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The Effect of Using Concept Maps as Study Tools on Achievement in Chemistry

Saouma BouJaoude and May Attieh
American University of Beirut, Beirut, LEBANON

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The purposes of this study were to: (1) examine whether or not the construction of concept maps by students improves their achievement and ability to solve higher order questions in chemistry, (2) investigate the differential effect of the treatment by gender and achievement level, and (3) explore the relationships between performance on concept maps and chemistry achievement. Participants were 60 tenth-grade students randomly divided into two groups. The study spanned six weeks in a class that met five times a week. The material covered was acid-base titration and equilibrium in weak acids. The students were pre- and post-tested using a teacher-constructed chemistry test. Results showed that while there were no significant differences on the achievement total score, there were significant differences favoring the experimental group for scores on the knowledge level questions. Moreover, there were sex-achievement interactions at the knowledge and comprehension level questions favoring females and achievement level – achievement interactions favoring low achievers. Finally, there were significant correlations between students' scores on high level questions and the convergence and total concept map scores.

Keywords: Concept maps, Meaningful learning, Chemistry, Achievement.

INTRODUCTION

Research has shown that many students lack the necessary knowledge and skills in science and technology to function in the modern world (American Association for the Advancement of Science [AAAS], 1989; Ogawa, 1998) at a time when there is increasing demand for scientifically literate individuals who can analyze and anticipate novel problems, rather than memorize disparate facts, and with the potential to change and adapt (AAAS, 1989). However, what is happening in schools is not promising. Students' performance and interest in science are declining (Markow & Lonning, 1998). Secondary school and college students' knowledge of science is often characterized by lack of coherence and the majority of students engage in essentially rote learning (BouJaoude & Barakat, 2000, Brandt et al., 2001; Nakhleh, 1992). The problem is twofold: The abstract and highly conceptual nature of science seems to be particularly difficult for students and teaching methods and techniques do not seem to make the learning process sufficiently easy for students (Gabel, 1999; Schmid & Telaro, 1990).

Correspondence to: Saouma BouJaoude, Prof. Dr. Science Education, Department of Education, American University of Beirut, P.O. Box 11-0236, Beirut, LEBANON
E-mail: boujaoud@aub.edu.lb

These problems are quite serious in chemistry, which is widely perceived as a difficult subject because of its specialized language, mathematical and abstract conceptual nature, and the amount of content to be learned (Gabel, 1999; Moore, 1989). The prevailing teaching practices do not actively involve students in the learning process and seem to deprive them from taking charge of their learning (Francisco, Nicoll, & Trautmann, 1998). Novak (1998) accentuated the need for educators to take advantage of the available knowledge base of learning, learners, knowledge construction, and instructional tools to improve

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educational quality, a knowledge base that has not been tapped sufficiently.

Improving educational quality requires, at the least, placing learners in active rather than passive roles (Moore, 1989). People learn by being engaged actively, and a person is not an empty vessel to be filled with information. Knowledge that empowers and increases the learner's self-confidence is that which results from the coming together of individual actions, feelings, and conscious thoughts (Novak, 1998). Rote memorization disempowers learners and promotes fear of learning because it is irrelevant to their own experiences. In addition, information learned by rote in the absence of connections with previously acquired frameworks is largely forgotten (Novak, 1998). Thus, the goal of education should be to develop educational experiences that facilitate meaningful learning and reduce the need for rote learning. Ausubel (1968) describes meaningful learning as the establishment of non-arbitrary relations among concepts and sees that meaningful learning is achieved if learners choose to relate new information to ideas they already know. Meaningful learning occurs if learners have relevant prior knowledge and meaningful learning material and are willing to understand and apply the effort needed to attain meaningful understanding (Novak, 1998).

Concept Mapping

As the problem of improving the teaching/learning process preoccupies educators, concept mapping promises to be useful in enhancing meaningful learning. Concept maps help learners to make evident the key concepts or propositions to be learned and suggest connections between new and previous knowledge. Concept maps have been used in a variety of educational contexts. Each context reflects an alternative theory of knowledge acquisition. On the one hand, the rationalist theory of learning suggests that disciplines have inherent structures that should be conveyed to learners. Therefore, concept maps should be evaluated by relating them to ideal maps, teacher-constructed maps, or expert concept maps. On the other hand, constructivists highlight the uniqueness of each individual's representation of concepts (Beyerebach & Smith, 1990) leading them to devise various mechanisms to evaluate students' concept maps. Nevertheless, both theories concur that meaningful learning occurs when concepts are organized in an individual's cognitive structure.

Concept maps are flexible tools that can be used in a variety of educational settings (Stewart, Van-Kirk, & Rowell, 1979). For example, they can play a significant role in curriculum development, learning, and teaching (Novak, 1984). Concept maps are useful in science curriculum planning for separating significant from trivial content (Starr & Krajcik, 1990) and in focusing the attention of curriculum designers on teaching concepts and distinguishing the intended curriculum from instructional techniques that serve as vehicles for learning (Stewart et al., 1979). Furthermore, concept maps have been used as assessment tools to measure learning outcomes different from those revealed in commonly used psychometric instruments (Markham, Mintzes, & Jones, 1994). However, Johnstone and Otis, (2006) suggested that "maps should be treated as very personal learning tools" and consequently, are not appropriate for assessment purposes. Finally, more recent studies have used concept mapping to engender relational conceptual change in college level chemistry (Liu, 2004).

