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CONCEPT MAPPING IN CHEMISTRY LESSONS: TOOLS FOR INCULCATING THINKING SKILLS IN CHEMISTRY LEARNING

Kamisah Osman,
Wahidin,
Subahan Mohd Meerah

Abstract. *The aim of this study is to investigate the combination effect of concept mapping and vee diagrams as thinking tools in Chemistry among some 360 secondary students in Indonesia. This study employed a quasi-experimental approach whereby students were segregated into three intervention groups: concept mapping, vee diagram and thinking skills embedded throughout the lesson (E1), concept mapping (E2) and a conventional approach (E3). Students were also characterized in terms of their ability: High (H), Moderate (M) and Low (L). Students' thinking skills were measured using a modified version of the Test of Integrated Process Skills (TIPS), which has beed systematically justified in terms of reliability and validity. Analysis of findings reveal that the EI approach is the most effective technique in inculcating students' thinking skills. A series of follow-up analyses also demonstrate that the E1 approach is best suited for the high ability (H) students as compared to their moderate (M) and low (L) ability counterparts.*

Key words: *chemistry learning, concept mapping, scientific thinking skills, vee diagram.*

Kamisah Osman, Wahidin, Subahan Mohd Meerah
The National University of Malaysia, Malaysia

Introduction

Teaching is "a profession with an undeveloped technical culture characterized by uncertainty about its process as well as outcomes" (Carlgren & Lindblad, 1991; p. 59). In order to reduce the uncertainties accompanying teaching activities certain beliefs and sound pedagogical content knowledge are required. It has been widely argued that teachers' adroitness, especially in terms of their pedagogical content knowledge skills, is still very low. For most teachers, teaching is often considered as routine and it is very difficult for them to manifest their creativity through teaching. It is almost a truism that most teachers hold strong personal theories of teaching and a model of the teacher, well established from their own school experiences and childhood culture (Bullough, 1991). Such scenarios are made worse by teachers' disinclination to conduct action research, ultimately hindering their professional development as well as innovation in teaching.

A synthesis of related science education literature about effective teaching and learning revealed that initiatives to improve the status of science education are gaining attention at almost all levels of educational schooling from the pre-school level to tertiary education. Propagation of effective pedagogical strategies coupled with increasing awareness of the importance of leaner-centeredness in teaching-learning situations has led to an understanding of how learners learn leading to efforts to assist and students to acquire and grasp new concepts meaningfully. Jegede, Alaiyemola, and Okebukola (1990) concur that findings from research on how students at the secondary and tertiary levels acquire new knowledge reflects that only a few received formal instruction in learning how to learn. Currently, extensive efforts have been initiated in assisting learners how to learn, leading to the subsequent development of metacognitive strategies and hence the realization of meaningful learning (Aleven & Koedinger, 2002; Schraw, Crippen, & Hartley, 2006)

Novak and Gowin (1984) advocate that metacognitive strategies provide space for empowerment - a situation in which the learner takes charge of his/her own learning in a highly meaningful fashion. These strategies include: metalearning, described as learning about meaningful learning and metaknowledge which includes learning about the nature of knowledge. In the process of sharpening those metacognitive strategies, concept mapping as well as vee diagrams serve as tools in helping learners to organize their cognitive psyche into more powerful and integrated patterns. The heuristics nature of concept mapping and vee diagrams as metacognitive tools assists learners in assimilating and accommodating concepts as well as understanding the inter-relationship between them. In addition, it can be exploited in such a way that learners can visualize the hierarchical, conceptual and even the prepositional nature of knowledge. Such descriptions paint a rich picture of meaningful learning - a situation in which learners are aware of, and can control, the cognitive processes associated with learning. Concept mapping and vee diagrams were thus found to be effective in creating a meaningful atmosphere in science lessons. It also was found that when these thinking tools are meaningfully and systematically integrated within the teaching of thinking, its effectiveness is significantly better as compared to ordinary modes of teaching (Afamasaga-Fuata'I, 2008; Edmondson, 2000; Nesbit & Adesope, 2006; Stoica, Moraru & Miron, 2011; Tseng, Chang, Lou, Tan & Chin, 2012; Taylor & Coll, 2000).

Concept Mapping and Vee Diagram: Some Theoretical Background

The domination of the cognitive view of learning over behavioral approach since the 1960*s* has altered views about teaching and learning in such a way that teaching must be conducted in a meaningful manner and the material learned must be conceptually clear and equivocally presented with language and examples relatable to the learners' prior knowledge (Ausubel, 1968). As boldly stated by Eggen and Kauchak (2004), such a cognitive revolution perceives learning as an active process in which learners attempt to make sense of what they study. The realization of a cognitive view of learning definitely necessitated a shift in the teaching and learning paradigm; the teachers' role must be changed from that of traditional, knowledge transmitter or provider, to that of facilitator, initiating students' motivation to learn and hence incorporating new meanings into their prior knowledge. Cognizance of the importance of students' prior knowledge in navigating further meaningful understanding had inspired Novak and Gowin (1984) to produce two teaching alternatives - concept mapping and the Vee diagram. It could therefore be argued that the advent of concept and Vee mapping has inspired many researches to focus on specific issues in determining the effectiveness of these thinking, tools especially in tackling problems that are related to the teaching and learning processes (e.g. Stoica et al, 2011; Afamasaga-Fuata'I, 2008; Nesbit & Adesope, 2006; Wheeler & Collins, 2003).

In an extensive review on concept mapping, Edmondson (2000) reports that concept mapping has been widely used in promoting meaningful learning and effective teaching. Not only is it helpful in representing qualitative aspects of students' learning, it might also be used as a learning and evaluation tool, enhancing learning, and even facilitates curriculum planning. It has also been used widely as "road maps" and as an heuristic device. Based on research by Tseng et al (2012), concept-mapping is helpful for knowledge transfer in five learning stages: acquisition, communication, application, acceptance, and assimilation. Concept mapping perceptual strategy or pedagogy improves the knowledge transfer performance because students facilitate the application of knowledge. They use the concept mapping perceptual strategy to gain insight into new and existing knowledge. Furthermore, concept mapping can help students develop good learning habits, which may contribute to future knowledge transfer. Research has also shown that concept mapping successfully increases students' academic achievement (Tseng et al, 2012).

