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Concept Mapping as a Teaching and Learning Technique with Senior Secondary School Science Students in Ghana

Joseph G. Ampiah
Institute of Education
University of Cape Coast,
Ghana

Ishmael Quartey
St. Mary's Secondary School
Accra, Ghana

Abstract

Concept mapping as a strategy for teaching and learning was explored to ascertain its effectiveness on students' understanding in chemistry as studies done so far in Ghana have concentrated on only biology. The sample consists of 60 chemistry students with an average age of 16 years from a girls' school in the Greater Accra Region. A pretest-posttest quasi-experimental design with random assignment of classes to experimental and control groups were employed to examine possible treatment effects due to exposure to the concept mapping strategy. Achievements were higher for the experimental group on questions, which demanded understanding, explanation and application of concepts but not on questions that demanded recall of facts using a Chemistry Achievement Test. Both groups failed to answer calculation questions satisfactorily. This implies that it is inappropriate for teachers to use the concept mapping technique only in teaching science. Teachers must have a repertoire of teaching skills.

The teaching and learning of science consist of learning of facts and figures, rules, laws, formulae, problem - solving (which includes calculations), understanding of basic scientific concepts, and explanations of concepts and observed phenomena (Ampiah, 2002). It is of utmost significance to understand that the learning of facts and figures, rules, laws, and formulae definitely require some memorization if one has to be able to recall them for use. The total rejection of memorization per se, in the learning of science is therefore unacceptable. However, it must be pointed out that the other aspects of science like problem solving, understanding of basic scientific concepts and explanations based on observed phenomena require understanding as well as explanatory and problem solving power on the part of the student. Unfortunately, the sole use of memorization by students even in the areas of problem - solving, explanation of observed phenomena, and understanding of basic concepts seems to be encouraged by the traditional/expository approach to teaching. Students' role has been the "reception and storing of the deposited knowledge as well as retrieving it when demanded to do so" (Tabulawa, 1997, p.189). This strategy, which is excessively teacher-dominated does not task the student to organise and restructure what he/she has learned (Tabulawa, 1997). Students are not likely to learn in a way that helps them see how knowledge is organized, and to file it in their mental filing cabinets in a way that they can remember and access later (Capper, 1996). In fact Capper asserts that:

> Numerous studies have shown that much of the learning that occur in the classrooms around the world is superficial. Facts, rules, laws, formulas are memorized, but often this information is not connected in a coherent frame work that would allow students to make sense of it and to see it in new situations. (p. 4)

No wonder research has shown that few students at secondary school level have had any formal instruction in learning how to learn (Novak, 1988). Capper (1996) posited that "one powerful way of organizing knowledge is through the use of concepts" (p 17). She defined a concept as "a collection of facts, principles and ideas that are related to one another in specific ways and that have more explanatory power than do isolated facts" (p. 17). The use of concept mapping as a teaching strategy is one possible way of teaching concepts. A number of researches on concept mapping have been carried out for purposes of learning, teaching, curriculum development, evaluation and research (Anamuah-Mensah, Otuka & Ngaman-Wara, 1995; Jegede, Alaiyemola, Okebukola, 1990; Novak and Gowin, 1984; Roth and Roychoudhury, 1993). Roth and Roychoudhury (1993) reported that in the past concept maps helped students in the meaningful learning of science concepts. A research carried out by Anamuah-Mensah, Otuka and Ngaman-Wara (1996) concluded that concept mapping could be used as a pre-instructional and post-instructional strategy in biology. In another study using junior secondary school students. Anamuah-Mensah, et al. (1995) stated that "...the present state of science instruction in Ghanaian schools, especially at the basic education level, calls for an introduction of more innovative and effective teaching and learning techniques" (p. 67). Basically, concept maps are expected to enhance meaningful rather than rote learning. According to Tamir (1991), that could be accomplished by:

1. forcing students to think and engage in active learning as they try to construct the most plausible relationships.
2. helping students develop new relationships among concepts in a particular domain, thereby creating new meanings.
3. making students aware of the explicit role language plays in the exchange of information.
4. allowing learners to exchange views, thereby achieving shared meaning, which is possible because concept maps are explicit, overt representation of the concepts and propositions a person holds.

