Liceo Journal of HighResearchEducation Research
Print ISSN 2094-1064 • Electronic ISSN 2244-0437 doi: http://dx.doi.org/10.7828/ljher.v7i1.17

Effects of Vee Diagram and Concept Mapping on the Achievement of Students in Chemistry

DOMINIC T. POLANCOS
dpolancos74@gmail.com
Liceo de Cagayan University

Abstract - This paper presents the results of an experiment that compared the effectiveness of the use of Vee Diagrams against that of Concept Maps in learning chemistry concepts. It followed a quasi-experimental and a non-equivalent comparison group approach. The experiment involved two classes of third-year students of Liceo de Cagayan University High School in Cagayan de Oro City during the school year 2009-2010. Before the intervention, two similar tests were prepared, the pretest (PRT) and the posttest (POT). The t-test and Analysis of Covariance (ANCOVA) were used to analyze the delta between the PRT and POT. The POT result shows that there is no significant difference in students' achievement between these two approaches: Vee Diagrams and Concept Maps. Evidently, both help students develop a rich system of concepts and their learning strategies that stimulate learners not only to use concepts that have already internalized but also to build conceptual interconnections. The conceptual interconnections that help students formulate theoretical explanations about observed changes. Teachers should stimulate students to integrate knowledge from the various scientific disciplines. The findings point to the importance of emphasizing connections between concepts in high-school Chemistry instruction.

Keywords - vee diagram, concept mapping, achievement in chemistry

---

This paper passed the plagiarism detector, spelling and grammar checker, Gunning Fog Index, Flesch Reading Ease, reference checker, and formula checker.

INTRODUCTION

High-school students generally perceive chemistry as a difficult subject. Coping with this, many chemistry teachers consider the teaching of chemistry and then science concepts to be key components of instruction. Such chemistry teachers' impression stems from students' vague understanding of science and chemistry concepts; therefore, chemistry teachers incline to focus on teaching the concepts. Indeed chemistry teachers have made various endeavors to overcome this problem. Although teaching chemistry concepts in high-school is demanding of chemistry teachers, it is not only challenging but also rewarding for them to make sure that students improve the quality of their learning the concepts over the course of instruction. It will be more challenging if chemistry teachers have a rich science curriculum that allows them to build an exciting activity-based exploratory learning environment. In order to make their endeavors successful, chemistry teachers have to take account of three factors: specialized usage of terms, mathematical nature and the volume of material to be learned within a limited period of time.

In recent decades, the concept of meaningful learning styles has steadily gained influence in the endeavors of teaching and imparting knowledge to the learners. These styles include progress in monitoring of high school students' achievement in chemistry, for example, their understanding of the science concepts we, chemistry teachers, have just taught. Our endeavors are essentials for the progress as Toh, Ho, Chew & Riley (2003) pointed out that most science textbooks do not explain to teachers how to deeply explore ever deeper into content concepts. Science textbooks of this kind result in weak learning or non-learning. Learning is definitely weak and poor (Yuan & Hong Kween, 2007) without Vee Diagram (VD) or Concept Maps (CM) in science classroom teaching.

It is true that CMs or VDs make it easier for students to gain a better understanding of a scientific concept, but it is also true that students learn science concepts by rote (Songer& Linn, 1991). However, those students who acquire an understanding of science concepts by rote tend to view science as dissembled pieces of information nor do they see the big picture of a unit of learning (diSessa, 1988). Consequently, those students do not assimilate new concepts into their long-term memory (Novak, 1993), and often, the students have a lack of right understanding of concepts and principles by which those concepts are formulated.

FRAMEWORK

In the context of organized systems of education, the issue of students' period of learning is extremely important because of the progressive structuring of knowledge and understanding. Despite this feature of the structuring, teachers expect students to acquire not only new knowledge in sufficient depth but also to retain this knowledge for a long period of time. Therefore, teachers can believe that the more durable the concepts remain in the mind, the better will the students be equipped with the knowledge and set of skills that they can apply and use for real-life settings. Consequently, further learning must be based on the current set of concepts (Novak &Gowin, 1984).

In addition to the issue of students' period for learning, another issue of educational tools should be taken in consideration. Unless the tools to synthesize information from multiple sources are available to students, they might be handicapped at integrating and reconciling concepts. As Gabel (1987) has shown, for that such students may produce correct answers to various kinds of problems, but their understanding of the underlying science concepts is lacking. Although students appear able to perform the required operations, students' generally fail-in producing a creditable achievement owing to their shallow understanding.