Besides significantly affecting students learning and performance, concept mapping also help teachers design better lesson plans by increasing students' cognitive learning, enhancing retention, and producing a higher order of learning, logical thinking, analysis, and application. In the process

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of mapping concepts, student's own concepts and ideas are revealed allowing any misconceptions to be corrected (Snead & Snead. 2004).

In the teaching and learning process, concept mapping is used as a medium to communicate to students on how new learning is built upon their existing knowledge compendium. It is also used as a tool for getting students to examine their prior-knowledge before studying new materials (Gurlitt & Renkl. 2007). As an heuristic device concept maps elicit the structure of knowledge to expose student idiosyncrasies, errors in reasoning and their alternative frameworks. In short, concept maps are tools for organizing and representing knowledge. In terms of structure it includes concepts, usually enclosed in circles or boxes of some type, as well as the relationship between concepts or propositions, indicated by a connecting line between two concepts. Words on the line specify the relationship between two concepts. Another characteristic of concept maps is that the concepts are represented in hierarchical fashion with the most inclusive, most general concepts at the top of the map and more specific, less general concepts arranged in an hierarchical manner below (Novak & Cañas, 2008) An example of concept mapping is illustrated in Figure 1.

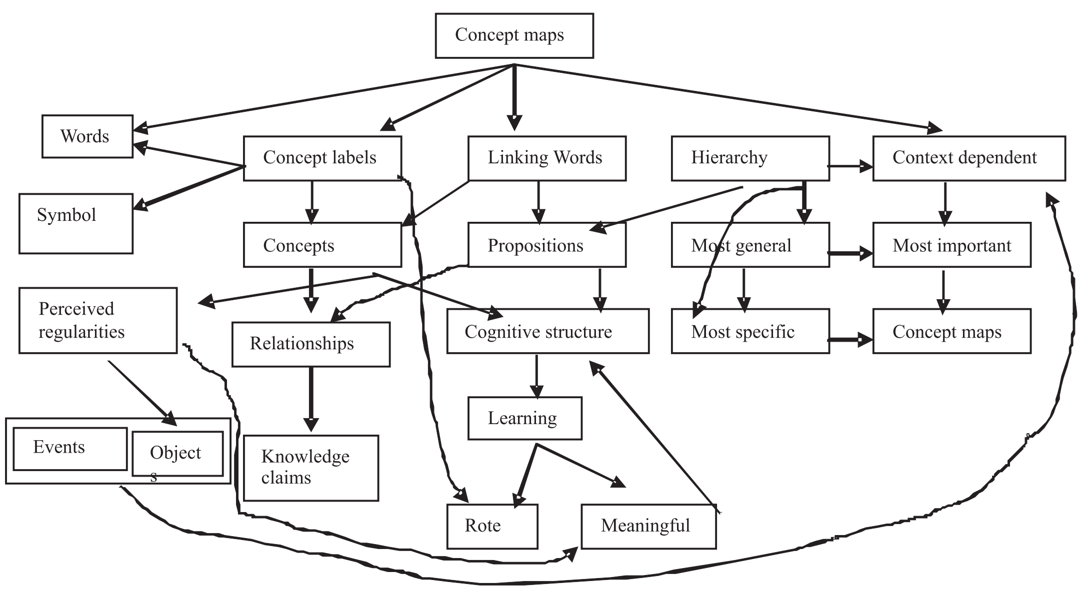

Figure 1: Concept Mapping.

As mentioned by Gurlitt and Renkl (2007), concept maps can be created entirely by the student. Alternatively, educators may prepare incomplete maps and leave specific activities such as creating and labeling connecting lines for the learners. In terms of the construction techniques, there are three that have been established: i) computer-based 'freeconstruction', ii) 'construct-on scaffold,' and iii) 'paper-pencil free-construction' mapping tasks. In conjunction, research about concept mapping tasks used for assessment indicates that different mapping tasks evoke different cognitive processes.

In complementing the advantages offered by concept mapping in navigating students towards meaningful learning, Novak and Gowin (1984) introduce another thinking tool known as vee mapping. Vee mapping, like concept mapping, is a tool for assisting learners to acquire knowledge explicitly *(metalearning)* and to learn the nature of knowledge and its construction *(metaknowledge)* (Kelesi & Ozsoy. 2009; Alvares & Risko, 2007) by offering a visual means by which the relationship between methodological aspects of an activity can be demonstrated. Furthermore, vee diagrams also help a student to construct links between practical knowledge and theoritical knowledge, as well as providing opportunity for students to use the knowledge that they already have (Alvarez & Risko, 2007). The benefits of vee diagrams are imposed by it less structured than conventional teaching methods. Thus, vee diagrams caused students to participate in effective group work by questioning what are their aims and what they should learn in their learning process (Kelesi & Ozsoy, 2009). Figure 2 offers a graphical illustration of a bee diagram with each of its elements equivocally labelled.

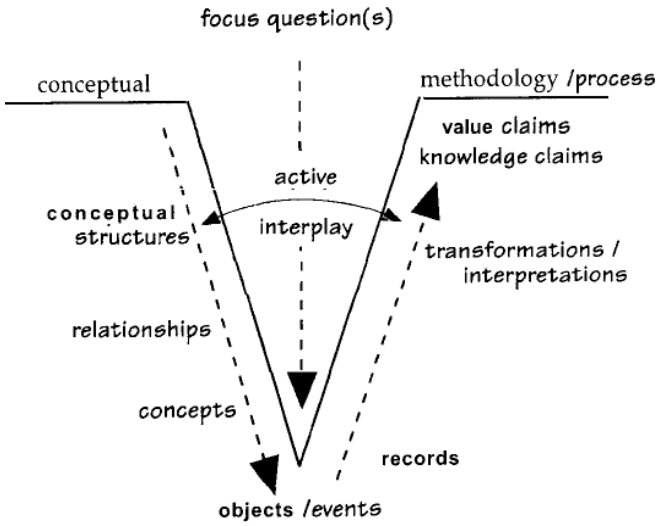

Figure 2: Vee Diagram and Its Components.