In an attempt to identify more conceptually based teaching and learning methods, research has investigated the use of concept maps in many content areas such as biology, physics, and chemistry. Stensvold and Wilson (1992) investigated the effect of students' construction of concept mapping in high school chemistry laboratories on their comprehension of chemical concepts. No differences were found between the experimental and control groups. In their turn, Nicoll, Francisco, and Nakhleh (2001) investigated the effect of construction of concept maps on freshman chemistry students' achievement and ability to link concepts. Positive results were achieved for both variables. Horton et al. (1993) conducted a meta-analysis study in which they found that there were many more studies using concept mapping in biology than in physical sciences and that, although results showed positive effects on attitude and achievement, these effects were more obvious in the biological than the physical sciences. In addition, Horton et al. found that concept maps were constructed mostly by students in class and that there were no differences between males and females, even though previous research (e.g. Novak & Musonda, 1991) suggested otherwise.

As seen above, research addressing the use of concept maps in chemistry has been limited and has produced inconclusive results. Moreover, there are disagreements between researchers on the effectiveness of concept mapping in chemistry teaching. Zoller (1990), for example, questions the effectiveness of concept mapping in chemistry because many chemistry concepts are abstract, nonintuitive, and not directly interrelated. In contrast, Novak (1994) argues that the problems are not due to the nature of chemistry; problems rather arise from the fact that students learn chemistry by rote and do not recognize key concepts and their relationships. Moreover, Novak contends that instruction fails to stress chemical concepts and relationships. Differing results could arise also from the fact that studies have focused on the use of concept maps an instructional, curriculum development, and assessment tools but not as study tools, especially in homework assignments.

Many students struggle to learn chemistry, but are often unsuccessful. It seems that many of them do not construct appropriate understandings of fundamental chemical concepts throughout their educational experiences (Nakhleh, 1992). Instead of having well structured and integrated domain-specific knowledge structures, students consider the different chemical concepts as isolated elements of knowledge. This lack of integration may be the main reason for difficulties in concept formation and application of acquired knowledge (Brandt et al., 2001). Thus, concept mapping as a method to build explicit links and relations between concepts, as a study tool that I used as personal learning tool (Johnstone & Otis, 2006), and as an opportunity for students to construct maps using their own terms (Horton, et al., 1993), is expected to stimulate the construction of integrated knowledge structures leading students to achieve higher in tests that measure high cognitive levels.

Research has demonstrated that concept mapping is a skill that requires time for mastery. However, a metal-analysis conducted by Horton et al. (1993) has shown that positive effects were achieved in studies than ranged in length from 2 to 22 weeks, with an average duration of six weeks. As a study tool, concept mapping is most effective if it is used on an on-going basis over the course of instruction. Thus, when students build concept maps in homework assignments recurrently, they will get the chance to revise their understanding by modifying their maps leading to better understanding. Furthermore, because of personal involvement and the ability to revise offered by homework assignments, concept mapping is expected to help students overcome difficulties with abstract and complex science concepts by integrating them into well-structured cognitive frameworks.

Purpose

The purpose of this study was to answer the following questions:

1. Will Grade 10 students who construct concept maps as homework have significantly higher grades on chemistry achievement school tests than Grade 10 students who do not construct such maps as homework?
2. Will the use of concept maps as homework with Grade 10 students have significantly different effects on students with different achievement levels?
3. Will the use of concept maps as homework with Grade 10 students have significantly different effects on males and females?
4. Will there be a significant correlation between students' mastery of concept mapping skill and their achievement in chemistry?

METHOD

Participants

Participants in this study were sixty Grade 10 chemistry students from a co-educational private high school in Lebanon. They were randomly divided into two sections based on achievement, which is the school policy. For the purposes of the study, the sections were randomly assigned to the experimental and control groups.

Instruments

Chemistry Achievement Tests. The dependent variable in this study is the students' chemistry achievement. Two tests were used to measure achievement. One of the tests measured students' pre-requisite knowledge in topics related to the ones covered during the study (Appendix A presents examples of the questions used in the pretest). The second test measured student achievement at the conclusion of the study (Appendix B presents examples of the questions used in the posttest).

According to Lehman, Carter, and Kahle (1985) and Willerman and MacHarg (1991), a test must be at the comprehension level and above in order to measure meaningful learning. Consequently, many items on the achievement tests used in this study were at the comprehension level or above. The pre-test assessed students' achievement in solubility equilibrium. The post-test assessed students' achievement in acid/base titration and weak acids equilibrium. A table of specifications was used guarantee that the items on the two tests represented the content. Moreover, a detailed description of the six levels of Blooms' taxonomy (Bloom, 1969) was used to make sure that the items were at the different levels of Blooms taxonomy. Two science education faculty members, a science teacher, and a chemistry education doctoral student were provided with the objectives based on which the lesson plans and tests were designed along with a detailed description and examples of Bloom's taxonomy and were asked to classify the test items and match them with the objectives. Differences in classification were discussed among the faculty members, teacher, and doctoral student and the researcher in order to reach consensus. The reliability (α) of the pretest was .83 while that of the posttest was .84. The two researchers and the chemistry teacher of the control group corrected the achievement tests based on a detailed, agreed upon, common key.

