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Original Paper

Composite Effect of Concept Mapping and ICT on Students' Performance in Organic Chemistry

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Abstract

Generally, the performance of students in organic chemistry in Zambia is not encouraging. This can be attributed to the nature of the subject in addition to other factors. This study explored the composite effect of concept mapping and ICT on students' performance in selected topics in organic chemistry. One hundred and thirty-four grade 12 students were involved. Data was collected using an organic chemistry performance test. A pre-test, the post-test quasi-experimental design was adopted. The study comprised of three groups randomly assigned to experimental group one, experimental group two and a control group. Experimental group one was taught using concept mapping, experimental group two was taught using a combination of concept mapping and ICT and the control group was taught using conventional methods (discussion). ANOVA results for the three groups were $F(2,131) = 2.237$ and $p = 0.111$. This indicates that there was no significant difference amongst the three groups at the beginning of the study. After treatment the results revealed that experimental group two outperformed the other two groups with a p valuep-value 0 at $F(2,131) = 2.237$ at $\alpha = 0.05$. Post hoc analysis using Fisher's Least Significant Difference (LSD) test showed that the mean scores were statistically significant amongst the three groups. A very large effect was seen between experimental group one and control and between experimental group two and control. A sizable effect was seen between experimental group one and two. The conclusion is that using concept mapping with ICT has a positive effect on the performance of students in organic chemistry. The results corroborate the findings of studies that the use of concept mapping and ICT teaching strategy improves the performance of students. Consequently, this study seems to offer a positive solution towards the enhancement of students' performance in organic chemistry in secondary schools.

Keywords
concept mapping, conventional methods, ict, organic chemistry, performance

1. Introduction

Organic chemistry as defined by American chemical society is the study of organic compounds (American Chemical Society, 2018). Many secondary school students consider organic chemistry as abstract in nature. This is because, it is perceived to be too theory-oriented and not connected to everyday life. To the contrary, most of the substances in our everyday life are organic compounds. In addition, it also prepares students for different types of careers in chemical industries and vocations at higher learning institutions. Therefore, endeavour should be made to improve the teaching of organic chemistry that provides a better conceptual base leading to enhanced students' performance.

Research shows that students have great difficulty in understanding organic chemistry (Birk & Kurtz, 1999; Childs & Sheehan, 2009; Gaddis, 2001; Gaulich, 2015; O'Dwyer & Childs, 2011; Taagepera & Noori, 2000; Wasacz, 2010). Some documented research reports suggest a number of factors to that effect. Gabel (1999) reports that, this course (organic chemistry) is also full of abstract concepts, resulting from the complex nature of the course. Johnstone (2006) explains that, a lot of the negativity and pessimism that surrounds organic chemistry as a topic is associated with bad experiences students have had with other topics in chemistry.

It is therefore important that, if organic chemistry has to be learnt meaningfully to bring about the much-desired improved performance, it must be presented in a "conceptually transparent" form (Novak & Musonda, 1991). In organic chemistry like in general chemistry, students face what has been termed three levels of representation: 1) the macroscopic, 2) the sub-microscopic, and 3) the symbolic level (Johnstone, 1991). The macroscopic level deals with substances that are visible and tangible while the sub-microscopic level relates to what is molecular and symbolic. On the other hand, symbolic refers to chemical symbols and equations that represent the molecules and atoms (Johnstone, 1991). The underlying chemical concepts can be represented on each level that generally results in students having difficulty transferring the concept from one level to the other (Gabel, 1998). In early organic chemistry education, it is essential to guarantee students' ability to transfer knowledge from the macroscopic level, including concepts from the students' everyday life experiences, to the sub-microscopic level, relating to the underlying concepts of matter like atoms, molecules and other particles (O'Dwyer, 2012). This implies that, for students to explain phenomena on macroscopic level they have to acquire knowledge on the sub-microscopic level. Concept maps can therefore, be one means to facilitate this transfer by either linking concepts on the macroscopic level with those on the sub-microscopic level or help students to link the underlying concepts on the sub-microscopic level only (O'Dwyer, 2012). This process is at all times viewed as constructivist in that the students construct knowledge by connecting the related concepts. However, the composite use of concept mapping and ICT may even better enable the transfer of concepts at a macroscopic level to the sub-microscopic level. The composite use of concept mapping and ICT was therefore in keeping with the goal of designing learning environments based on constructivist theories and meaningful learning.