Theoretically, at the top of the vee diagram is a *focus question*, which expresses what learners want to find out. The focus question is then directed to an event and the objects used in the event. The left side of the vee is *conceptual*: at this side, lie the *conceptual structures*, *relationship*, and *concepts* that are or might be involved in directing the learners towards the solution of the focus question. The right side of the diagram begins with making *records* of the event. The *transformation* and *interpretation* of these records may involve reorganization and rearrangement of the records and may include constructing tables, charts, and graphs from which conclusions can more readily be drawn. The *knowledge claims* share the answers to the focus questions and these claims should be the products of interaction between the conceptual and methodological elements of the vee. In ensuring the effective solution of the question, the interaction between the concept and the event is considered essential. Finally, there is a *value* claim, which address the issues of the worthiness of the knowledge claim as well as the process that leads to that claim

Despite its usefulness in facilitating meaningful learning, Uzuntiryaki and Geban (2005); Liu, Chen and Chang, (2010) cautiously reminds us that when these support materials are used as thinking tools, its' effectiveness will depend on the cognitive ability of the students; mixed results were found when exposed to students from various cognitive abilities raising doubts about the effectiveness of these thinking tools.

For this research, concept mapping and vee diagram tools were applied to chemistry lessons. Concepts are the main component in the chemistry conceptual system. Through the process of conceptual thinking students actively developed the chemistry conceptual system in their cognitive structure. By assessing the significant relationship between a new concept and a prior concept they already possessed, the process of concept development can occur smoothly. Based on the Piaget and Vigotsky (1934) constructivist theory and Ausubel (1968) and Novak and Tyler (1977) meaningful learning theory, concept development and meaningful concept learning can be done by executing concept mapping and vee diagram technique. Chemistry is selected as subject area in this study due to low Indonesian students' achievement in this subject. Additionally, for the vast majority of students in Indonesia, Chemistry has been regarded as a difficult, unattractive subject and discourages further career embarkment in Chem-

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istry related areas. Thus, effective use of concept and vee mapping in Chemistry lesson will produce meaningful teaching and learning episodes while at the same time taking into account diversity in terms of students' ability level. Moreover, scientific thinking skill is an essential element that should be practiced by teachers and students at all levels, in line with the purpose of science teaching and learning. In the Chemistry syllabus, teaching Chemistry should develop those human resources who have the necessary chemistry intellectual and psychomotor competencies, based on scientific attitude, so that they may proceed to higher studies and a career in a chemistry related field and so contributing to an area of the economy identified as strategic and in which there is a shortage of skilled Indonesians.

This research focuses on the effectiveness of concept mapping and vee diagram in inculcating thinking skills in chemistry lessons, while at the same time, taking into account the students' cognitive abilities. Specifically, this paper is designed to address the following main questions:

1. Do concept and vee mapping when used as support techniques in the teaching of thinking embedded within the chemistry curriculum significantly improve the students' thinking skills?; and
2. Does the students' cognitive ability level have significant impact on their thinking skills when exposed to chemistry lessons supported by the use of concept and vee mapping?

Research Methodology

Design and Procedures

The "intact" nature of the sample under investigation (and the impossibility therefore of random assignment) justifies the use of a quasi-experimental research design as being most appropriate for this study (Cohen & Manion, 1980). Campbell and Stanley (1969) stress the importance of a "self-critical" approach to quasi-experimentation, since findings from it arguably, are never "airtight" unless an extensive effort is made to anticipate and minimize threats to the internal and external validity (Campbell & Stanley, 1969; Cook & Campbell, 1979) of the study. Additionally, the design chosen must satisfy conclusion validity as well as construct validity of cause and effect. In order to secure construct validity in particular, a reversed treatment design, specifically known as "the reversed-treatment non-equivalent control group design' with pre-test and post-test was employed (Cook & Campbell, 1979). A diagrammatic description is given in Table 1 where X+ represents a treatment given by means of concept mapping, vee diagrams and thinking skills, X- represents the conceptually opposite treatment that would be expected to reverse the patterns of findings in the X+ group; viz. concept mapping. The control group is used as a no-treatment group in order to provide a no-cause database, which should help secure the statistical conclusion validity of the design.

Table 1. Design of the Study.

Group	Pretest	Treatment	Post test
Experiment 1 (E1)	O1	X1	O2
Experiment 2 (E2)	O3	X2	O4
Control (E3)	O5	X3	O6

Notes:

X_1 = *Vee diagram, concept mapping, which is embedded in the thinking skills*
X_2 = *Teaching use concept mapping*
X_3 = *Conventional*
O_1, O_3, O_5 = *Pretest*
O_2, O_4, O_6 = *Posttest*
………… = *Absence of random assignment*

Prior to the segregation of students into the experimental and control groups, they were given the test of thinking skills to measure their thinking skills ability. The intact group was then sub-divided into three different groups; two experimental and one control group of "no treatment". In the first group, concept mapping and vee diagrams were used as support techniques in the teaching of thinking via the embedded approach where the teaching of thinking is implemented by using the content of the curriculum as the vehicle for thinking. As opposed to the first group, students in the second group were exposed to the teaching of science content, which emphasized the use of merely concept mapping. Finally, the cohort in the third group underwent teaching and learning using the traditional, conventional method. These were subsequently exposed to the "intervention strategy" which lasted for sixteen weeks (one semester). The content areas covered during that experimental period were Atomic Structure, the Periodic Table and Chemical Bonding. After the "intervention strategy" students' thinking skills ability was measured for the second time in a post - test. Figure 3 depicts a schematic diagram of procedures involved in planning the teaching strategies as mentioned in the research procedures.