In spite of the many claims by researchers of higher achievement by students, Rogan cited in Tamir (1991) observed that "so far no significant differences could be detected on the average, and the expectation that concept mapping can improve learning directly remains an intriguing possibility"(p. 335). This claim by Tamir needs to be further investigated using a wider variety of questions. This study attempted to compare the achievement of two groups of students on a wide range of questions after they had been instructed using different approaches. One group was instructed using the concept mapping strategy, and were encouraged to use it to study for the achievement test whilst the other group was instructed using the expository strategy and studied for the achievement test using strategies they had been used to. The purpose was to find out if there would be any differences in the achievement of the stu ents with respect to definition, understanding, explanations, and problem - solving, which constitute the normal kind of chemistry questions expected at the Senior Secondary School (SSS).

Method

Participants

The Senior Secondary School used was a girls' school and was chosen by convenience. The target population of the study was students of a girls' SSS in the Greater Accra Region of Ghana. The two intact classes were randomly sampled (out of three) and assigned to become the two groups-experimental (30 students) and control (30 students). The average age of the subjects was 16 years. Students in the second year were used for the study because as at the time of the study SS1 students had just been admitted and had not had much exposure to senior secondary school chemistry while SS3 students were getting themselves ready for their final examinations. All the students were offering elective chemistry, which they had studied for 20 months at the time of the study. However, none of the students had used concept mapping as a study technique.

Design and Procedure

A pretest-posttest quasi-experimental design with random assignment of classes to experimental and control groups was employed to examine any possible treatment effect due to exposure to the concept mapping (metacognitive) strategy. The experimental group became familiar with concept mapping strategy over a two-week period. The familiarization programme consisted of discussions on concept mapping and practice sessions on how concept maps are constructed. The students were required to use the major concepts of a lesson on *changes of states of matter,* which they had already treated, by using concept maps. They were expected to list the key subordinate concepts, words and phrases that were used during the lesson on *changes of states of matter*. The prime descriptors (or concepts) were generated through a revision session with the students. After this they practised linking related concepts by means of arrows and explanatory notes until a concept map was produced. The students worked individually, and later in groups of five. The whole class discussed each group's work. After the two-week period (14 periods of 40 minutes' duration for each period) the researchers were satisfied that the students had had a fair grasp of concept mapping based on their presentations and the discussions that emerged among the groups.

After the two-week period of familiarisation, both experimental and control groups were administered the pretest in achievement (Chemistry Achievement Test) to ascertain their performance on *Acids, Bases and Salts*. The students responded to the pen-and-paper test in the presence of one of the researchers. The test covered the following areas of the science syllabus: (a) Arrhenius and Bronsted-Lowry concepts of acids and bases, (b) Sources of acids and bases, (c) Types of acids and bases, (d) pH, (e) Properties of acids and bases.

The pretest was followed immediately by four weeks of the treatment. The experimental group was exposed to teaching that required each student to construct concept maps during each lesson. The concept map class was encouraged to use the concept mapping technique in learning for any test that would be given on the topic. The control group did not carry out concept mapping but was taught using the traditional/expository approach. The second investigator (who was the regular chemistry teacher for both groups) named in this study taught both the experimental and control groups. During the four-week treatment, each group was exposed to 7 periods of 40 minutes' duration each per week for four weeks.

The treatment consisted of teaching the students the concepts from the unit on *Acids, Bases and Salts* in the chemistry syllabus and covered the five areas, which constituted the pre-test. This topic was selected because it was the next to be taught by the regular chemistry teacher at the time of the study. One week after instructions had been completed, the two groups were given the posttest on chemistry achievement, in the same manner as the pretest was administered. The answers were scored by the second investigator and cross-checked by the first investigator. The two researchers reached an agreement on the score to be given to each student. The posttest was made up of the same questions as the pretest but the questions did not require the drawing of concept maps.

In undertaking the data analysis the mean ($\bar{x}$) and standard deviation (SD) of the scores on the posttest of the two groups were computed. Detailed qualitative analysis of the answers to the posttest questions provided by five students with the highest scores from both the concept map and the control groups were discussed question by question.