1.1 Statement of the Problem

Performance of students in organic chemistry in senior secondary school certificate examinations in Zambia has not been up to the expectation as evidenced from the Examinations Council of Zambia Chief Examiners' Reports (2007-2012) and the Examinations performance reports for Natural Sciences (ECZ, 2013; ECZ, 2014; ECZ, 2015, 2016). Some other nations also experience poor performance in organic chemistry as well. A study carried out in Ireland revealed that the performance in organic chemistry was poor (O'Dwyer, 2012). In another study conducted by Mahajan and Singh (2005) on the performance of university students in organic chemistry in the Southern African Development Community (SADC) region revealed that the problem of poor performance is not only in secondary schools but also in higher learning institutions. The study by Mahajan and Singh (2005) recommended active learning methods and use of concept maps as some of the factors that can improve performance in organic chemistry. Factors associated with quality education at international, regional and local levels have shown that existing limited teaching methods have not benefited the teaching and learning process (Kelly, 1999; Orr, 2004). In teaching and learning of organic chemistry concepts, teachers should take into account that students are from diverse backgrounds and that they learn in different ways.

For this reason, teaching must not be a linear process with a one-way knowledge provision but rather a combination of learner-centred learning and collaborative process between students and teachers. Appropriately and rightly applying learner-centred approaches can significantly contribute towards changing and improving the current state of poor performance in national examinations (Mahajan & Singh, 2005). Furthermore, most Secondary Schools these days have ICT facilities and tools but teachers maybe hesitant to combine new techniques in their teaching methods in order to improve student performance. Thus, it is necessary to find thought-provoking ways that can lead towards more meaningful organic chemistry teaching and learning, and eventually improved student performance in the topic. With regard to the above factors, it merits to come up with new ideas to be infused in the teaching of the subject. Therefore, this study sought to assess the composite effect of concept mapping and ICT on students' performance in organic chemistry. Besides, there seems to be few similar studies conducted. This seems to expose a large void in terms of research available in this area. As such, this study sought to help fill this void by investigating the composite effect of concept mapping and ICT on secondary school students' performance in organic chemistry.

1.2 Objectives of the Study

The objectives of the study were to assess the composite effect of concept mapping and ICT on students' performance in organic chemistry and to find out if the composite use of concept mapping and ICT is more effective in improving students' performance compared to the use of concept mapping and conventional approach.

1.3 Research Hypothesis

There is a statistically significant difference in performance in organic chemistry between students taught by the composite use of concept mapping and ICT and those taught using concept mapping and the conventional approach.

1.4 Null Hypothesis

There is no statistically significant difference in performance in organic chemistry between students taught by the composite use of concept mapping and ICT and those taught using concept mapping and the conventional approach.

1.5 Significance of the Study

The findings of this research paper may be significant for teachers, students, curriculum designers and architects. The research findings may offer a sound basis for teachers regarding the composite use of concept mapping and ICT. It may encourage them to implement these processes in the teaching-learning process, which in turn may aid in enhancing students' understanding and performance in organic chemistry. The findings of this research paper may also help to improve students' performance in organic chemistry as their teachers implement the processes of integrating concept mapping and ICT. It may also aid and lead students to engage in meaningful learning in so doing enhancing their performance. It may as well facilitate and encourage students take responsibility for learning on their own and inculcate thinking and problem-solving attitude as demanded by the use of concept mapping and ICT processes.

To curriculum designers and architects, the findings of this paper will furnish them with information that may help them make a decision whether or not to include the combined use of concept mapping and ICT as a teaching method in the curriculum. This is likely to help in improving students' performance in organic chemistry and consequently chemistry as a subject.

1.6 Theoretical Framework

Constructivists' theories and meaningful learning form the basis of the use of concept mapping and ICT. Constructivism is a theory that proposes that humans construct knowledge and meaning from their experiences (Novak & Gowin, 1984). The core of this approach is the assertion that cognition (learning) is the result of mental construction (Novak & Gowin, 1984). According to constructivist theorists, people learn best when they create their own knowledge and the learner instead of the teacher is the focus of attention. The theories prefer guided discovery to expository learning, genuine, rooted-learning situations unlike theorized artificial ones. The theory bases on Ausubel (1968) who stressed the importance of prior knowledge in being able to learn about new concepts. Ausubel, Novak, and Hanesian (1978) believed that the most important factor affecting learning is the learners' available knowledge. Novak (1990) also believed that, meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures. Material learnt meaningfully serves as an anchor for subsequent learning because of its longer retention (Novak & Gowin, 1984; Prosser, 1987).