In order to improve this, it is efficient to foster learning of superordinate concepts. The learning gives new meanings to relevant subordinate concepts and propositions; then it facilitates the process of integrating and reconciling concepts.

Jean Piaget (1995) when writing about the development of the human cognitive process, states that the building of concepts is a system in which their elements are necessarily constructed on top of one another while at the same time essentially open to multiple exchanges with the outside elements. To learn better, learning must be meaningful. When superordinate concepts are learned meaningfully, they become able to give new meaning to relevant subordinate concepts and propositions. This contributes to an integrative synthesis of concepts concerned. Presumably then, it would be impossible to build from a single concept as a starting point in a classification without using other domain-related concepts which students have not yet establish a hierarchical relationship. The establishment of the hierarchical relationship is a dynamic process for students' interconnecting variables.

After this process goes on to a certain degree, concepts are linked. The lower concepts in the hierarchical structure are subsumed within those of the higher levels. The subordinates are depicted above the subsumed concepts. In the hierarchical structure, a subordinates and super ordinates are defined relatively, and two or more concepts linked together by words to create a proposition that is described by an arrow indicating the direction of a superordinate-subordinate relationship. The propositions help to develop the connections between linked concepts with greater precision (Novak &Gowin, 1984). Constructing concept maps, students develop well-organized conceptual frameworks and well-integrated superordinate concept (Duffy & Jonassen, 1992).

From the perspective of both the theory of learning and the theory of knowledge, it is an interesting challenge for science educators to design an instruction strategy that encourages students to accomplish higher levels of meaningful learning. Dutra et. al. (2004), declares: in the dynamic of making a concept map, one can follow the representation of a system of meanings activated in an individual so that in it we also recognize subsystems that relate to one another by mutual support in the building of such meanings. The key factor contributing to low level conceptual understanding and large number of misconceptions among students is that currently employed science teaching methods do not seek to diagnose or engage student's prior knowledge. Informative instruction conducted in such a lesson encourages passive learning only (Boo, 2005).

This kind of instruction is the reason why students come to science class with misconceptions, preconceptions or alternative conceptions already are formed as a result of their interactions with the world. These alternative conceptions have great influence on how they interpret and construct new conceptions in science class.

In this theory, a teacher should serve as a facilitator who attempts to structure an environment in which learners organizes meaning at their personal level (Cooper & Robinson, 2002). This is the constructivist perspective of learning. There learners are constantly creating and revising his or her internal representation of knowledge when new concepts are linked to familiar concepts existing in learners' cognitive structure. Thus, learners become able to apply their cognitive structure to all subject matters.

OBJECTIVES OF THE STUDY

Focusing on their effectiveness, the study compares Vee Diagrams (VD) against Concept Maps (CM) as learning tools in understanding science chemistry concepts. The comparative study has been carried out having the following objectives: (1) to determine the pretest (PRT) and posttest (POT) scores in order to compare results from Vee Diagrams and Concept Maps; (2) to determine whether the combined pretest (PRT) and posttest (POT) scores of the Vee Diagram or Concept Maps differ significantly (*á* = 0.05); (3) to determine whether the posttest (POT) scores of the use of the Vee Diagram and Concept Map differ significantly (*á* = 0.05).

HYPOTHESES

The following null hypotheses are formulated for testing at a significance level of 0.05.

Ho1: No significant difference between the pretest and posttest scores of the VDG and CMG.

Ho2: No significant difference between the achievement scores before and after the interventions.

FRAMEWORK

The study was anchored on Ausubel's and Novak's theory of meaningful learning where the student chooses to relate new information to existing knowledge (Ausubel, Novak &Hanesian 1978; Novak 2002, 1998, 1985). The process of relating particular concepts in learning is best facilitated through the construction of CMs and VDs. Because students' temporal cognitive structures and patterns of meaning appear as their concept hierarchies, the chemistry teachers had them identify main concepts and organize them into concept hierarchies. The hierarchies consist of interconnecting nodes with propositional links.