Concept Map Scoring Rubric. The researchers developed an expert concept map (Appendix C) and a scoring rubric (Appendix D) to monitor students when constructing concept maps. The scoring rubric used in this study combined the qualitative analysis of gross structure and the quantitative analysis of links, in order to provide a valuable tool to highlight the key characteristics of concept maps. The qualitative "spoke-chain-net" classification put forward by Kinchin, Hay, and Adams (2000) is able to describe the gross changes in a concept map which is indicative of radical restructuring. In addition, the degree of valid cross-linkage, the amount of branching, and the hierarchical structure are included in the analysis because they reflect associative and superordinate-subordinate categorical relationships among concepts.

The quantitative analysis of the concept maps consisted of three dimensions: The links' validity, convergence, and salience. McClure, Sonak and Suen (1999) showed that the most reliable scoring procedures are those that focus on the links in the map, the element which is most problematic to students but which reveals a good deal about their depth of understanding. In the scoring rubric, each proposition is scored from zero to three in accordance with the following scoring protocol: Zero is assigned to invalid links, the links that were constructed based on incorrect scientific information. One is assigned to the link that connects interrelated concepts but that misses the label. Two is given to the link that is scientifically correct and has a possible label indicated, but does not specify the direction. Three is given to the correctly labeled links with the directions specified by an arrow.

Convergence measures the extent to which the possible links are actualized in the students' maps. The convergence score is computed as the number of the valid links in a map divided by the number of all possible links as derived from the expert map. Finally, salience measures the abundance of valid links. Salience is computed as the number of valid links divided by the number of all links in a student's map.

Procedure

The treatment took place during the third term of the school year. The students were pre-tested using a teacher-constructed chemistry achievement pretest (Appendix A). The study extended over six weeks. The class met five times per week for fifty minutes daily. The material covered was acid base titration and weak acid equilibrium. At the end of the treatment period, the students were post-tested (Appendix B). Study participants were randomly assigned to two sections based on overall achievement. A different teacher taught each section. One teacher taught the experimental group in which students were trained to construct concept maps as homework while a different teacher taught the control group in which students covered the same chemistry content with regular exercises assigned as homework. It is important to note that the school is which the study was conducted belongs to a worldwide network of schools that has adopted standardized curricula, teaching and assessment methods, and pacing charts on which all teachers are trained extensively before joining any of the schools in the network. Consequently, both teachers followed a teaching pacing chart which contained a detailed description of the content and teaching methods to use in each period. These charts are established at the beginning of the semester to insure that teachers cover the same material and use the same teaching and assessment methodologies. Moreover, the average achievement of the two sections was equivalent during the first semester of the academic year during which the study was conducted. Finally, the tests used before the start of the study consisted of high-order thinking skill questions as per school policy.

The treatment period was divided into two parts. The first part consisted of one week during which the experimental group students were trained to construct concept maps. One preliminary session was assigned at the beginning of the week to introduce concept mapping, then an example of a concept map was provided followed by guided practice. For the rest of the week students in the experimental group were accorded, towards the end of each session, some time to practice the construction of concept maps using a concept list provided by the teacher. The concept lists were related to the material taught in class, they included chemistry concepts known to students in order to help them focus on learning the process of concept mapping. Students received feedback on their concept maps.

During the second week, students in the experimental group were required to construct concept maps using concept lists identified in class. These concept maps were scored using the researcher scoring rubric developed by the researchers and turned back the next day to the students. The scored maps included detailed feedback to help students improve their concept mapping skills. At the end of the second week, the second part of the treatment started and the experimental and control groups started the acid-base titration chapter, which took four more weeks to complete. During this 4-week period students in the experimental group were required to submit twice per week a concept map constructed by using the concepts taught in class. The teacher did not provide the list of concepts to the students. Students in the control group completed traditional homework assignments during the six weeks of the study. These assignments were scored and students were provided with detailed feedback. At the end of the treatment period, both the experimental and control group students took the post-test at the same time.

RESULTS

Pre-Test

The mean score of the pretest for the experimental group was found to be 30.66, while that of the control group was found to be 29.28 out of a maximum possible score of 45. A t-test for independent samples showed that there were no significant differences between the two groups (t = 0.68, p > 0.05).

Post-Test

Because there were no significant differences on the pretest, it was assumed that the two groups started out with equivalent means. Table 1 presents the means and standard deviations of the posttest results for the control and experimental groups. These results include the scores on the knowledge (K-post), comprehension (C-post), and application-and-above (App-post) level questions along with the total scores on the chemistry achievement post-test (Tot-post). The maximum possible scores are as follows: Knowledge level questions = 11, comprehension level questions = 7, application Level-and-above questions = 22, and chemistry achievement post-test = 40.

A t-test for independent samples was carried out to test whether the experimental and control groups differed significantly on the post-test achievement in chemistry (Tot-post). No significant differences were found (t = 1.55, p > 0.05). In addition, a t-test for independent samples was carried out to test whether the scores of the experimental and control groups differed significantly on the questions at different cognitive levels. A significant difference was found for the questions at the knowledge level (k-post) (t = 1.97, p < 0.05) on which the experimental group scored 8% higher than the control group. No significant differences were found at the comprehension level (t = 1.75, p > 0.05) and application-and-above level (t = 1.07, p > 0.05). Results are shown in Table 1. Nevertheless, Table 1 shows that the scores of the experimental group were consistently higher than those of the control group while the standard deviations were consistently lower.