As highlighted by Becta (2003) some assumptions of the constructivist learning are that learning is an active process and consists of meaning construction and learning is associated with connections the learner makes with others as they socialise. Since learning is contextual, a learner cannot learn facts or theories in isolation, abstraction and separate from the real world situation. Additionally, knowledge is important because new ideas are not comprehensible without some structure developed from prior knowledge to build upon.

Bruner (1960) also believed that learning is an active process in which learners construct new ideas or concepts based upon their prior knowledge. The assumptions of these theories are that learners are active agents purposefully looking for and contributing collaborative knowledge within a meaningful context.

2. Materials and Method

2.1 Research Design

A pre-test post-test control quasi-experimental design was utilised in this study. According to Nworgu (2006), a quasi-experimental design is a design in which intact or pre-existing groups are used where the random assignment of subjects to experimental and control groups is impossible. This choice was because intact classes were used for the study. Therefore, the selection of whole classes to be the research subjects was purposive in order not to disrupt the running of the school programme. In other words, randomization of participants was avoided in order not to disturb the activities and administrative set up of the classes used. However, the subjects were randomly assigned to the control and experimental groups. This study was comprised of three groups, experimental group 1 that was taught using concept maps; experimental group 2 used ICT and concept maps and the control group used conventional teaching method (discussion).

Equivalency of the three groups in terms of performance was assessed using the organic chemistry performance pre-tests. According to Sherri (2009, p. 323), "a pre-test allows us to assess whether the groups are equivalent on the dependent measure before the treatment is given to the experimental group".

This was the structure of the quasi-experimental design utilised in the study.

$$\begin{matrix} O_1 & X_1 & O_2 \\ O_1 & X_2 & O_2 \\ O_1 & - & O_2 \end{matrix}$$

In this design;

O_1—were the observations made during the administration of pre-tests to all the three groups (Organic Chemistry Performance Tests).

X_1—was the treatment given to the experimental group 1, in this case, the use of concept mapping.

X_2—was the treatment given to the experimental group 2, which was the use of concept mapping and ICT.

O_2—were the observations made after the administration of the post-tests.

2.2 Participants

The sample was made up of one hundred and thirty-four grade 12 students from three intact classes studying the 5124 science syllabus and they were purposively selected. However, the participants were randomly assigned to the experimental and the control groups. The sample constituted students of different nationalities.

2.3 Materials

The researcher constructed an Organic Chemistry Performance test to collect data on performance. The performance test items consisted of explanatory questions related to the topic in the study. The questions required the students' personal expression of conceptual understanding. The same test items were used in the post-test to assess the performance of students in organic chemistry after the treatment but the test items were reorganised. In order to ensure the validity of the instrument two specialists in organic chemistry were involved in validation.

2.4 Procedure

At the beginning of the study, the experimental group 1 and experimental group 2 were taught how to construct a concept map from a topic which students were familiar with, the topic bonding was picked. One introductory session was apportioned at the start of the week in order to introduce concept mapping to the students, an example of a concept map was then presented followed by a guided exercise. For that particular week, students in the experimental groups were given some time towards the end of each learning session to practice how to construct concept maps using a list of concepts provided by the researcher. The concept lists were related to the material learnt in the class, they consisted of chemistry concepts known to students in order to assist them to focus on learning the process of concept mapping.

Experimental Group I: The instructional approach used to teach organic chemistry concepts in this group was concept mapping. During lessons, the method of instruction used was concept mapping together with the explanation. To teach organic chemistry concepts, concept maps were constructed on the chalkboard to show how the concepts in the lesson were related. In addition, the students were asked to construct concept maps in groups and as individuals, which were presented to the class and discussed. The concept maps constructed by the students were scored using a scoring rubric adapted from Novak and Gowin (1984). The maps scored included detailed feedback to aid students in improving their concept mapping skills. In all the lessons, the concept maps were used as assessment and evaluation tools.

Experimental Group II: In this group, concept mapping and ICT was used as a method of instruction. Initially, this group was taught using concept mapping as described earlier for experimental group 1. In addition, the group had discussions using the discussion forum using ICT twice a week after lessons. During these discussions, each student had an opportunity to share questions or problems they had on the topic using cell phones online. The tentative answers would also be shared and discussed within the group and monitored by the teacher online. Finally, the teacher, if required would consolidate answers and contributions. This discussion exercise was carried out after each lesson of experimental group 2. The discussion forum was one way of engaging students in learning and stimulating interaction as its use went further than the corners and walls of the classroom or the limitations of the class period.