The method of presenting individual work and criticizing peer work is based on several principles established in social constructivist and socio-linguistics perspectives that view the process of learning as being influenced and modulated by the nature of interactions and linguistic discourse undertaken in a social setting (Ball 1993; Schoenfeld 1996; Ernest 1999; Richards 1991; Knuth & Peressini 2001). Gowin's (1981) theory of educating, Ausubel's (1963-1968) cognitive theory of meaningful reception learning, and a constructivist epistemology provide the philosophical and theoretical bases: how CMs and VDs are constructed. The theories help the teacher classify the relevant aspects of educative event. In an educative event, teachers and learners share meanings and feelings to bring about a change in the meaningful experience

Concept Maps

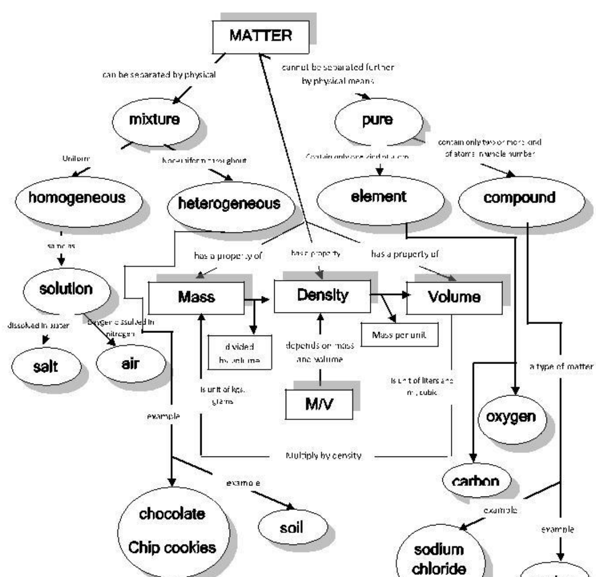

Fig. 1. Concept Map constructed by the teacher to serve as a template for students

Novak and Gowin (1983) pioneered the design and use of CMs. They drew inspiration from David Ausubel's meaningful learning theory. Usually, CMs are two–dimensional hierarchical diagrams that illustrate the relationships between and among individual concepts. A basic Novakian CM depicts a hierarchy of concepts. In the CM more specific and less inclusive concepts are linked together by valid and meaningful propositions that are subsumed under the broader, more inclusive concepts. The perceptions of learners rely on three fundamental qualities: hierarchical structure, progressive differentiation and integrative reconciliation (Novak &Gowin 1983).

Hence, CMs are intended to tap into a learner's cognitive structure and also to externalize for both the learner and teacher what the learner already knows (Novak &Gowin 1984). CMs mirror the constructivist definition of curriculum as the set of learning experience that enables the learners to develop their understanding (Driver 1986). Researchers (e.g., Cliburn 1990; Heizne-Fry & Novak 1990; Roth & Bowen 1993; Roth & Roychoudhury 1993) have touted CMs as a strategy for promoting meaningful learning. CMs are also useful as an instructional tool (Martin 1994; Mason 1992), an assessment procedure of processes and products (e.g., Malone & Dekkers 1984; Roth & Bowen 1993), and a heuristic for developing science curriculum (e.g., Starr & Krajcik 1990).

The Vee Diagram is essentially a pedagogical technique, or heuristic, whereby learning occurs via student-directed, constructivist, and inquiry-based discoveries (Roehrig, Luft, & Edwards 2001). It is ideal for enabling students to understand how events, processes, or objects are meaningfully related because its overall purpose is the interplay between what is familiar and what they has yet to be known or understood in scientific or mathematical investigations (Gowin& Alvarez 2005). The Vee heuristic was developed by Gowin (1981) to enable students to understand the structure of knowledge (e.g., relational networks, hierarchies, and combinations) and to understand the process of knowledge construction. Gowin's fundamental assumption is knowledge is not absolute but, dependent upon concepts, theories, and methodologies by which we view the world.