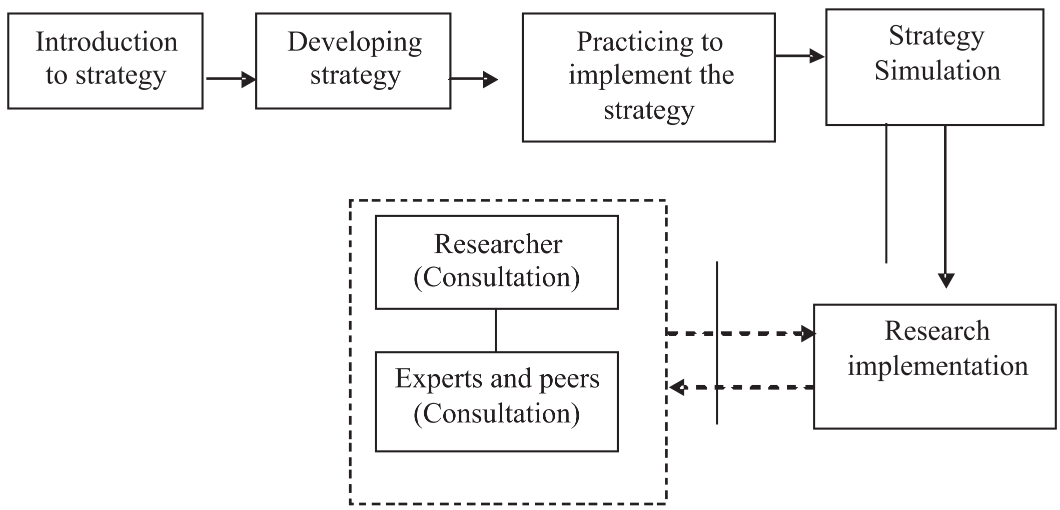

Figure 3: Schematic Procedures in the Planning Stage of Teaching Strategy.

Samples: The Intact Group

The target population of the study consisted of a total of 3400 Form Four students in the District of Ciamis, East Jawa, Indonesia, out of which 360 were chosen, from three secondary schools in each of the districts, as the sample for the study. In an attempt to reduce initial differences, whilst securing the internal validity of the quasi-experiment approach employed in this study, students in the intact group were matched so that in every method of intervention strategy (concept mapping, vee diagram and thinking skills (E1), concept mapping (E2), conventional (E3)) there was an equal balance in terms of previous academic achievement with each group consisting of three different achievement levels: high (H), moderate (M) and low (L)).

Instrument

In this study, students' thinking skills are gauged using a modified version of Test of Integrated Process Skills (TIPS) (Okey & Dillshaw, 1980; Alias, 1997). A four-option, multiple choices question type is employed and the content of the test is fully modified to suit the context within which the test will be employed, as well as the psychological and sociological backgrounds of the East Jawa Province's society. TIPS is primarily designed to measure integrated science process skills, nevertheless, its suitability for this study is justified based on the notion that there is a strong association between integrated sci-

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ence process skills and thinking skills. Additionally, a synthesis of many research outcomes as well as of the relevant literature also confirmed the associations between science process skills and thinking skills (Taylor, 1991) (see Table 2). The modified version of TIPS used in this study was made up of of 36 multiple-choice questions. Prior to the study, the modified TIPS proved its validity as well as reliability with a KR-21 value of 0.7112. Correspondingly, a comprehensive item-analysis was also conducted to determine the suitability of items in terms of its difficulty as well as discriminating power (Pallant, 2011). Detailed descriptions of the modified TIPS used in this study are as summarized in Table 3.

Table 2. The Dimensions of Science Thinking Skills and Its interrelatedness with Integrated Science Process Skills.

	No	Category	
		Science Process Skills	Thinking Skills
THE CHARACTERISTICS OF SCIENTIFIC THINKING SKILLS	1	Interpret data and graph	Make connection, draw conclusion, analyze, differentiate
	2	Design investigation	Generate idea, analyze, characterize, differentiate
	3	Identify variables	Analysis, differentiate, characterize
	4	Define operationally	Visualize mentally, analyze, and draw conclusion
	5	Hypothesize	Generate idea, differentiate, make connections and hypothesize
	6	Observe	Differentiate, characterize
	7	Classify	Draw conclusion, classify
	8	Measure and use of numbers	Differentiate
	9	Make inference	Differentiate, making inference
	10.	Use space and time relationship	Arrange based on priority

Table 3. Description of Test to Measure Thinking Skills.

Dimesion	Category		No Item	Item Descriptions
	Science Process Skills*	Thinking Skills **		
1	Interpret data and graph	Make relationships, draw conclusion, analyze, synthesize, differentiate	8	1, 29,31,32,33,34, 35, 36.
2	Design investigation	Generate ideas, analyze, differentiate	5	21,22,23, 24,30
3	Identify variables	Analyze, differentiate, characterize	10	3,5,6,7,9,10,12,13, 15, 16
4	Define operationally	Make mental visualization, analyze, draw conclusion	5	2,8,26,27, 28
5	Identify and make hypothesis	Generate ideas, differentiate, make connection, hypothesize	8	4,11,14,17,18, 19,20, 25.

** American Association for the achievement of science (AAAS 1970), (Okey & Dilshaw, 1980)*
*** Salbiah (1999)*

Statistical Data Analysis

In dealing with the quantifiable data gathered from the research design two main stages of data analysis are employed. In the first stage, a descriptive analysis is used, thereafter, a chain of inductive reasoning follows. At this stage inferential statistical analysis is conducted in order to predict population parameters from sample measures. The main statistical analysis used is the Analysis of Covariance (ANCOVA) due to its capability of showing, not only, significance between total scores (thinking skills), but also interaction between sub-scores. This is particularly important in this study since the dependent and independent variables are sub-divided into several different sub-scores and categories.

Research Results

Figure 4 and 5 show the example of concept maps that had been produced during the intervention on the topic of the Periodic Elements Table and Chemical Bonding by the students, while Figure 6 shows vee diagram that had been produced by the students on the topic of Atomic Structure.