Control Group: The conventional method (discussion) was used in this group to teach concepts in organic chemistry to the students. The lesson content taught to all the groups was the same. At the end of the treatment administration, the students were post-tested using the same test items as in the pre-test but reshuffled.

2.5 Construction of Concept Maps

The procedure employed followed the five phases involved in the Concept mapping method defined by Novak and Gowin (1984). In phase, 1 brainstorming is involved. This stage involved coming up with concepts, items or explanatory words related to the topic at hand. The teacher at the beginning of instruction provided a list of keywords and concepts from a familiar topic to students.

Phase 2 had to do with organizing and identifying the most important word, concept, or challenge over which to construct the concept map such as saturated hydrocarbons, unsaturated hydrocarbons, alkanes, alkenes, fuels, oxygen, carbon dioxide and water. The concepts were then written on the blackboard so that all could read easily. The class was then required to form groups and sub-groups of associated items. Items were grouped to underscore the hierarchies.

Phase 3 was the layout. This phase involved coming up with a design that best represents the shared understanding of the links and associations among groupings. The adopted hierarchy had the most important concepts at the top.

Phase 4 was linking. Lines with arrows were used to join and display the relationship between linked items. A word or short expression by every arrow was written to state the association and finalize the Concept Map. Phase 5 was the revising and finalising stage, where the drafted concept maps were examined. At that stage, some corrections and rearrangements were done.

2.6 Analysis

The data was analysed using the IBM Statistical Package for Social Sciences (SPSS) statistics version 23. One-way analysis of variance (ANOVA) was used to determine if there was a statistically significant difference between the three groups, in performance. The significance level (α-level) was set at 0.05.

3. Results

3.1 Analysis of Performance Scores from Pre-Tests

The sample from which the analysed data was collected comprised one hundred and thirty-four (N = 134) grade twelve students from three intact classes. One class (experimental group 1) had 45 students; the second class (experimental group 2) had 43 students while the third class (control group) had 46 students. The pre-test results were analysed using descriptive statistics and one way ANOVA. Table 1 shows the pre-test results of descriptive analysis from the IBM SPSS for experimental group 1, experimental group 2 and the control group.

Table 1. Descriptive Statistics for the Pretest All the Three Groups

Descriptive Statistics

		N	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
Group		Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
Experimental group 1	pretest performance	45	0	52	25.96	2.133	14.311	.328	.354	-.723	.695
	Valid N (listwise)	45									
Experimental group 2	pretest performance	43	2	50	31.67	1.735	11.380	-.140	.361	-.397	.709
	Valid N (listwise)	43									
Control	pretest performance	46	0	48	28.22	1.820	12.345	-.105	.350	-.668	.688
	Valid N (listwise)	46									

From Table 1 the mean scores for the pre-test for experimental group 1 (N = 45) were 25.96 and Std. Deviation 14.311, for experimental group 2 (N = 43) mean score was 31.67 and Std. Deviation 11.380 and for the control group (N = 46) mean score was 28.22 and Std. Deviation 12.345.

3.2 Homogeneity of Variances for the Performance in the Pre-Test

A Levene's test of homogeneity of variances was conducted to determine if the groups had equal variances in the pre-test scores. Table 2 shows the results of the analysis of homogeneity of variance for the pre-test.

Table 2. Homogeneity of Variances for the Performance in the Pre-Test

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.997	2	131	.372

Note. df = degrees of freedom.

Table 2 shows that at $p > .05$ there were no statistically significant differences in the variances between the groups in the pre-test, $p = .372$ satisfying the assumption of equal variances enabling the researcher to proceed with the statistical analysis chosen.

3.3 Normality Test for the Performance in the Pre-Test

Normality in the data set (scores from the pre-test) was assessed using the skewness (asymmetry in a distribution) and kurtosis (how flat or peaked the distribution is). Table 1 shows that the values for the skewness were within the range of $\pm$ 2, and for the kurtosis values were within the range of $\pm$ 7 (Hair, Black, Babin, Anderson, & Tatham, 2010; Byrne, 2010). Figure 1 shows the distribution of the pre-test scores.