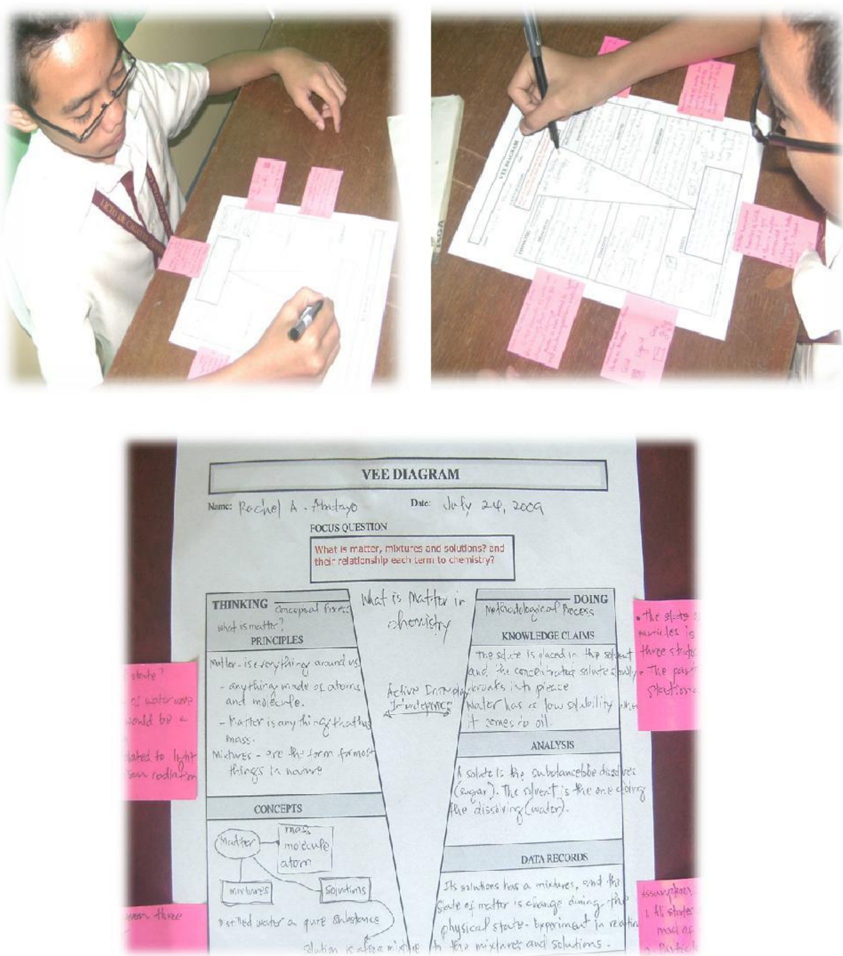

Fig. 2 Vee diagram created by student

Vee Diagram

To encourage meaningful learning, teachers must lead individuals to relate new knowledge to relevant concepts and propositions they already know. Carrying out this policy, Vee Diagrams help student to link concepts by acting as a metacognitive tool. Students make explicit connections between previously learned and newly acquired information.

The VD separates theoretical/conceptual thinking on the left from methodological (doing) elements of inquiry on the right. Both sides are so arranged that theoretical/conceptual thinking actively interact with methodological (doing) elements of inquiry through the use of a focus or some telling questions that relate the Chemistry concepts to objects and/or events. In addition, epistemic elements are arrayed around the VD; the epistemic elements are on red stickers as shown in Fig. 2 They represent units that form the structure of some segments or portions of knowledge required to construct new meaning or piece of knowledge.

The conceptual side (the left side) includes philosophy, theory, principles/conceptual systems, and concepts, all of which are related to each other and with objects and/or events. On the methodology side, records of these objects/events are transformed into graphs, charts, tables, transcriptions of audio or videotapes, and so forth. Then, the right hand side becomes the basis for making knowledge and value claims.

The need for the Vee Diagram as an instructional tool to enhance conceptual learning has been stressed repeatedly by Novak (1977, 1990). In a study with seventh and eighth graders, Novak, Gowin, and Johansen (1983) found that students can understand and use VDs in science classrooms. There science teachers become able to use this strategy as a part of daily teaching/learning practice at the same time. The results of their findings, as well as others (e.g., Alvarez 1987; Alvarez, Risko, Waddell, Drake, & Patterson 1988; Chen 1980; Gurley 1982; Leahy 1986; Taylor 1985), demonstrate that VDs do indeed help students learn better.