Table 1. Means and Standard Deviations of the Variables Used in the Study for the Control and Experimental Groups

	Control			Experimental			t
	N	M	SD	N	M	SD	
K-post	30	7.53	2.08	29	8.45	1.40	1.97*
C-post	30	3.81	2.29	29	4.71	1.61	1.75
App-post	30	13.48	5.37	28 [a]	14.75	3.55	1.07
Tot-post	30	24.83	8.92	28 [a]	27.84	5.68	1.55

*P < 0.05

[a] One of the scores on the Application level in the experimental group was not valid

K-post = scores of knowledge level questions in the post-test (the maximum score is 11).

C-post = scores on comprehension level questions in the post-test (maximum score is 7).

App-post = scores of the Application-and-above level questions in the post-test (Maximum score is 22).

Tot-post = Total scores on the post-test (the maximum score is 40).

Table 2. Analysis of Variance for Group-Sex Interactions on the Chemistry Achievement Post-Test (Tot-post)

Source	SS	df	MS	F
Sex	0.33	1	0.33	0.002
Group	177.81	1	177.81	1.12
Sex X Group	158.47	1	158.47	2.84***

*** P < 0.1

Table 3. Mean Scores of Males and Females on the Chemistry Achievement Post-Test (Tot-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Males	20	26.01	8.39	14[a]	26.21	6.06
Females	10	22.45	9.91	14	29.46	4.95

[a] One of the achievement scores in the males' experimental group was invalid.

[b] Total score on the Chemistry Achievement Post- Test is 40.

Table 4. Analysis of Variance for Group-Sex Interactions on the Knowledge Level Questions (K-post) in the Chemistry Achievement Post-Test

Source	SS	df	MS	F
Sex	1.24	1	1.24	0.10
Group	17.87	1	17.87	1.42
Sex X Group	12.56	1	12.56	4.13*

* $p < 0.05$

Table 5. Mean Scores of Males and Females on the Knowledge Level Questions in the Chemistry Achievement Post-Test

	Control			Experimental		
	N	M	SD	N	M	SD
Males	20	7.95	1.99	15	8.13	1.51
Females	10	6.70	2.11	14	8.79	1.25

Note: The total score on the knowledge level questions is 11

Table 6. Analysis of Variance for Group-Sex Interactions on the Comprehension Level Questions in the Chemistry Achievement Post-Test (C-post)

Source	SS	df	MS	F
Sex	0.44	1	0.44	0.04
Group	15.16	1	15.16	1.23
Sex X Group	12.29	1	12.29	3.20***

*** $p < 0.1$

Table 7. Mean Scores of Males and Females on the Comprehension Level Questions in the Chemistry Achievement Post-Test (C-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Males	20	4.06	2.30	15	4.17	1.30
Females	10	3.30	2.31	14	5.29	1.74

Table 8. Analysis of Variance for Group-Sex Interactions on the Application Level and above Questions in the Chemistry Achievement Post-Test (App-post)

Source	SS	df	MS	F
Sex	0.24	1	0.24	0.01
Group	31.77	1	31.77	1.16
Sex X Group	27.46	1	27.46	1.29

Table 9. Mean Scores of Achievement Level I and Achievement Level II Groups on the Chemistry Achievement Pre-Test (Tot-pre)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-pre	16	23.25	3.68	12	23.46	5.15
Achlevel II-pre	13[a]	36.69	3.29	17	35.75	4.82

[a] Achlevel = Achievement level of students on the pre-test in chemistry
[b] One of the achievement Pre-test scores in the control group was invalid.
[c] Total score on the chemistry Achievement Pre-test is 45

Sex Group Interaction. Another test was conducted to investigate whether or not there were group-sex interactions. To investigate group-sex interactions a two-way ANOVA was conducted with sex and group as the two variables. Table 2 shows that there was a significant interaction between group and sex. To find the sources of the interaction, the means of males and females on the post-test for the control and experimental group were calculated (Table 3). Table 3 shows that while the scores of females in the control group were lower than those of the males; their scores increased more significantly then the males. The mean of the females in the experimental group was 18% higher that that of the females in the control group, while the mean of the males did not differ significantly between groups.

A two-way ANOVA was performed to check whether there were group-sex interactions for the different level questions. Table 4 shows that there was a significant interaction between group and sex at the knowledge level. To find the sources of the interaction, the means of males and females on the knowledge level post-test questions were calculated for the control and experimental groups (Table 5). Table 5 shows that while the females' scores in the control group were lower than those of the males', their scores increased more significantly then those of the males. The mean for the females in the experimental group was 19% higher than that of the females in the control group, while the mean of the males increased by 9%.

Table 6 shows that there was a significant interaction between group and sex at the comprehension level. To find the sources of the interaction, the means of males and females on the comprehension level post-test scores were calculated for the control and experimental groups (Table 7). Table 7 shows that while the scores of the females in the control group were lower than those of the males; their scores increased more significantly then those of the males. The mean of the females in the experimental group was 28.4% higher than that of the females in the control group, while the mean of the males increased by 1.5%. Finally, there was no significant interaction between group and sex at the application level scores (Table 8).