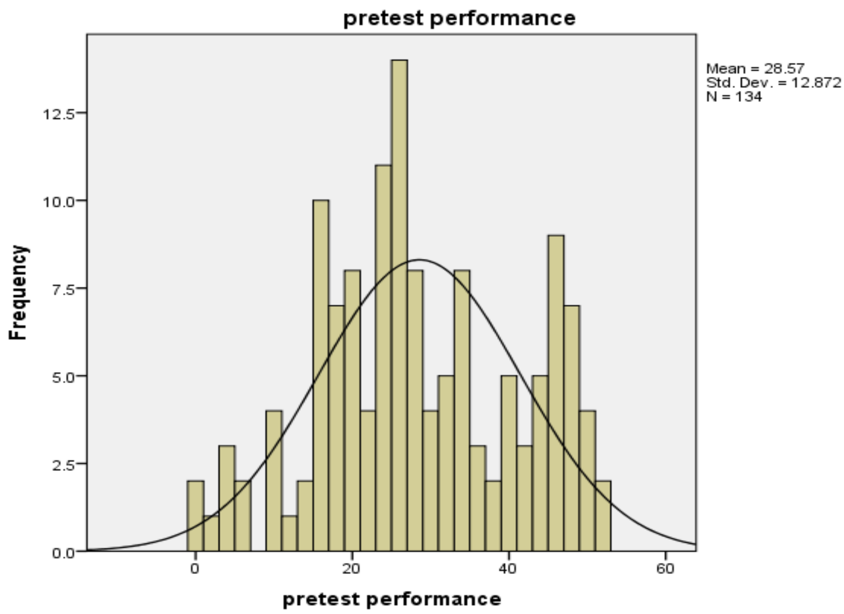

Figure 1. Distribution of Scores for the Pre-Test

3.4 One-Way ANOVA for Performance in the Pre-Test

To determine if the means of the three groups were statistically significantly different before the treatment, one way ANOVA was applied. Table 3 shows the results of the analysis.

Table 3. Scores of Pre-Test ANOVA

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
pre-test performance	Between Groups	727.716	2	363.858	2.237	.111
	Within groups	21309.179	131	162.665		
	Total	22036.896	133			

Note. Df = degrees of freedom.

Table 3 reveals that there were no statistically significant differences at $p > 0.05$ between the three groups in the pre-test scores $F(2,131) = 2.237$, $p = .111$. This suggests that the students were equivalent in terms of their knowledge in organic chemistry before treatment. This entailed that the groups were suitable for the study.

3.5 Analysis of Performance Scores from Post-Tests

The post-test results were also analysed using descriptive statistics and ANOVA. Table 4 shows the results of descriptive analysis from the IBM SPSS for experimental group 1, experimental group 2 and the control group.

Table 4. Descriptive Statistics for the Post-Test for all the Three Groups

Descriptive Statistics

Group		N	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
		Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
Experimental group 1	posttest performance	45	30	82	53.38	1.736	11.645	.387	.354	-.085	.695
	Valid N (listwise)	45									
Experimental group 2	posttest performance	43	28	88	61.02	2.367	15.519	-.274	.361	-.839	.709
	Valid N (listwise)	43									
Control	posttest performance	46	2	62	32.26	1.930	13.088	-.051	.350	.109	.688
	Valid N (listwise)	46									

As shown in Table 4 the mean scores for the post-test for experimental group 1 (N = 45) were .38 and Std. Deviation 11.645, for experimental group 2 (N = 43) the mean score was 61.02 and Std. Deviation 15.519 and 32.26 was the mean score for the control group (N = 46) and the Std. deviations was 13.088. The standard deviation values show that most of the students' scores were close to the mean scores.

3.6 Homogeneity of Variances for the Performance in the Post-Test

A Levene's test of homogeneity of variances was conducted to determine if the groups had equal variances in the post-test scores. Table 5 shows the results of the analysis of homogeneity of variance for the post-test.

Table 5. Homogeneity of Variances for the Performance in the Post-Test

Test of Homogeneity of Variances			
post-test performance			
Levene Statistic	df1	df2	Sig.
2.357	2	131	.099

Table 5 reveals that at $p > 0.05$ there were no statistically significant differences in the variances between the groups in the post-test, $p = .099$. The results show that the groups had equal variances in the post-test scores.

3.7 Normality Test for the Performance in the Post-Test

Using the values for the skewness and kurtosis as presented in Table 4 the distribution of scores in the post-tests was considered normal. Figure 2 shows the distribution of the post-test scores for performance.