Results and Discussion

The mean score of the test scores of the students in the experiment and control groups were calculated and compared to see if there had been an differences in performance between students in the two groups.

Table 1
Means and standard deviations of the chemistry achievement pretest an posttest scores for groups

	Control (n=30)		Experimental (n=30)	
	($\bar{x}$)	SD	($\bar{x}$)	SD
Pretest	15.9	6.9	16.3	7.3
Posttest	24.7	7.1	30.9	8.5

Maximum scores on pretest and posttest = 60

Table 1 reveals that there was very little difference (0.4) between the concept map group and the control group with respect to their initial understanding of *Acids, Bases and Salts*. The posttest shows an improvement in achievement of both groups with the mean of the experimental group being higher than that of the control group by 6.2 . Since the entire group of students in each class was used for the study, this difference represents a real difference between the two groups. The result therefore showed that students in the experimental group achieved far better on *Acids, Basis and Salts* than their counterparts in the control group after the treatment. The performances of the five students with the highest scores from each group are analysed in detail. The students have been designated A to E as follows:

Students A_1, B_1, C_1, D_1 and E_1 (Experimental group)
Students A_2, B_2, C_2, D_2 and E_2 (Control group)

Only students' responses which differ are reproduced here and discussed.

Question 1: Explain why ashes from burnt plantain peels dissolved in water give the solution a bitter taste. In answer to this item the student is expected to know that for a solution to taste bitter, it must contain an alkali. The alkali should therefore come from the mixture of the ashes and water. An equation showing how the alkali is produced from the potassium in the ash and the water to give potassium hydroxide solution was expected.

Three students A_1, B_1 and C_1 from the experimental group wrote:
The ashes contain potassium. It dissolves in the water to give potassium hydroxide solution, which is an alkaline solution and has a bitter taste
Students D_1 and E_1 from the experimental group gave the following response:
Potassium or sodium is present in the ashes from the burnt plantain peel. On dissolving in water potassium or sodium hydroxide is produced which are bases and one property of a base is that they have a bitter taste.

Four of the students A_2, B_2, C_2 and D_2 from the control group wrote that *ashes from burnt plantain peels contain potassium hydroxide, which tastes bitter.*

Student E_2 from the control group wrote:
The solution obtained when the ashes from the plantain peels dissolved in water, produces potassium hydroxide, which is an alkaline solution.

The question demands the application of knowledge and the responses from the sample of the experimental group satisfy this demand better than the control group. However, all the students in the two groups indicated directly or indirectly that the bitter taste of the solution was due to the presence of the potassium hydroxide. Apart from student E_2 in the control group, all the other students went a step further to indicate that the ashes contain potassium, which reacted with the water to produce the potassium hydroxide solution.

Question 2: Distinguish between a mineral acid and an organic acid either with respect to their sources or relative strengths. Name one example in each case. This question demands that the student states the sources of a mineral acid and an organic acid and then give one example in each case.

The following are responses of three students from the experimental group.

Student A_1
A mineral acid is one, which is obtained from the earth, and an organic acid is one, which is obtained from organic matter
Mineral acid - *Hydrochloric acid*
Organic acid - methanoic acid

Student B_1
Mineral acids are usually made from inorganic substances while organic acids occur naturally in nature
Mineral acid - *Nitric acid*
Organic acid - ethanoic acid

Student C_1
Mineral acids are strong acids, which dissociate completely. Organic acids are weak acids, which dissociate partially.
Mineral acid - *tetraoxosulphate (VI) acid*
Organic acid - *citric acid*
The following are responses of two students from the control group.
Student A_2
Mineral acids are produced from mineral e.g. hydrochloric acid while organic acids are produced from living things" e.g. methanoic acid.

Student C_2
Mineral acids are prepared in industries from mineral from the earth like sulphur e.g. tetraoxosulphate(vi) acid. Organic acids are obtained from nature especially in plants. Example is palmitic acid.
The question was very well attempted by students in both groups. Being a recall question, the students were able to recollect the sources/strengths of the two types of acids and gave an example of each type. There were no qualitative differences in the students' responses in both the experimental and control groups.