Group - Achievement Level Interactions. Students in the experimental and control groups were reassigned to one of two achievement levels based on the Tot-pre scores. Students who scored below the mean on the chemistry pre-test were assigned to one achievement level (Achlevel I-pre) and students who scored above the mean were assigned to another achievement level (Achlevel II-pre). Consequently, a comparison was carried out to see whether there were differences between the means for different achievement levels and groups on the total scores of the chemistry achievement pre-test. Table 9 shows that the mean of the Achlevel I-pre in the experimental group is very close to that in the control group. While the mean of the Achlevel II-pre in the control group is only 2% higher than that in the experimental group. Note that 59% (17 out of 29) of the students in the experimental group scored above the mean (Achlevel II-pre), while in the control group only 45% (13 out of 29) scored above the mean.

Other analyses were performed to check the effect of using concept maps as homework tools on the achievement level of the students in the posttest. Based on the Tot-post scores, students in the experimental and control groups were reassigned to one of two achievement levels. Students who scored below the mean on the chemistry post-test were assigned to one achievement level (Achlevel I-post) and students who scored above the mean were assigned to another achievement level (Achlevel II-post). Consequently, means were compared to see whether there were differences between the means for different achievement levels and groups on the total scores of the chemistry achievement post-test. Results are shown in Table 10, which shows that the mean of the Achlevel I in the experimental group is 8% higher than that in the control group. While the mean of the Achlevel II-post in the control group is 5% higher than that in the experimental group. Note that 68% (19 out of 28) of the students in the experimental group scored above the mean (Achlevel II-post) while in the control group only 47% (14 out of 30) scored above the mean.

Another comparison of the means was performed to check whether there were difference in achievement for the experimental and control groups in the two achievement level groups, at the knowledge, comprehension, and application-and- above level questions in the post-test respectively (Tables 11,12, and 13). Table 11 presents the results of the analysis at the knowledge level. Table 11 shows that students in Achlevel II in the experimental group scored 5.4% higher than those in the control group on the knowledge level questions. In addition, Achlevel I in the experimental group scored 4.0% higher than those in the control group on the knowledge level questions.

Table 12 presents the results of the mean scores comparison at the comprehension level. The means of Achlevel I and Achlevel II at the comprehension level were calculated for both control and experimental groups (Table 12). Table 12 shows that the mean of the Achlevel I in the experimental group is 21.5% higher than that in the control group while the mean of the Achlevel II in the control group is 7% higher than that in the experimental group. Note that the number of students who scored above the mean (Achlevel II) in the experimental group (19 out of 29) is larger than that of the students who scored above the mean (Achlevel II) in the control group (14 out of 30).

Table 13 represents the results of the comparison of scores at the application-and above level questions. The means of Achlevel I and Achlevel II group scores at the application -and-above level were calculated for both control and experimental groups. Analysis of these results shows that the Achlevel I group mean in the experimental group is 8% larger than that of the control group while the mean of the Achlevel II in the control group is 8% higher than that in the experimental group.

Table 10. Mean Scores of Achievement Level I and Achievement level II groups on the Chemistry Achievement Post-Test (Tot-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-post	16	17.69	5.16	9[a]	21.06	2.63
Achlevel II-post	14	32.98	3.49	19	31.05	3.37

[a] One of the achievement scores in the males' experimental group was invalid.
[b] Total score on the chemistry Achievement test is 40
[c] Achlevel = Achievement level of students on the post-test in chemistry

Table 11. Means of Achievement Levels in the Control and Experimental Groups at the Knowledge Level in the Chemistry Achievement Post-Test (K-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-post	16	6.50	2.10	10	7.1	1.20
Achlevel II-post	14	8.71	1.33	19	9.16	0.90

Achlevel = Achievement level of students on the post-test in chemistry
K-post = scores of the knowledge level questions in the chemistry achievement post-test.
The Total score on the Knowledge level questions is 11

Table 12. Means of Achievement Levels in the Control and Experimental Groups at the Comprehension Level in the Chemistry Achievement Post-Test (C-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-post	16	2.05	1.37	10	3.55	1.38
Achlevel II-post	14	5.82	1.17	19	5.31	1.39

Achlevel = Achievement level of students on the post-test in chemistry
The Total score on the comprehension level questions is 7

Table 13. Means of Achievement Levels in the Control and Experimental Groups at the Application and Above Levels in the Chemistry Achievement Post-Test (App-post)

	Control			Experimental		
	N	M	SD	N	M	SD
Achlevel I-post	16	9.14	3.08	9[a]	10.89	1.83
Achlevel II-post	14	18.45	1.90	19	16.58	2.53

[a] One of the scores on the Application levels in the experimental group was not valid
The total score on the Application Level -and-above questions is 22

Table 14. Correlation between Concept Map No. 4 Subscores and the Post Achievement Test Scores

	K-post	C-post	App-post	Tot-post
Students (n=28)				
CMSal	0.19	0.12	0.18	0.18
CMConv	0.39	0.31	0.61**	0.55**
CMTot	0.41	0.32	0.61**	0.55**

**Correlation is significant at the 0.01 level (2-tailed).
C-post= scores on the comprehension level questions in the chemistry achievement post-test.
K-post = scores of the knowledge level questions in the chemistry achievement post-test.
App-post = scores of the Application -and-above level questions in the chemistry achievement post-test.
Tot-post = Total scores on the chemistry achievement post-test.
CMSal= salience score on the last concept map
CMConv=convergence score on the last concept map
CMTot= Total score on the last concept map

Note that the number of students that scored above the mean (Achlevel II) in the experimental group (19 out of 28) is larger than that of the students who scored above the mean (Achlevel II) in the control group (14 out of 30).