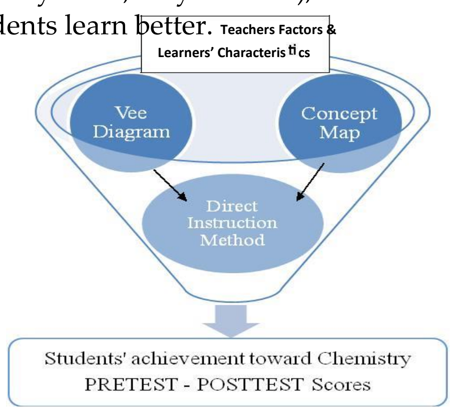

Fig. 3. Schematic diagram of the study

MATERIALS AND METHODS

Two groups of third-year high-school chemistry students took part in the study at Liceo de Cagayan University High School. Two classes of 35 students (total of 70 students) constituted each group. Since the classes existed as intact groups, which means that these groups could not be reconstituted for research purposes for ethical reasons to impaired the internal validity and reliability of the results to suffer, the study used a modified group design along the lines traced by (Gall et al., 1996) for experimental and quasi-experimental studies. Each class received the lecture in a different manner. Class A-the experimental group also called Vee Diagram Group (VDG) used Vee Diagrams.

Class B- the comparison group also called the Concept Map Group (CMG) used Concept Maps.

The two Chemistry classes were taught by the same teacher to eliminate Teacher Factor as a threat to internal validity. Classes were schedules were arranged immediately following each other. The design of the pretest (PRT) and posttest (POT) was used determine the knowledge increment for both classes. The same lessons were taught: classification of matter, mixtures and solutions. An identical measure was also used to assess the learning outcome of each class. Thus, an effect the following non-equivalent comparison group design was adopted.

Class A	VDG	O1	X1	O2
Class B	CMG	O1	X2	O2

Illus1. Research Design

Class A and Class B separately met for four 50-min lectures and 2-hour lab sessions per week. Both classes took a 40-item multiple choice Chemistry concepts pretest (PRT) at the beginning of the treatment and the scores were used to establish the comparability of the two classes. Students in the CMG and VDG were introduced to the theory and construction of Concept Maps following the procedures of Novak and Gowin (1984). These students practiced constructing several CMs and VDs prior to the topics used for data collection.

Several students in the CMG used the Post-It paper to construct concept maps. Both CMG and VDG received a handout and a list of Concepts for each topic a week prior to each experiment. For each topic, the VDG was asked to construct a list of objectives that included the concepts to be learned as an assignment, while the CMG constructed a concept map. Both groups received 40–50 minutes of the same instruction and performed the activity.

A researcher-made 40-item test instrument (40-IT) was used for pretesting (PRT) and post-testing (POT). To ensure test validity and comparability of the PRT and the POT, the 40-ITs were reviewed by three experienced Chemistry teachers. The 40-IT was used to measure student achievement for the CMG and the VDG. To protect against potential bias that might stem from having the teacher teach both the CMG and VDG, two science teachers served as observers during the instruction. The observers evaluate the nature of the instruction. These observers had a list of the concepts to be presented. They checked whether the concepts were covered during instruction. The observers were also asked to compare the nature of the instruction between the two groups.

One week after completing all instructional activities, a 40IT was given to both groups at the beginning of the lecture period. Two equivalent forms (identical questions in different response orders) of each test were constructed to prevent the possibility that students in the CMG could benefit from talking with students in the VDG and skew the results. Analyses of variance (ANOVAs) were used to test for the significant difference between the achievement test score means for the CMG and the VDG. Covariance analysis (ANCOVA) was likewise used. ANCOVA is used in experimental studies when researchers want to remove the effects of some antecedent variable. Pretest (PRT) scores are used as covariates in pretest-posttest (PRT-POT) experimental designs. ANCOVA is also used in non-experimental research, such as survey or nonrandom samples, or in experimental groups (Vogts, 1999). Paired sample *t*-tests were used to test for the significant difference between the students' pretest and posttest scores for each group.

RESULTS AND DISCUSSION

Level of Pretest (PRT) and Posttest (POT) of the Scores of Students

Table 1. Mean and standard deviation of PRT and POT scores of the student 40Its

Variable	Pretest		Posttest		Difference
	Mean	SD	Mean	SD	Mean
VDG	17.06	5.179	27.14	4.609	10.08
CMG	15.57	4.060	26.91	4.010	11.34

In the PRT, the VDG obtained a mean score of 17.06 while the CMG got a mean score of 15.57 as shown in Table 1. The mean scores are considered analogous since the difference in PRT is only 1.79. Furthermore, the mean scores reveal that VDG and CMG achievements fare below the accepted institutional passing score. This meant that the students had very poor entry knowledge of Chemistry concepts.