Question 3: Give the sources of each of the following substances in nature

(i) Ammonia
(ii) Calcium oxide
(iii) Potassium chloride
(iv) Calcium tetraoxosulphate (IV)

Even though the question simply demands recall of facts the students were expected to know that ammonia and calcium oxide could be obtained in nature from decomposition of organic matter and limestone respectively. Potassium chloride from brine (NaCl) and calcium tetraoxosulphate(VI) from gypsum. The responses to this question are drawn in Tables 2 and 3.

Table 2

Experimental group's responses to Question 3

	Sources		
	Students responses		
Substances	A_1	B_1	C_1
(i) Ammonia	Decomposition of organic matter	Rotten fishes	Urine
(ii) Calcium oxide	Heating limestone	Heating $CaCO_3$	Decomposition of limestone
(iii) Potassium chloride	Rock salt	Ashes from plantain peels	Rock salt
(iv) Calcium tetraoxosulphate (IV)	Rock salt	Gypsum	Gypsum

Table 3

Control group's responses to Question 3

Substances	Sources — Students Responses A2	B2	C2
(i) Ammonia	Urine	Swamp	Urea
(ii) Calcium oxide	Heating limestone	Limestone	Rocks
(iii) Potassium chloride	Brine	Salt petre	Sea water
(iv) Calcium tetraoxosulphate (IV)	Carbide	Gypsum	Gypsum

Tables 2 and 3 show that both groups made a fair attempt in answering the question but the experimental group emphasized heating/decomposition of limestone whilst the other group did not.

Question 4: What is the Bronsted-Lowry theory of acids and bases? Give one example in each case: was the test for this question. Students were expected to give the definitions of acids and bases by the Bronsted Lowry concept and one example in each case. This question is knowledge based.

Bronsted-Lowry acid is a proton donor example, HCl. Bronsted-Lowry base is a proton acceptor example, OH^-. Almost all the students in both experimental and control groups answered this question very well. This question demanded a definition of the terms acid and base according to the Bronsted- Lowry concept. Students committed the definitions to memory irrespective of the method of teaching, and were able to recall them.

Students from both groups therefore gave good answers and there was no difference in their answers.

Question 5: Give the conjugate base of ethanoic acid and explain whether the conjugate base is a strong or weak one? Students were expected to give CH3COO- as the conjugate base of ethanoic acid and use the equilibrium dissociation of CH3COOH to explain the strength of the base. The following are responses of two students from the experimental group.

Student A_1

The conjugate base is CH_3COO^-

$CH_3COOH(aq) \longrightarrow CH_3COO^-(aq) + H^+(aq)$

CH_3COO^- *is a strong base because it is a conjugate base of a weak acid and it accepts proton more readily making the equilibrium move to the left.*

Student B_1

The conjugate base of ethanoic acid is CH_3COO^-. *It is a strong base because the strength of a base depends on its ability to accept a proton. Since* CH_3COOH *cannot ionize fully in solution because it is a weak acid, its conjugate base readily accepts a proton.*

The following are responses of two students from the control group.

Student A_2

The conjugate base of ethanoic acid is CH_3COO^-. *It is a strong base because conjugate base of a weak acid is a strong base.*

Student B_2

$CH_3COOH(aq) \longrightarrow CH_3COO^-(aq) + H^+(aq)$

CH_3COO^- *is the conjugate base of* CH_3COOH.

It is a strong base because CH_3COOH *is a weak acid.*

The responses provided by the experimental group were closer to the expected answer than those given by the control group. At least the students from the experimental group attempted to construct knowledge by first stating the conjugate base and then systematically using the extent of the dissociation of the acid to determine the strength of the conjugate base. They therefore gave a more meaningful and concise explanation compared to the answers provided by students from the control group who gave answers which, were more factual or statement of facts and lacked the systematic explanation required to arrive at the correct answer. Many of the students in this group wrote that "conjugate base of a weak acid is a strong base" without giving the reason for that fact.

Question 6: Explain the term amphoteric oxide using aluminium oxide as an example. For an oxide to be amphoteric it must react with both an acid and a base. Secondly, the students must write two equations involving a reaction between Aluminium Oxide and an acid and a base for the explanation of the concept to be complete. A specific acid or base could be used for the reactions.