Correlation between Chemistry and Concept Mapping Subscores. The experimental group students' chemistry test scores were correlated with the corresponding concept map subscores on salience, convergence, and Total on the last concept map constructed by the students (Concept Map No. 4*)*. Results are shown in Table 14, which shows that the salience score did not show significant correlation with any of the scores.

The convergence scores, however, showed a significant correlation with the scores on the application-and-above level questions and the total scores and showed non-significant correlations with the knowledge and comprehension levels. Finally, the total scores on the concept map, showed a significant correlation with the scores on the application-and-above level questions and the total scores and non-significant correlations with the knowledge and comprehension levels. It is worth noting that a high CMSal score means that the student concept map includes a high number of correct propositions. A high CMConv score means that the student concept map is close to the expert concept map. A high CMTot score means that the student included in his or her concept map a larger number of directional correct propositions.

DISCUSSION

Using concept maps as homework tools was expected to result in higher achievement in chemistry. This expectation was based on the assumption that using concept maps helps organize information, fosters metacognition, and engages students in building their knowledge structures.

Results showed that the mean score of the chemistry achievement post-test for the experimental group exceeded that of the control group; however the different was not statistically significant. Further analyses investigated the interaction between sex and the effect of using concept mapping as a homework tool. There were no significant interactions between sex and the intervention at the application-and-above level. However, concept mapping favored girls over boys in the total scores in the chemistry achievement test and when knowledge and comprehension level questions were considered.

The significant interactions between using concept maps and gender can be interpreted in light of the cognitive style theory that categorizes males and females into different learning styles. According to Wapner (1986), males are field-independent learners while females are field-dependent learners. Field independent individuals, such as males, use active reasoning patterns that include cognitive structuring skills, while field dependent individuals, such as females, accept reality and may become passive learners. The concept mapping technique, used as a homework tool, presented students with a novel experience in which structure was absent and involved them in an active process of identifying links between concepts, leading to the inference that the concept mapping should favor males over females, but this is not the case in this study.

At a first glance, the results of this study might seem to contradict the conclusions derived from cognitive style theory. However, a closer look at the results may provide some clarification. On the one hand, studies have shown that concept map construction is difficult (Lehman et al., 1985) and that students need excessive training to master the concept mapping technique (Beyerebach & Smith, 1990; Brandt et al., 2001). Thus, it is possible the learning style of females would enable them, more so than males, to master the new technique of building the concept map. The field-dependent learners (females) must have been more conforming to teachers' demands and more consistent in their work than the field-independent learners (males) in following the instructions to master the technique of building the concept map. Consequently, because mastery is crucial for deriving benefit from concept mapping (Beyerebach & Smith, 1990; Brandt et al., 2001), students who conformed to teachers' demands benefited more from using concept maps as homework tools.

Other analyses dealt with the differential effect of using concept maps on high- and low-achieving students. Achievement level interactions were not detected at the knowledge level. However, significant interactions were achieved at the comprehension and application-and-above levels. In addition, a significant interaction was found when the total scores were considered. The means of achievement level group I (Achlevel I-post -- students who scored below the mean) in the experimental group were higher than those in the control group for the comprehension level questions, the application-and-above level questions, and for the total scores. These results showed that concept mapping helped students who scored below the test scores mean (achievement level group I) to achieve better on high cognitive level questions.

What deserves attention is that the means of achievement level group II in the experimental group on the post-test (Achlevel II-post) at the comprehension and application-and-above level questions and at the total scores, were slightly lower than those in the control group. The differences between the experimental and control group means, for the achievement level group II, were not significant for the comprehension level and total scores. However, the achievement level group II students in the control group scored higher, at the application-and-above level questions, than those in the experimental group with. Stensvold and Wilson (1992) got similar results in their two studies with grade 9 and high school students. Among students with high abilities, those who constructed concept maps scored lower on the comprehension test than those who did not construct maps. However, among students with lower abilities, those who constructed concept maps scored higher than those who did not. Stensvold and Wilson suggested that concept maps might have disadvantaged high ability students because they might have had there own successful strategies which were not applied when they used concept maps.

The correlation between the chemistry total post-test scores and the concept map subscores, (Salience, Convergence, and Total) indicated that students who mastered concept-mapping skills performed better on high cognitive level questions. These results are in agreement with Novak's (1994, 1998) description of meaningful learning as the establishment of non-arbitrary relations among concepts in the learners' minds. Moreover, it highlights the importance of chemistry instruction that emphasizes identifying key concepts and stresses on teaching concepts and their relationships (Novak, 1994). Thus, it can be concluded that concept mapping involved students who mastered concept mapping in actively relating new information to prior knowledge resulting in meaningful learning and consequently higher achievement. This situation, however, does not suggest that concept mapping is a solution for all problems in learning chemistry because, as Zoller (1990) suggests, there are chemistry concepts that are abstract, nonintuitive, and not directly interrelated and cannot be taught by using concept mapping.