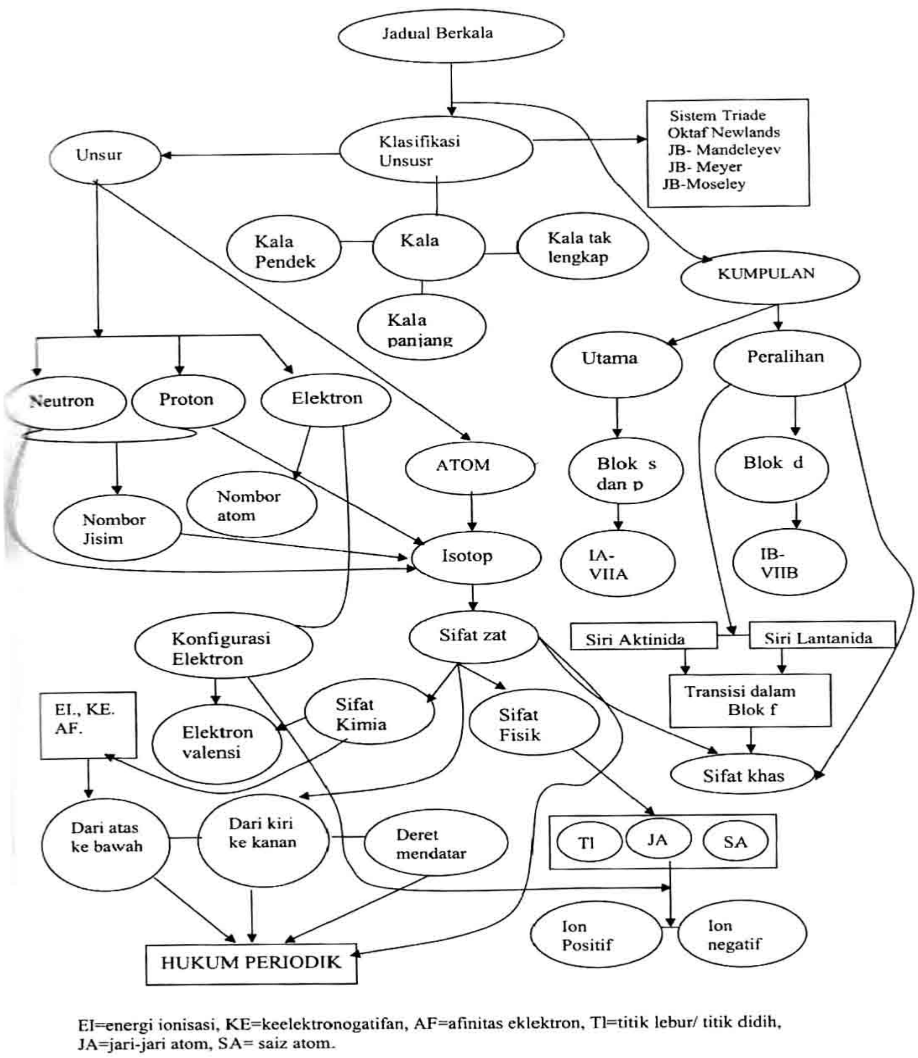

Figure 4: Mapping on Periodic Element Table.

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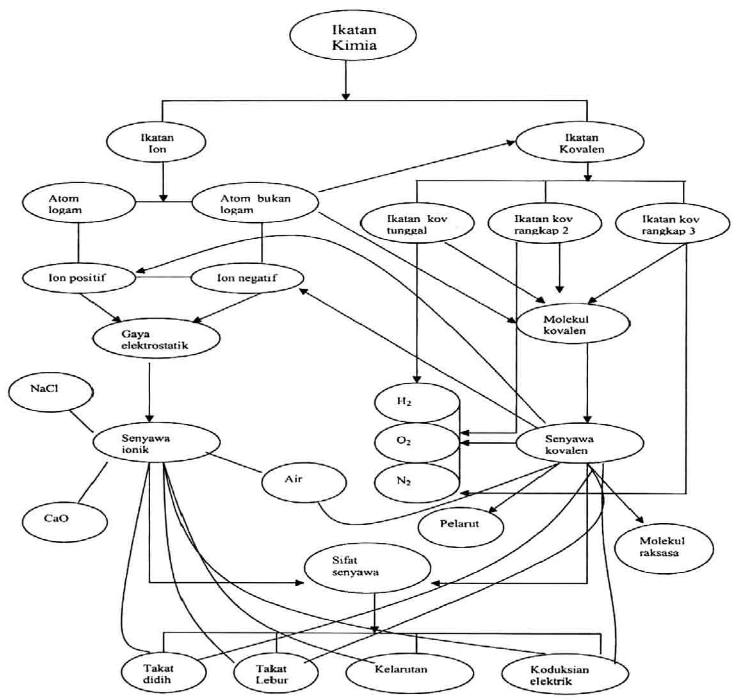

Figure 5: Mapping on Chemical Bonding Topic.

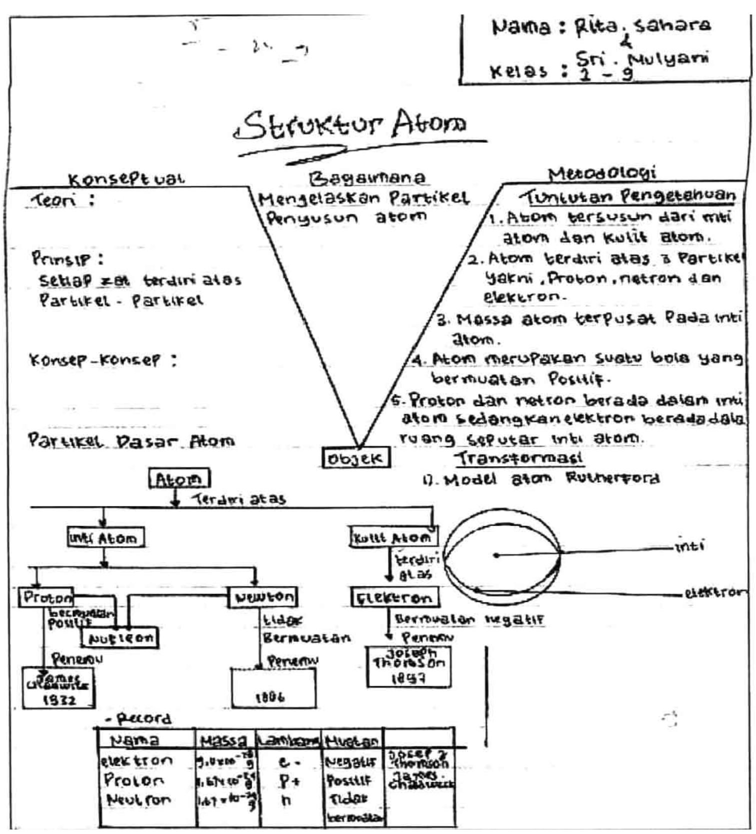

Figure 6: Vee Diagram on Atomic Structure Topic.