The following are responses of four students from the experimental group.

Student A_1

An amphoteric oxide is one, which reacts, in both an acidic and basic medium

$$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O \text{ (acidic medium)}$$

$$Al_2O_3 + 2NaOH \rightarrow Na_2(Al_2O_2) + H_2O + O_2 \text{ (basic medium)}$$

Student B_1

Aluminium oxide is Amphoteric because it has the ability to react with both bases and acids.

$$Al_2O_3(s) + 6H^+(aq) \rightarrow 2Al^{3+}(aq) + 3H_2O(l)$$

$$Al_2O_3 + 3OH^-(aq) \rightarrow Al(OH)_6^{2-}$$

Student C_1

Amphoteric are oxides that has the ability to react with both acid and base

$$Al_2O_3 + HCl \rightarrow 2AlCl_3 + H_2O$$

$$Al_2O_3 + NaOH \rightarrow NaAl(OH)_4(aq)$$

Student D_1

Amphoteric oxide is an oxide of a substance, which can act as both acid and base

$$Al_2O_3(S) + 6H^+ (aq) \rightarrow 2Al^{3+}(aq) + 3H_2O(l)$$

$$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2Al(OH)^-_4 (aq)$$

The following are responses of four students from the control group.

Student A_2

Amphoteric oxides are oxides whose behaviour show both acidic and basic characters

$$Al_2O_3 + 6HCl \rightarrow AlCl_3 + 3H_2O$$

$$Al_2O_3 + NaOH \rightarrow Al(OH)_3 + NaO + H_2O$$

Student B_2

An oxide is amphoteric if it produces both OH- ions and H+ ions when in solution or behaves as a base and an acid.

$$Al_2O_3(s) + 3H_2O \rightarrow Al(OH)_3(aq) + H_3O^+(aq)$$

Student C_2

Amphoteric oxide is an oxide which behaves as both acid and a base.

$$Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3 + 3H_2O(l)$$

$$Al_2O_3(s) + NaOH(aq) \rightarrow NaAl(OH)_4 (aq)$$

Student D_2

An oxide which has both basic and acidic properties is said to be amphoteric. Aluminium oxide can be neutralized by an acid.

The control group gave a better explanation than the experimental group. However, the idea of using equations to show the amphoteric nature of aluminium oxide was better done by the experimental group even though some of the equations were not balanced. The writing of the equations was virtually a recall exercise and the experimental group did better.

Question 7: (a) Distinguish between pH and pH scale

(b) $50cm^3$ of sodium hydroxide was added to $50cm^3$ of 0.50M HCl. If the concentration of sodium hydroxide is 0.05M. Calculate the pH of the mixture.

The student must know that both terms are measurements but while pH measures the hydrogen ion concentration, the pH scale measures the acidity or the alkalinity of the solution. In the calculation aspect the amount of substance in each solution must first be worked out. Using the mole ratio of the neutralization reaction, the concentration of the substance in excess amount, that is, NaOH, should be calculated. From this value the pH of the mixture could then be obtained.

The following are responses of three students from the experimental group.

Student A_1

(a) pH is the negative logarithm of the concentration of hydroxonium ions in solution and pH scale is used to measure the acidity or alkalinity of a medium

(b) $NaOH + HCl \rightarrow NaCl + H_2O$

$$n(HCl) = c(HCl) \times V(HCl)$$

$$= 0.05 \times 0.05$$

$$= 2.5 \times 10^{-3} \text{ mole}$$

$$\frac{n(NaOH)}{n(HCl)} = \frac{1}{1}$$

Total volume of solution $= (0.05 + 0.05)\ dm^3$

$= 0.1\ dm^3$

$$[H_3O^+] = \frac{2.5 \times 10^{-3}}{0.5} = 0.025\,m$$

$pH = -log\,[H_3O^+] = -log\ 0.025 = 1.60$

Student B_1

(a) pH is a measure of the hydroxonium ions in a solution while the pH scale is a measure of the acidity or the alkalinity of a medium.