CONCLUSION

The results of the study support using concept mapping as homework to engage students in constructing and altering their own knowledge structures, with the understanding that there is a need to help males become more engaged in using the technique because of its possible benefits. In addition, concept maps were successful tools in helping low achievers improve their grades. Nevertheless, concept mapping may become effective for high achievers too if they are encouraged to periodically check their maps during the learning process. Moreover, there is a need for longer training sessions and direct feedback to give learners the opportunity to master concept mapping the technique.

While promising, the results of this and others studies on using concept maps are not conclusive. Consequently, more research should be conducted to test further the effect of concept mapping as homework with a larger number of students, in different types of schools, and for different age groups. Other areas for further investigation include the amount of time needed to reap the benefits of using concept maps in a classroom setting and the possible benefits derived from using computers in the process.

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Appendix A
Examples of items from the Chemistry Pre-Test

1. Gases A, B, C, D and E are all diatomic. The heat change, in KJ/mole, that takes place when each of them dissolves in water is given. On the basis of the energy consideration *only*, which gas do you expect to have the lowest solubility at room temperature?
   a. $\Delta H = +100$
   b. $\Delta H = -100$
   c. $\Delta H = -10$
   d. $\Delta H = +20$
   e. $\Delta H = -30$

2. Which equation represents what happens when H_2SO_4 dissolves in water?
   a. $H_2SO_4 \longrightarrow H_2^{+}{}_{(aq)} + SO^{-4}{}_{(aq)}$
   b. $H_2SO_4 \longrightarrow 2\,H^{+}{}_{(aq)} + 4\,SO^{-2}{}_{(aq)}$
   c. $H_2SO_4 \longrightarrow H_2^{+}{}_{(aq)} + SO_4{}^{-2}{}_{(aq)}$
   d. $H_2SO_4 \longrightarrow 2\,H^{+}{}_{(aq)} + SO_4{}^{-2}{}_{(aq)}$
   e. $H_2SO_4 \longrightarrow 2\,H^{-}{}_{(aq)} + SO_4{}^{+2}{}_{(aq)}$

3. Which of the following four chemicals is soluble in water?
   a. $ZnSO_4$
   b. $Pb(OH)_2$
   c. $CuCO_3$
   d. Fe_2O_3
   e. All of the above are insoluble

4. A few drops of $Na_2SO_{4(aq)}$ were added to a test tube containing little of $BaCl_{2(aq)}$. What equation represents the reaction that is expected to take place in the tube?
   a. $Ba^{+2}{}_{(aq)} + 2SO_4{}^{-}{}_{(aq)} \longrightarrow Ba(SO_4)_2{}_{(s)}$
   b. $Ba^{+2}{}_{(aq)} + SO_4{}^{-2}{}_{(aq)} \longrightarrow BaSO_4{}_{(s)}$
   c. $Na^{+}{}_{(aq)} + Cl^{-}{}_{(aq)} \longrightarrow NaCl_{(aq)}$
   d. $Ba^{+2}{}_{(aq)} + SO_4{}^{-2}{}_{(aq)} \longrightarrow Ba(SO_4)_2{}_{(s)}$
   e. $Na^{+}{}_{(aq)} + Cl^{-}{}_{(aq)} \longrightarrow NaCl_{(s)}$

4. Sulfuric acid is a hygroscopic liquid. What can you predict about its solubility in water with respect to i) heat of reaction and ii) equilibrium. Justify your answer.

5. Using Le Chatelier principle, explain why a layer of scale forms when tap water is heated.

6. The solubility product constant, K_{sp}, of PbS is 4×10^{-28} at $25^{0}C$. Find the maximum mass of PbS that can dissolve in 200 cm^3 solution at the same temperature. Molar mass of PbS = 239g/mol.

Appendix B
Examples of items from the Chemistry Post-Test

1) Which of the following dissolves in water to produce a strong electrolyte?
CH_3COOH ii. CH_3COONa iii. NH_4Cl
   a) ii only
   b) ii and iii only
   c) i and ii only
   d) i and iii only
   e) iii only

2) 0.1M HCl (aq) was gradually added to 25 cm^3 of 0.1 M $NaOH_{(aq)}$ in a beaker and the conductivity was measured at regular intervals. Which of the reported observations describes the variation of conductivity of the resulting solution as the acid is added until it is in excess?
   a) The initial conductivity was high. It drops as the acid is added.
   b) The lowest value of conductivity will be recorded when the volume of acid added is 25cm^3.

3) As acid is added beyond the equivalence point, the conductivity will increase slowly.
   i) a and b only
   ii) a only
   iii) a, b and c
   iv) a and b only
   v) a and c only

4) What is the $[H^+]$ of a solution labeled 0.01M $KNO_{3(aq)}$?

5) 3.65g of HCl were dissolved in 500 cm^3 solution. What is the $[OH^-]$ in the resulting solution? [H=1.0, Cl=35.5]

6) The pH of 0.1 M $CH_3COOH_{(aq)}$ solution is 3. What is the $[OH^-]$ in the solution? Determine the pH value of the resulting solution when the conductivity of the solution reaches its lowest value.

7) HNO_2 and HF are both weak acids. HF is a stronger acid than HNO_2 .
   a) Calculate the volume of 0.10M NaOH solution needed to neutralize 50.0 ml of 0.10M HNO_2 solution .
   b) Deduce the volume of 0.10M NaOH needed to neutralize 50.0ml of 0.10M HF solution.