In the POT, VDG got a mean score of 27.14 while CMG got 26.91. They differ by 0.23 as shown in Table 1.The differences in the PRT and POT scores of the VDG and CMG were 10.08 and 11.34, respectively. These scores indicate that both groups had a significant knowledge increment about Chemistry concepts. However, CMG obtained a higher knowledge increment (11.34) than VDG (10.08). This means that the use of CMs is more effective for learning than the use of VDs.

Regarding the standard deviations in the PRT and POT of the two groups, the CMG had less spread than the VDG had more spread means that the CMG is more homogeneous.

Table 2. Paired difference Posttest Score

	Mean	SD	SE of Mean	t-value	df	2-tail Sig.
Pretest	1.486	6.581	1.112	1.336	34	0.191
Posttest	2.971	3.468	0.586	**5.069**	34	0.000

The paired difference test yielded a t-value of 5.069 as shown in Table 2. There is higher than the t-critical of 2.03 at 0.05 level of significance. The reason is that there is a significant difference in the PRT and POT scores of two groups. Then, the null hypothesis we adopted is rejected.

However, the increments that the two groups accomplished strongly imply that both CMs and VDs have a positive effect on learning. The present results are validated by the findings of Afamasaga-Fuata'i 2002: students showed improvement in learning over time as a consequence of group presentations, individual work, peer critique, and one-on-one consultation. The increasing complexity of conceptual structure that the students acquired a deeper understanding of the links between theoretical principles and chemistry concepts that students had just learned.

Table 3. One-way ANCOVA for PRT and POT scores of VDG [a.]
R Squared = 0.105 (Adjusted R Squared = 0.078) criteria = á (0.05)
Dependent Variable: PostVEEVee Diagram Test Score

Source of Variation	Type III Sum of Squares	df	Mean Square	F-ratio	p-value
Corrected Model	30.385(a)	1	30.385	3.890	0.057
Intercept	2044.228	1	2044.228	261.688	0.000
Pretest Vee Diagram	**30.385**	**1**	**30.385**	**3.890**	**0.057**
Error	257.786	**33**	7.812		
Total	31310.000	35			
Corrected Total	288.171	34			

Table 4.*One-way* ANCOVA *for PRT and POT achievement score of CMG*
[a.] R Squared = 0.010 (Adjusted R Squared = -0.020) criteria = á (0.05)
Dependent Variable: PostCON Concept Mapping Test Score

Source of Variation	Type III Sum of Squares	df	Mean Square	F-ratio	p-value
Corrected Model	5.202(a)	1	5.202	0.338	0.565
Intercept	1736.870	1	1736.870	112.740	0.000
Pretest Concept Map	**5.202**	**1**	**5.202**	**0.338**	**0.565**
Error	508.398	**33**	15.406		
Total	25652.000	35			
Corrected Total	513.600	34			

Tables 3-4 show the result of covariance analysis (ANCOVA) of the POT scores of the VDG and CMG. There is no significant difference in the PRT and POT mean scores between both groups. Both learning strategies (CM and VG) are almost equally effective in facilitating the learning of chemistry concepts.

Table 5. ANCOVA *of the Posttest mean scores for VDG and CMG.*
R Squared = 0.261 (Adjusted R Squared = 0.238) Alpha level of 0.05 Dependent Variable: PostVEE

Source	Type III Sum of Squares	df	Mean Square	F-ratio	p-value
Corrected Model	75.103(a)	1	75.103	11.632	0.002
Intercept	267.098	1	267.098	41.368	0.000
PostCON	**75.103**	**1**	**75.103**	**11.632**	**0.002**
Error	213.068	**33**	**6.457**		
Total	31310.000	35			
Corrected Total	288.171	34			

Table 5 shows the result of covariance analysis (ANCOVA) for the POT scores of both groups. There is a significant difference in the POT scores. Both CMs and VDGs help students learn better the basic concepts of Chemistry; however, CMs seem to be a slightly better learning strategy for this specific student sample.

Table 6. Test of difference in means between the VDG and CMG.

Source of Variation	Mean Score		Knowledge Gain	SE of Mean	Difference in Knowledge Gain	N
	PRT	POT		POT		
VDG	17.06	27.14	10.08	.492	1.26	35
CMG	15.57	26.91	11.34	.657		35

Table 6 shows the knowledge increment for each group, the Knowledge gain for the VDG, 10.08 (=27.14-17.06) on average and that for CMG is 11.34. The CMG obtained a higher mean of Knowledge gain that CMs facilitate learning better than VDs as stated in the foregoing. However, from the viewpoint of mean scores of knowledge gain, both groups did not differ significantly. The t-values for VDG and CMG were less than the t-critical value of 2.03 at p (0.05) level of significance. The mean difference was insignificant. Clearly then, the CMG tended to have an edge over the VDG.

