-gains scores.

Based on observations of student activities observed with observation sheets and observed by 6 observers. Data obtained that above 90%, students are actively involved in finding information to analyze, discuss, brainstorm, cooperate in evaluating the position of concepts and arrange the interrelationships between concepts in the form of concept maps.

Data from a questionnaire that can be shows that students college gave of a positive response to the learning process of concept map model of learning and the teaching materials used, obtain a score of 93-100% (> 61%). Therefore, based on data, the learning based on concept map has practicality for use in HOTS training for Students College of chemical education, though it still needs to be improved.

b. Discussion

Based on the data in table 1, the results of the pretest in the domain of analysis, evaluation, and synthesis after homogeneity and normality tests were done using SPSS 16.0, where p-value> 0.05 and t-test value> 0.05, it can be concluded PKU class and PKA is a class with normal distribution and homogeneous.

The increase in the average n-gains scores on the ability to analyze (C4), evaluate (C5), and synthesize in the PKU and PKA classes respectively with moderate categories, namely: (a) analyzing PKU (0.54) and PKA (0.55); (b) evaluating PKU (0.47) and PKA (0.47); and (c) PKU (0.48) and PKA (047). The three high-level thinking skills after being tested with statistical tests turned out to be t count> 0.05, both PKU and PKA classes on the ability to analyze, evaluate, and synthesize did not have significant differences.

The increase in n-gains scores on the ability to analyze, evaluate, and synthesize in the medium category, this is consistent with the theory of Piaget and Novak that the students are still in the stage of "semi-beginner" to analysis and evaluation of key concepts from teaching materials and to construct of concept map from key concept. so the student are need for more intensive training to conduct an analysis of key concepts contained in teaching materials, evaluation of key concepts, and create a concept map. according of Vygotsky that it is necessary for the training stage by stage (scaffolding) to students so that they can be trained to analyze, evaluate key concepts in teaching materials and draw up a hierarchy of concept maps is good and right.

Retention tests (table 1) were carried out after 5 months from the posttest. Data on the retention test results when compared with the results of the posttest, both PKU and PKA classes on the ability to analyze, evaluate and synthesize using the t test did not experience a significant difference (t count> 0.05). This means that students are able to maintain the ability to analyze, evaluate, and synthesize within 5 months after the posttest.

Based on the data, it appears that the learners after retested after a period of three months after the posttest, using test instruments equivalent to instruments post test, learners are able to maintain (retention) of each of the components of thinking skills such high levels analysis, synthesis, and evaluation. It is seen that the value of Sig (0.00-0, 02) < α (0.05), it can be concluded that there is a significant correlation between the results of the posttest – retention test. There are differences in average significantly between test scores post-test and retention test, and tends to increase high order thinking skills.

This indicates that the knowledge of higher order thinking skills of learners enter into long-term memory of learners. This premise is supported by the information processing theory to explain when the knowledge (concepts) are frequently used and have entered into long-term memory cognitive learners, then such knowledge will be stored in long term memory of students. While based on the constructivist theory and learning from Ausubel, knowledge learners will be able to continue to grow when the learner is able to link the knowledge that has been owned previously by new knowledge. Knowledge then this knowledge has entered into long-term memory of students, then such knowledge will be presented again when the time taken back again.

IV. CONCLUSION

The results of the study were: (a) the teaching based on concept map in terms of differences in gain scores and the ability to maintain a high level thinking skills (retention). Practicality of concept map have a relatively good practicality because: (a) is able to increase the average score gain the ability to higher order thinking skills learners i.e. for analysis skills, average normalized gain <g> = 0.54 – 0.55 (medium category), evaluation, average normalized gain <g> = 0.47 (medium category), and synthesis/create, average normalized gain <g> = 0.47-0.48 (medium category); (b) based on spss 16 test, learners are able to maintain (retention) of high order thinking skills PKU and PKA class; (c) excellent collaborative work,

discussion and motivation; and (d) facilitate educational students in compiling of teaching material

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