8) An average adult produces between 2 to 3 l of gastric juice daily. Gastric juice is an acidic digestive fluid. It contains 0.03 M H^+ acidic solution. The purpose of the highly acidic medium within the stomach is to digest food and to activate certain digestive enzymes.
   a) Calculate the pH of gastric juice solution in the stomach. [log 3=0.48]
   b) From the text, explain why drinking water during a meal causes digestive problems.

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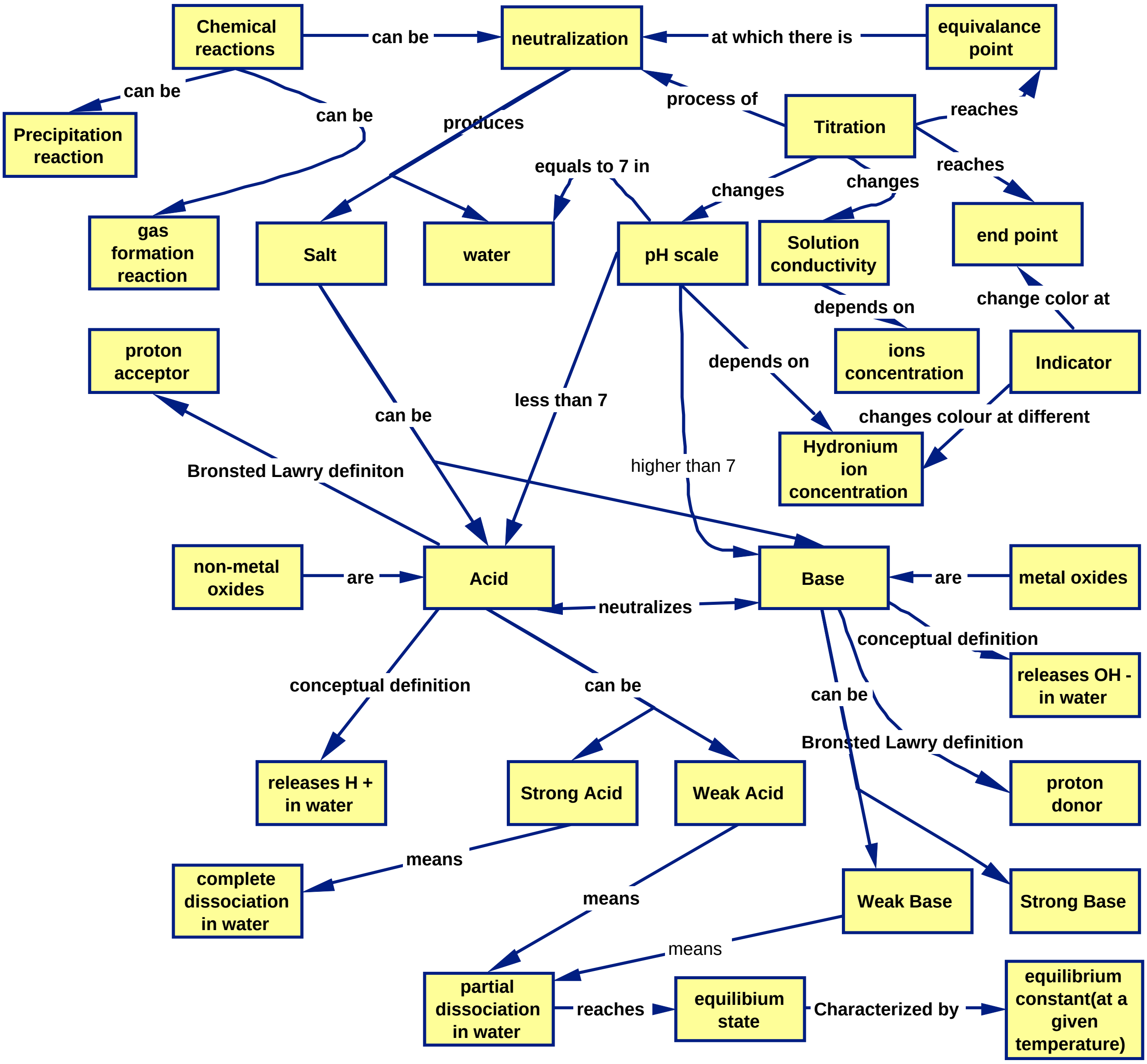
Appendix C
Expert Concept Map

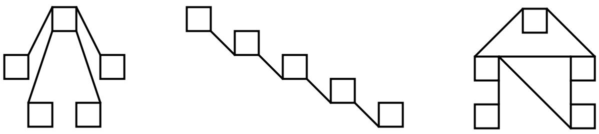


Appendix D
Scoring Rubric of the Concept Map

Student Name:

1. Map Structure:

a. Spoke b. Chain c. Net



2. # of Correct Hierarchy levels:__________

3. # of Correct Cross-Link:_____________

4. Quality of Propositions

Invalid proposition: ___________x 0 =_____

Possible relationship: __________x 1 =_____

Correct-label proposition: ______x 2 = _____

Directional correct proposition: _x 3 =_____

5. Convergence Score =____________

6. Salience Score =____________

Total =______________