CONCLUSIONS

Evidently, both Vee Diagrams and Concept Maps help students develop a rich system of concepts and their learning, strategies. Both stimulate students not only to use concepts the students have already internalized but also to build conceptual interconnections. The conceptual interconnections help students formulate theoretical explanations about observed changes. VDs and CMs help students conduct a qualitative analysis of a problem from different angles. From teachers' point of view, both VDs and CMs help teachers detect and track the causes of the students' eventual misconceptions. Tracking students' thought and detecting their misconception will provide valuable information for planning and facilitating instruction.

As a general rule, when teachers teach a new concept, they should teach the new concept by connecting it with the other concepts at different levels of generality. Students need to be encouraged to look for similarities and differences between the concepts of the same level of generality. They ought to be directed to essential conceptual properties. The teacher should not simply point out merely perceptive features of phenomena. In the Philippines, where the study of scientific disciplines within separate subjects starts early, the problem of teaching by rote memory (without associating concepts) is aptly resolved by the use of CMs and VDs. This promotes active student learning.

Chemistry concepts should be taught from the simplest to more generalized and complex concepts in line with Ausubel's idea about the structure of knowledge. Demonstrably, science subjects are more effectively taught using VDs and CMs.

Too, it is interesting to note that the CMG outperform the VDG. Concept Maps seems to be slightly better learning strategy. Students should be able to learn Chemistry concepts better and faster by suing Concept Maps because it offers a unique graphical view of how to organize, connect, and synthesize concepts.

Following the Concept Map approach, teacher become able to train students to perceive and explain a phenomenon. Moreover, teachers can lead students to perceive changes in the phenomenon from different angles. If teacher fail in the training, the same concept that is taught in different subjects will remain in disconnected domains of meanings, for example he concept of atom in physics versus that atom in chemistry. Even when teacher teach different subject of sciences, teachers have remind students that atom in physics is the same concept that in chemistry. Teachers should help students integrate individual concepts into a system of knowledge. Since not many students study natural science in college student who integrate knowledge effectively will tend to retain basic concept longer. By contrast students who do not integrate knowledge will more rapidly forget their basic concepts. Therefore, teachers should stimulate students to integrate knowledge from the various scientific disciplines. Obviously, because different scientific disciplines are converging and then numerous interdisciplinary fields are emerging the present situation in different discipline of school science requires this.

LITERATURE CITED

Ausubel, D. P.
2000 *The acquisition and retention of knowledge: A cognitive view*. Dordrecht; Boston: Kluwer Academic Publishers.

Ausubel, D.
1963 The psychology of meaningful verbal learning. New York: Grune and Stratton

Ausubel, D.
1968 Educational psychology: A cognitive view. New York: Rinehalt and Winston

Ausubel, D., J. D. Novak
1978 Educational psychology: A cognitive view. New York, NY, Holt, Rinehart and Winston

Afamasaga-Fuata'i, K.
2002 Vee diagrams & concept maps in mathematics problem solving. Paper presented at the Pacific Education Conference (PEC 2002), Department of Education, American Samoa, July 23, 2002.

Boo, H.K.
2005 Teachers' and students' understandings of the nature of science and implications on learning processes and outcomes. Paper presented at the 9th Annual Conference of the Educational Research Association, Singapore, (22- 24 November 1995)

Cooper, J. & Robinson, P.
2002 *Small-group instruction in Science, Mathematics Engineering and Technology disciplines*. Dominguez Hills: California State University.

Daffy & DH Jonassen
1992 Constructivism: New implications for instructional

technology 10th annual international conference on Systems documentation, p.7-17,October 13-16 di Sessa, A. (1988). Knowledge in pieces. In: Forman, G., Pufall, P. (Eds) Constructivism in the Computer Age, 49-70 Hillsdale, N.J.: Lawrence Erlbaum

diSessa, A. A.
1988 Knowledge in pieces. In G. Forman and P. Pufall (Eds.), Constructivism in the Computer Age. Hillsdale, NJ: Lawrence
Erlbaum, 49-70.