(b) $NaOH + HCl \longrightarrow NaOH + H_2O$

n(NaOH)	*n(HCl)*
=(0.05 x 0.5)	*=(0.05 x0.05)*
= 0.025mol	*= 0.0025mol*

From the reaction mole ratio 1:1 the base will be present in excess and hence the medium is basic

n(NaOH) excess = 0.0225 mol

$NaOH\,(aq) \longrightarrow Na^+(aq) + OH^-\,(aq)$

Since it is a strong base it dissociates completely

Therefore $OH^- = 0.0225$

$pH = -log\ OH^-$

$$C(OH^-) = \frac{n}{v} = \frac{0.0225}{0.1} = 0.225\ mol/dm^3$$

$pOH = -log\ 0.225$

$= 0.65$

2.0 $= pH + pOH$

$pH = 13.35$

Student C_1

(a) *pH is the negative log of the concentration of H^+ ions but pH scale is a scale used to grade the level of acidity or the alkalinity of a substance usually graduated from O to 14*

(b) $NaOH + HCl \rightarrow NaCl + H_2O$

$50cm^3$ $\quad$ $50cm^3$

0.5m $\quad$ *0.05m*

$n(NaOH) = 0.5mol$	$n(HCl) = 0.5mol$
$conc. = n \times v$	$conc = n \times$
$= \frac{0.5 \times 50}{1000}$	$\frac{0.05 \times 50}{1000}$
$= 0.025$	$= 0.0025$

$pH = -\log\ 0.0025 = 2.6$

$pH = -\log\ 0.025 \quad = 1.6$

$pH + pOH = 2.6 + 1.6 \quad = 4.2$

The following are responses of three students from the control group.

Student A_2

(a) *pH is used to measure the hydrogen ions concentration of solution while pH scale is the measure of the acidity or alkalinity of a substance.*

(b) $NaOH + HCl \rightarrow NaCl + H_2O$

No. of moles of NaOH $= 0.5 \times 50 \times 10^{-3} = 0.025$ *moles*

No. of moles of HCl $= 50 \times 10^{-3} \times 0.05 = 0.0025$ *moles*

Mole ratio $\frac{n(NaOH)}{n(HCl)} = \frac{1}{1}$

Therefore no. of moles which reacted $= 0.0025$ *moles*

Total volume = 100 cm³

Therefore final concentration = $\frac{0.0025}{100 \times 10^{-3}} = 0.025m$

pH = - log (0.025) = 1.6

Student B_2

(a) pH is the negative logarithm of the concentration of hydroxonium ion.

pH = - log [H_30^+] while pH scale is used in measuring the acidity or alkalinity of a substance.

(b) $HCl + NaOH \rightarrow NaCl + H_2O$

0.05M *0.5M*

50cm³ *50cm³*

Total volume = 100cm³

Amount of substance of HCl = 0.05×0.05

$= 2.5 \times 10^{-3}$

Amount of substance of NaOH = 0.5×0.05

$= 0.025$

Total amount of substance $= 0.0275$

Concentration $= \frac{0.0275}{0.1} = 0.275\ moldm^{-3}$

$pH = -log\ [H_30^+]$

$= -log\ [0.275] =$ <u>0.56</u>

Student C_2

(a) pH of a solution is the measure of the hydroxonium ion concentration.

pH scale is used to determine the acidity and alkalinity of a substance.

(b) $NaOH + HCl \rightarrow NaOH + H_2O$

$n\ (NaOH) = 0.05 \times 0.5 = 0.025\ mol$

$n\ (HCl) = 0.05 \times 0.05 = 0.005\ mol$

$Total\ number\ of\ moles = 0.025 + 0.0025 = 0.0275\ mol$

$Total\ volume = 100cm^3$

$$Concentration = \frac{0.0275}{0.1} = 0.275\ mol/dm^3$$

$pOH = -log\ (0.275) = 0.56$

$pH = 14 - 0.56 = \underline{13.44}$

Part (a) of the question was well attempted by students in both groups. It is a recall question and even though the students from the two groups did not quote the definitions verbatim, almost all of them came up with the correct ideas.The calculation of the pH of the mixture of HCl and NaOH requires understanding of what takes place after the reaction especially using the mole ratio to determine which of the solutions would be in excess. This fact eluded students in the control group as well as students in the experimental group. However, one student in the experimental group gave a good account of herself in the calculation to display a better understanding and her application of the mole concept. Almost all the students, irrespective of the mode of instruction did not see that they needed to subtract in order to obtain the excess amount of substance of NaOH. With the exception of one student, students in both groups performed very poorly in this question.