The first stage in determining the significant main effect of the intervention strategy upon the students' thinking skills, is to compare the scores obtained by the experimental groups (concept mapping, vee diagram and thinking skills and concept mapping alone) with the control group across ability level. From Table 3, the mean score of E1, E2 and E3 is 17.10, 17.36 and 15.76 respectively. Across ability level, the mean score of high (H), moderate (M) and low ability (L) students is 19.79, 17.2 and 13.21 respectively. From this preliminary data it appears that this group of students (experimental and control) demonstrates an overall deficiency in terms of thinking skills and underpins the homogeneity of both test and control groups before the intervention strategy.

Table 4. Comparison of Mean Score, Standard Deviation, and Gain Score Science Thinking Skills Based on Method of Intervention Strategy and Ability Level.

Teaching Strategy	Ability Level of Student	N	Score Mean Pre test	Score Mean Post test	S. D.	Gain Score
E1	High	40	19.525	30.850	2.237	11.325
	Moderate	40	17.425	22.875	3.582	5.450
	Low	40	14.350	15.900	3.136	1.550
	Overall	120	17.100	23.208	3.424	6.108
E2	High	40	19.750	26.175	3.169	6.425
	Moderate	40	17.950	20.550	3.537	2.600
	Low	40	14.375	15.925	2.999	1.550
	Overall	120	17.358	20.883	3.498	3.525
E3	High	40	20.100	24.050	3.046	3.950
	Moderate	40	16.250	17.800	3.172	1.550
	Low	40	10.925	16.650	2.833	5.725
	Overall	120	15.758	19.500	2.443	3.742
Overall		360	16.739	21.197	5.779	4.460

After the intervention strategy, it was found that for most students, their thinking skills have been improved, this is especially true of the high ability students (H) who received treatment via the integration of concept mapping and vee diagrams embedded in the teaching of thinking skills (E1). For those in the E1 group, their score increased by 35 percent as compared to only 20 percent in the E2 and 23 percent in the E3 group. When students' thinking skills development is evaluated based on their cognitive ability, for each method of intervention strategy (E1, E2 and E3), it was found that students in high (H) category demonstrated the highest improvement in their thinking skills, followed by students in the moderate (M) and lower group (L) respectively. Looking across each category, a follow up analysis of paired sample t-test shows that there exist significant differences between the pretest and posttest scores (see Table 4). Output summarized in Table 5 shows whether such differences are being influenced by the method of intervention strategy and students' ability level.

Table 5. Paired Samples t-test for Total Thinking Skills Scores and Its Category.

Thinking Skills	Mean Difference	t	Degree of Freedom	Sig. (2-tailed)	Interval Difference (C.I.D 95%)	
					Lower	Upper
Total	3.642	14.740	359	0.000	3.155	4.127
Category 1	1.372	13.054	359	0.000	1.165	1.579

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Thinking Skills	Mean Difference	t	Degree of Freedom	Sig. (2-tailed)	Interval Difference (C.I.D 95%)	
					Lower	Upper
Category 2	0.214	2.291	359	0.023	0.030	0.397
Category 3	1.214	10.888	359	0.000	0.994	1.433
Category 4	0.425	7.473	359	0.000	0.312	0.536
Category 5	0.414	4.589	359	0.000	0.236	0.591

0.05 level of significance

An analysis of every sub-dimension of thinking skills also portrays similar trends (See Table 5). It was found that for each thinking category, scores yielded for the experimental and the control groups depends on their ability level. Generally, high ability students obtained a better score as compared to their moderate and low counterparts. As mentioned earlier, all the students are identical in terms of their thinking skills prior to exposure to an intervention strategy. Thus, analysis on the score for each category will focus on the post-test scores. It was found that for the first category (making relationship, draw conclusion, analyze, synthesize, differentiate), the means scores are E1=5.16, E2=5.13 and E3=4.27. The second category, which measures the ability to generate ideas, analyze, make differentiation, the mean score for each group is E1=4.38, E2=4.05, and E3=3.93 respectively. In terms of the ability to analyze, differentiate, characterize, the scores are E1=5.44, E2=5.03, and E3=4.65. Unlike, the first three, the scores gained for the forth category are slightly lower; E1=2.50, E2=2.41, and E3=2.10. Finally, for the fifth category, the mean score for E1, E2 and E3 is 4.05, 4.10 and 3.94 respectively.

When the mean scores are compared across ability level, a similar pattern of achievement is shown (See Table 6). For the first category, the mean scores are H=6.75, M=4.37 and L=3.42. The second category, which measure the ability to generate ideas, analyze, make differentiation, the mean score for each group is H=4.733, M=4.39, and L=3.23. The third category score for H is 6.48, and M score 26% higher than H; 4.775 and for those in the L group, the score is the lowest at 3.86. In terms of ability to produce mental visualization, analyze and draw conclusion, the score is H=2.87, M=2.34 and L=1.80. Again, in the fifth category, the pattern of score is similar; H=4.62, M=4.52 and L=2.95.

In the following section, output from Analysis of Covariance (ANCOVA) will be presented, to determine whether there is significant main effect of test time (pretest, posttest), method of intervention (E1, E2, E3) and ability level (H, M, L) in determining thinking skills among the students in Chemistry lessons.

Table 6. Comparison of Mean Score, Standard Deviation, and Gain Score for Every Thinking Skill Category based on Method of Intervention Strategy and Ability Level.