Dutra, I.M.; L.C. Fagundes, A.J. Cañas,
2004 *Uma proposta de uso dos mapasconceituaispara um paradigm construtivista da formação de professores à distância*. In: WORKSHOP SOBRE INFORMÁTICA NAESCOLA, 10, Salvador. Disponívelem: http://www.emack.com.br/info/ apostilas/ nestormapas_piaget.pdf>. Acessoem: 20 jul. 2005.

Gabel, D., & R. Sherwood
1983 Facilitating problem solving in high school chemistry. Journal of Research in Science Teaching, 20, 163-177

Gowin, D.B., J. D. Novak,
1984 *Learning How To Learn*. New York Cambridge University Press.

Gowin, B., & M. C. Alvarez
2005 *The art of educating with v diagrams*. Cambridge, MA: Cambridge University Press.

Keraro, F. N.
2007 Effects of Cooperative Concept Mapping Teaching Approach on Secondary School Students' Motivation in Biology in Gucha District, Kenya. International Journal of Science and Mathematics Education v. 5 no. 1 (March) p. 111-24

Knuth, E., & D. Peressini
2001 A theoretical framework for examining discourse in

mathematics classrooms. *Focus on Learning Problems in Mathematics,* 23(2 & 3), 5-22.

Novak, J. D. &A. J. Cañas
2006 The theory underlying concept maps and how to construct them. Technical Report IHMC Cmap Tools 2006-01, Florida Institute for Human and Machine Cognition, 2006, available at: http://cmap.ihmc.us/publications/ResearchPapers/Theory Underlying Concept Maps.pdf.

Novak, J.D., D.B. Gowin, & G. T. Johansen,
1984 The use of concept mapping and knowledge Vee mapping with junior high school science students. *Science Education*, *67,* 625-645.

Novak, J.D.
1990 Concept maps and Vee diagrams: Two metacognitive tools to facilitate meaningful learning. *Instructional Science*, *19*, 29-52.

Novak, J. D.
1993 *Learning, creating, and using knowledge: Concept Maps(R) as facilitative tools in schools and corporations.* Mahweh, NJ, Lawrence Erlbaum Associates, 1998.

Moreira, M.A.& B. Buchweitz.
1987 *Mapasconceituais***:** instrumentosdidáticos de avaliação e análise de currículo. São Paulo: EditoraMoraes, , 83 p.

Muijies, R. D. and D. Reynolds
2003 Student background and teacher effects on achievement and attainment in mathematics. Educational research and evaluation 9(1), 289-313

Nussbaum, E. M.
2007 Putting the pieces together: Online argumentation vee diagrams enhance thinking during discussions. International Journal of Computer-Supported Collaborative Learning v. 2 no. 4 (December) p. 479-500

Piaget, J. *O*
1978 *nascimento da inteligênciánacriança*. 3. ed. Rio de Janeiro: Zahar,.389 p.

Piaget, J. Abstração
1995 reflexionante**:** relaçõeslógico-aritméticas e ordem das relaçõesespaciais. Porto Alegre: ArtesMédicas,.292 p.

Roehrig, G., A. J.Luft,&M.Edwards,
2001 An alternative to the traditional laboratory report. *The Science Teacher, 68 (1), 28-31.*

Schoenfeld, A. H.
1996 In fostering communities of inquiry, must it matter that the teacher knows "the answer." *For the Learning of Mathematics*, 16(3), 569-600.

Senemoğlu, N.
1998 *Gelişim, ÖğrenmeveÖğretimKuramdanUygulamaya*. Ankara, Ozsen Mat., 513-527.

Songer, N.B. &M.C. Linn
1991 How do pupils' views of science influence knowledge integration. Journal of Research in Science Teaching, 28(9), 733-760

Toh, K. A., B. T.Ho, M. K. Chew, & J. P. Riley
2003 Teaching teacher knowledge and constructivism. *Educational Research Policy for Policy and Practice*, 2, 195-204.

Vogt, W. P.
1999 Dictionary of statistics and methodology: A nontechnical guide for the Social Sciences (2nded.). Thousand Oaks, CA: Sage Publications.

Yuan, L. & B. Hong Kween
2007 *Concepts mapping and pupils' learning in primary science in Singapore*. Retrieved April 23, 2009 from http://www.ied.edu.hk/apfslt/v8_issue2/lingy/lingy2.htm. Retrieved from http://www.classnetwork.net/foundations/drabdullah/drabd2008/97CONCEPTMAPPING.doc