Question 8: State two chemical properties each of acids and bases. Give equations to support your answers. Students must know which of the properties of acids and bases are chemical, that is those properties, which involve chemical changes, and be able to represent the changes with chemical equations.

The following are responses of two students from the experimental group.

Student A_1

i *Acids react with metals to produce hydrogen gas*

$2HCl + Mg \rightarrow MgCl_2 + H_{2(g)}$

ii. *Acids react with trioxocarbonates or HCO_3 to release carbon dioxide gas and water* $2HCl + CaCO_3 \rightarrow CaCl_2 + CO_2 + H_2O$

iii *Bases react with acids to produce salt and water*

$NaOH + HCl \rightarrow NaCl + H_2O$

iv *Base react with ammonium compounds to give ammonia gas*

$NaOH + NH_4Cl \rightarrow NaCl + H_2O + NH_{3(g)}$

Student B_1

i *Acids react with bases to form salt and water*

$HCl + KOH \rightarrow KCl + H_2O$

ii *Acids react with metal to produce hydrogen gas*

$Zn(s) + 2HCl \rightarrow ZnCl_2(aq) + HCl$

iii *Bases undergo neutralization with acids*

$NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$

iv *Bases heated with ammonium salts produce ammonia gas*

$CaO + 2NH_4Cl \rightarrow CaCl + H_2O + 2NH_{3(g)}$

The following are responses of three students from the control group.

Student A_2

i *Acids react with trioxocarbonates or hydrogen trioxocarbonates to produce $CO_2(g)$*

$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

ii *metals react with acids to release hydrogen gas*

$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

iii *Bases undergo neutralization reaction with acids*

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O_{(l)}$

iv *Bases react with ammonium compounds to give ammonia gas*

$NH_4Cl + NaOH \rightarrow NaCl + H_2O + NH_3$

Student B_2

i *Acids are neutralized by bases to form salt and* H_2O

$HCl + NaOH \rightarrow NaCl + H_2O$

ii *Acids react with carbonates to give* CO_2 $2HCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

iii. *Bases turn red litmus blue* $NH_3 + H_2O \rightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

iv. *Bases react with compounds of ammonia to release ammonia gas.*

$NaOH + NH_4Cl \rightarrow NaCl + H_2O + NH_{3(g)}$

Student C_3

i. *Metals react with acids to give hydrogen gas*

$Mg + 2HCl \rightarrow MgCl_2 + H_{2(g)}$

ii. *Carbonates heated with acid produce carbon dioxide.*

$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

iii. *Bases are neutralized by acids*

$KOH + HNO_3 \rightarrow KNO_3 + H_2O$

iv. *Red litmus paper changes to blue in alkaline solution.*

The question was a straight forward one and once the students knew what chemical changes are, they were able to give the correct responses. This was virtually a recall question and many of the students from both groups gave a good account of themselves.

Question 9: Underline the reactants, which are Arrhenius acids or bases if any in the following reactions.

(i) $NH_3 + H_2O_{(l)} \longrightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

(ii) $NH_4Cl_{(aq)} + AgNO_{3(aq)} \longrightarrow NH_4NO_{3(aq)} + AgCl_{(s)}$

(iii) $HCl + H_2O_{(l)} \longrightarrow H_3O^+{}_{(aq)} + Cl^-{}_{(aq)}$

(iv) $NH_4^+{}_{(aq)} + NaOH_{(aq)} \longrightarrow NH_{3(aq)} + Na^+{}_{(aq)} + H_2O_{(l)}$

Students were expected to know that an Arrhenius acid must be a compound that produces hydrogen ions or hydroxonium ions in aqueous solution and not necessarily any compound that contains hydrogen atom, and the base produces hydroxide ions in aqueous solution. In reaction (i) NH_3 is the base since it reacts with water to produce OH^- ions. In (ii) there is neither acid nor base. In reaction (iii), HCl is the acid since it reacts with H_2O to produce H_3O^+ (iv) NaOH is the base. It ionizes to produce OH^- ions, which reacts with $NH_4^+{}_{(aq)}$ to give the ammonia gas.