Category	Teaching Strategy (E1)						Teaching Strategy (E2)						Teaching Strategy (E3)					
	Pre Test			Post Test			Pre Test			Post Test			Pre Test			Post Test		
Mean Score	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L	H	M	L
Category 1	4.05	3.60	2.98	7.23	5.03	3.23	4.45	3.25	3.68	7.30	4.55	3.55	4.23	2.50	3.20	5.75	3.55	3.50
Category 2	4.83	3.78	3.13	5.25	4075	3.15	5.38	4.75	3.10	4.37	4.33	3.45	4.43	3.75	2.08	4.57	4.10	3.10
Category 3	4.50	4.05	3.65	6.90	5.73	3.70	3.03	3.78	3.65	6.73	4.78	3.58	5.45	3.35	2.98	6.73	4.78	3.58
Category 4	2.10	1.93	1.80	2.93	2.70	1.88	2.60	2.03	1.78	3.08	2.40	1.75	2.25	1.73	1.00	2.60	1.93	1.78
Category 5	4.05	4.08	2.80	4.58	4.68	2.90	4.30	4.15	2.78	4.60	4.50	3.20	3.75	4.48	1.68	4.68	4.40	2.75

Table 7. Analysis of Covariance (ANCOVA) based on Method of Intervention Strategy and Ability Level.

Dependent Variables	Main Effect	Sum of Square	Degree of Freedom	Mean Square	F value	Sig. Level
Science Thinking Skills	Test Time	271.063	1	271.063	25.598	0.000**
	Method of Intervention Strategy1	356.817	2	178.408	16.848	0.000**
	Ability Level2	2706.070	2	1353.035	127.774	0.000**
	Method of Intervention Strategy * Ability Level	485.020	4	121.255	11.451	0.000**
	Error	3685.083	248	10.589		
	Total	11050.864	359			

0.05 level of significance
1) E1, E2, E3 2) H, M, L

Research findings, succinctly presented in Table 4 to 7, provide evidence to show that students in the test group have demonstrated significant changes in their thinking skills post test score. As indicated earlier, there are two different methods by which students in the test groups were treated; concept mapping, vee diagrams and thinking skills and concept mapping alone. In this section, the main effect of method, test time and ability level and interaction among the three factors are explored. A summary of result is presented in Table 7. The main effect of method is significant at the 0.05 level of significance ($F = 16.848, p<.05$); the test time main effect ($F = 25.598, p<.05$), the ability level main effect ($F = 127.77, p<.05$) and method of intervention strategy by ability level interaction ($F = 11.45, p<.05$). Figure 4 plots the interaction between method of intervention strategy and ability level.

In Figure 7 interaction is indicated by the presence of nonparallel lines (Steven, 1992) representing the effect generated by the method of intervention strategy on students' thinking skills score as well as ability level. It is clear that the students' thinking skills changed noticeably after the intervention strategy. It is also apparent that the changes in thinking skills of students in the E1 group are significantly greater than the level of change in the E2 and the E3 group. There exists interaction between the H and the M group, the M and L group and the H and L. Patterns of interaction yielded from the analyses lead to the conclusion that the effect of the method of intervention strategy upon students' thinking skills is determined by students' cognitive ability

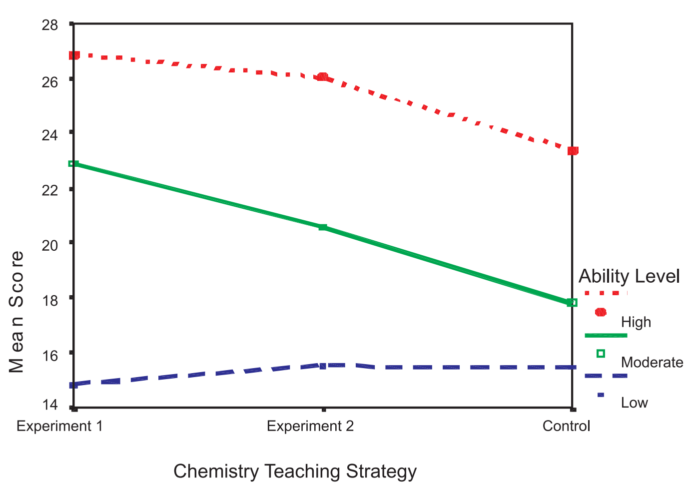

Figure 7: Graphical Illustration of Interaction between Method of Intervention Strategy and Ability Level.

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Discussion

This study provides empirical evidence of the effectiveness of concept and vee mapping as support techniques in an embedded approach of teaching how to think in Chemistry lessons. Specifically the topics involved were Atomic Structure, Periodic Table and Chemical Bonding. Students' thinking skills ability was significantly changed as a result of the intervention received. This is followed by students who received treatment via concept mapping and the cohort in the control group demonstrates the lowest changes in terms of their thinking skills. From these finding it can be concluded that when concept mapping and vee diagram techniques are embedded into chemistry learmimg they increase students' science thinking skills. In conjunction, this study supported the findings of Liliasari (1996) which highlighted that concept mapping when meaningfully integrated into Chemistry lessons enables teachers to explore students' thinking skills development and using the concept mapping produced, students' thinking skills can be analyzed. Moreover, the Chemistry concepts involved in this study could be meaningfully structured with the use of concept mapping and vee diagrams. Thus, students' thinking ability as measured in this study is equivocally manifested by the diagrams produced.

This study supports the learning psychology view and the findings of previous studies (Ausubel, 1968; Gagne, 1988; Novak & Gowin, 1999) which emphasise the importance of meaningful learning in order to develop students' intellectual skills. In this study, it has been shown that vee diagram and concept mapping are tools to help and change students' thinking patterns, developing improved techniques of thinking as they understood the concepts presented by their teachers, eventually leading to meaningful learning (Ahlberg, 2003). The main purpose of teaching as implemented in this study is not just about knowing the vee diagram and concept mapping tool techniques - an understanding of the chemistry concept is crucial. Besdies acquisition of chemistry concepts, the process of learning using concept mapping and vee diagrams create higher order thinking skills as an indirect effect. Therefore it is more meaningful if the students know actually how to use this technique. On the other hand, student misunderstanding on how to use these techniques may result in ineffective learning and, therefore, teachers need to provide the best possible strategies so that the use of concept maps and vee map will be beneficial for chemistry teaching and learning.