Tables 4 and 5 show that almost all the students in both groups gave a good account of themselves but the control group gave many species, which were not acids or bases according to the definition, compared to the experimental group. In question 9(i) the experimental group did better than the control group. The question demands understanding of the reaction and not just recall. Comparing question 9(i) to 9(iv), the NaOH contains OH^- ion and that is easy to be classified as the base but the NH_3 only produces the OH^- ions after reacting with H_2O and this was what some students in both groups failed to realize.

Table 4
Experimental group's identification of Arrhenius acids and bases

	Students' Responses							
	A_1		B_1		C_1		D_1	
Reaction	Acid	Base	Acid	Base	Acid	Base	Acid	Base
i.	-	NH_3	-	NH_3	-	NH_3	-	NH_3
ii.	-	-	-	-	-	-	-	-
iii.	HCl	-	HCl	-	HCl	-	HCl	-
iv	-	NaOH	-	NaOH	-	-	NH_4^+	NaOH

Table 5
Control group's identification of Arrhenius acids and bases

	Students' Responses							
	A_2		B_2		C_2		D_2	
Reaction	Acid	Base	Acid	Base	Acid	Base	Acid	Base
i.	-	NH_3	H_2O	NH_3	-	-	-	-
ii.	-	-	-	-	-	-	-	-
iii.	HCl	-	HCl	H_2O	HCl	H_2O	HCl	-
iv	-	NaOH	NH_4^+	NaOH	-	NaOH	-	NaOH

Conclusion

Looking critically at the general performance of the students and th responses provided by the ten students from the experimental and the contro groups, it can be concluded that in this study there was very little difference between the two groups in questions that demanded recall of facts.

However, in all questions that involved understanding, explanation and application, the experimental group performed better than the control group. On such questions, students from the experimental group made attempts to construct knowledge from the facts and thus in some cases gave more meaningful and concise explanations to the questions. Students in the control group provided answers that were mere statements of facts and lacked the systematic explanations to arrive at the correct answers in some questions that required some reflective thinking. It can be said that in this study, the use of concept mapping as a teaching and study strategy enhanced students' understanding of the topic on *Acids, Bases and Salts*, which led to both quantitative and qualitative differences in achievement between the two groups.

However, students in both groups irrespective of the mode of instruction and study, performed very poorly on the problem-solving question. In this study therefore, both the expository and concept mapping approaches seemed to have failed as strategies for teaching problem-solving skills to the students. However, since there was only one question on problem-solving (involving calculations), this assertion is inconclusive even in this study and needs to be further investigated.

Concept mapping demands group work and co-operative learning. It must however, be pointed out that the duration of this study was short because it had to be worked into the time constraints of the researcher's plan of work in the school term. The students therefore did not have enough exposure to appreciate the concept mapping technique to the extent that it would affect their study habits.

In a system where rote learning had been the practice, the students found it very uncomfortable to accept innovations into their traditional way of learning. Since the problem is also attitudinal, a longer period of exposure of students to this new technique is very necessary in order to make any meaningful impact.

Implication

The findings of this investigation have the following important implications and recommendations:

1. Since the teaching and learning of science consist of facts and figures rules, laws, formulas, calculations, understanding of basic scientific concepts and explanations, science teachers must have a repertoire of teaching skills to deal with these different aspects. Resorting to only one method of teaching students is therefore highly inappropriate.
2. Even though it appears concept mapping offers a better understanding in teaching areas that require understanding and explanation of concepts than the use of the traditional/expository approach, it must be complemented with other effective strategies of teaching since the concept mapping technique may not always be appropriate.
3. Science teachers at the senior secondary school level must be introduced to concept mapping and other cooperative learning techniques. This would help them acquire more teaching strategies to help students with the various aspects of science learning.

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