As highlighted earlier in the research design, this study uses two independent variables - students' ability level and method of intervention strategy. The results of the analysis suggest that the positive results shown for the intervention group are not merely influenced by the method of intervention strategy employed but also by the students'cognitive level. There is an interaction between the method of intervention and ability level in determining students' improvement in their thinking skills with higher achieving students tending to benefit more than those in the lower achiever group. A similar pattern of attaintment is also demonstrated for every category of thinking skill dimension and this study supports the view of Clifford, Boufal and Kurtz (2004) which states that cognitive factors determine a person's level of thinking skills. The results also support work by Alias (1996) which reported that cognitive style affects logical thinking skills, science process and science achievement. Nevertheless, as highlighted in the research instrument, there is a redundancy of skills for every category and explains why discussion will be focused on the total score, justifying the elimination of the thinking skills sub-category in the analysis. Theoretical background underpins the use of concept and vee mapping explicitly, explaining the advantages of these thinking tools in rejuvenating, and hence inculcating, students' thinking skills while at the same time maintaining their achievement.

Kirk (1968) and Howell (1997) argued that whenever the interaction is significant, analysis of the simple interaction effect should be made. Such an analysis has proved useful especially in terms of examining the source of the main effect of method in influencing the post-test score. In this study analyses of the simple interaction effect were performed on each ability level and the findings suggest that the method of intervention may have a significant effect in determining the thinking skills post-test score on every ability level. Correspondingly, in determining the source of the main effect of method of intervention and ability level, a series of analyses of variance followed by Bonferroni post hoc, as suggested by Myers (1979), were conducted. Outputs generated from these series of analyses lead to the final conclusion that significant main effect of method of intervention strategy is limited to the high ability group exclusively.

It is almost axiomatic that students with high ability levels will demonstrate positive behavior when introduced to new teaching techniques and approaches. By referring to the age old trilogy of attitude - affective, cognitive and conative (Rokeach, 1968), individuals who posses high cognitive skills about X will exhibit positive behavior towards X. Similarly, in this study, students with high cognitive ability will have positive attitude towards the use of concept and vee mapping and hence encourage them to participate actively in class. Based on a cognitive view of learning, students' active participation will lead to meaningful learning (Eggen & Kauchak, 2004). In addition, it could be argued that high ability level students did not respond well to teachers who dominated their learning process and they are more comfortable with teaching strategies that promote thinking, freedom of thought and put forward ideas. Thus concept mapping and vee diagram techniques are successful because they impose student-centered teaching strategies (Kelesi & Ozsoy 2009).

On the other hand, this study shows the significant positive increments of students' thinking skills in the high ability students are due to the level of students' readiness, willingness and motivation to undergo the learning process. Based on students' background information, it appears that the high ability students mostly derived from high socio-economic status families and parents with a good educational background. This is in contrast with students of lower ability, the majority of whom derive from lower socio-economic status families. In this case, the study assumes the role of parents as motivators with access to learning facilities playing a significant role in determining the students' thinking activities, thus effecting their thinking skills.

For those in the lower group, negative attitudes towards concept and vee mapping is shaped by their lower cognitive skills and lack of understanding of Chemistry concepts may be the most important factor leading to their lower scores in the thinking skills test. Results were worse when students were taught merely by the traditional, lecturing method. This group of students should be given conducive support for them to be able to develop their cognitive skills while at the same time understanding the Chemistry concepts that are being taught. Although the affect of concept mapping and vee diagsram strategy did not imply a major increment in their thinking skills performance, there is still some contribution. Thus it shows that the elements of concept mapping and vee diagrams demands higher-order thinking activities and it is essential for teachers to apply this teaching technique for all students and, by so doing, not merely their conceptual understamding can be improved, but their scientific thinking as well. Even though concept mapping and the vee diagram method result in a significant contribution to the high ability level students in comparison to the other groups, teachers should take certain initiatives in order to allow students from all levels of ability to optimize their thinking skills.

It is important to note that the success of the national curriculum is dependent on a dynamic and quality interaction process between teachers, students and curriculum development (Johnson, Maruyama, Johnson, Nelson & Skon, 1981). This study has proven that students' level of ability has a greater impact on their thinking skills when compared to the effect of teaching skills and strategy. Not all teachers are exposed to instructional strategies that opt for concept mapping and vee diagrams and are not always able to use this strategy effectively and creatively. There is an obvious need to improve teacher education and curriculum development, whether at the pre-service or in-service level.

Conclusions

To conclude, this study has made an important contribution to research by empirical data to support many previous studies on the effectiveness of concept and vee mapping in inculcating students thinking skills in Chemistry lessons. Undoubtedly, as previously mentioned, Chemistry is not a popular subject in the Republic of Indonesia. Meaningful use of concept and vee mapping as support techniques in that subject, however, has successfully improved the students' thinking skills, which arguably, lead to better achievement in that subject. Additionally, as shown in the follow-up analyses the use of concept mapping and vee diagrams is most effective for higher achievers students as compared to their lower achieving counterparts and effort must be made to instill a positive student attitude towards teaching and learning. This is in line with the ultimate aim of Chemistry education in general; to enlighten the students and make them realize the contribution of science in society at large, rather than merely bewildering

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them with intangible and abstract concepts, laws and theories. Meanwhile, the advent of technology has also transformed the features and activities of concept mapping and vee diagram teaching and learning and the availability of such innovations should allow creative teachers to use concept mapping and vee diagrams effectively with lower ability students to encourage higher order thinking skills resulting in the understanding of the concepts of Chemistry and a higher rate of achievement in tests.

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Kamisah Osman	PhD in Science Education from the University of Manchester, United Kingdom. Currently an Associate Professor, Department of Teaching and Learning Innovation, Faculty of Education, The National University of Malaysia, 43600 UKM Bangi, Selangor, Malaysia. E-mail: kamisah@ukm.my
Wahidin	PhD in Science Education from the National University of Malaysia. He is now a Professor in Science Education at Islamic State Institute Nurjati Cirebon, Indonesia. E-mail: wahid_stain@yahoo.com
Subahan Mohd Meerah	PhD in Science Education from the University of Southampton United Kingdom. Currently a Professor, Department of Educational Leadership and Policy, Faculty of Education, The National University of Malaysia, 43600 UKM Bangi, Selangor, Malaysia. E-mail: subhan@ukm.my