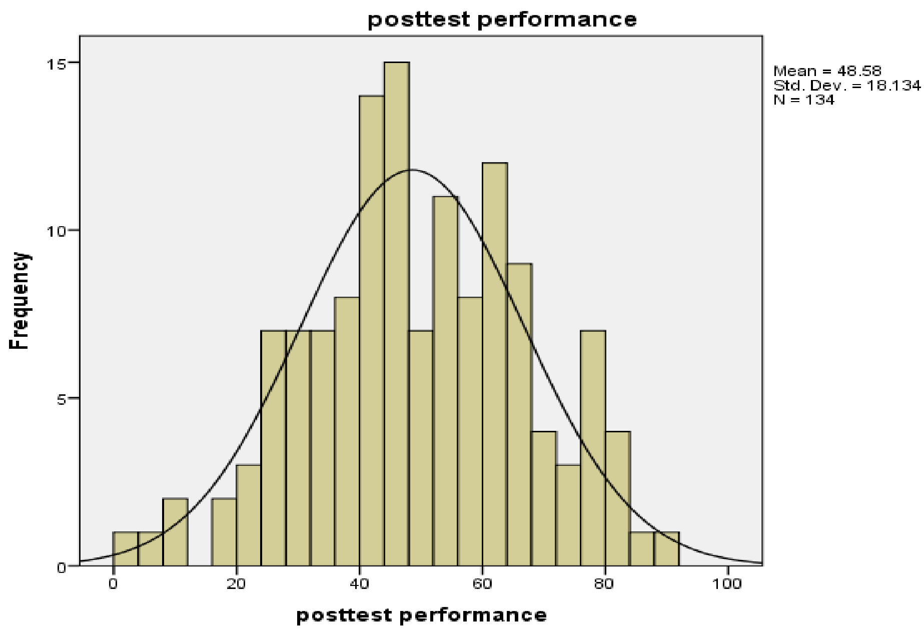

Figure 2. Distribution of Scores for the Post-Test

Figure 2 shows a histogram showing the distribution of the post-test scores enabling to proceed with the statistical analysis using One-way ANOVA.

3.8 One-Way ANOVA for Performance in the Post-Test

The post-test scores were analysed using ANOVA. Table 6 shows the ANOVA results for the post-test scores.

Table 6. Scores for Post-Test ANOVA

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
post-test performance	Between Groups	19944.173	2	9972.086	54.910	.000
	Within Groups	23790.424	131	181.606		
	Total	43734.597	133			

Note. Df = degrees of freedom.

Table 6 indicates that there was a statistically significant difference in at least one of the mean scores at $p < 0.05$ in the three groups at $F(2, 131) = 54.910, p = .000$. Nevertheless, this does not say which of the groups were statistically significantly different.

3.9 Post hoc Tests Analysis

Since there was a statistically significant difference in the mean scores of all the three groups, a post hoc test was performed to determine which of the groups were statistically significantly different. According to Hayter (1986) and Seaman, Levin, and Serlin (1991) when the means of exactly three groups are to be compared the best post hoc analysis to conduct is the Fisher's LSD as it protects the family wise error rate very well with three groups. Additionally, Sherri (2009) explained that, when sample sizes are not equal the best post hoc procedure to use is the Fisher's LSD. Table 7 shows the results of the LSD post hoc analysis.

Table 7. LSD Post Hoc Analysis for Performance in the Post-Test

LSD							
						95% Confidence Interval	
Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
post-test performance	Experimental group 1	Experimental group 2	-7.645*	2.874	.009	-13.33	-1.96
		Control	21.117*	2.826	.000	15.53	26.71
	Experimental group 2	Experimental group 1	7.645*	2.874	.009	1.96	13.33
		Control	28.762*	2.859	.000	23.11	34.42

	Control	Experimental group 1	-21.117*	2.826	.000	-26.71	-15.53
		Experimental group 2	-28.762*	2.859	.000	-34.42	-23.11

*. The mean difference is significant at the 0.05 level.

The multiple comparison test Table 7 shows that all the groups were statistically significantly different. That is to say, the mean score for experimental group 1 (M = 53.38, SD = 11.645) was statistically significantly different from experimental group 2 (M = 61.02, SD = 15.519) at $p < .05$. Experimental group1 mean score (M = 53.38, SD = 11.645) was statistically significantly different from the control group (M = 32.26, SD =13.088) at $p < .05$ while the mean score for experimental group 2 (M =61.02, SD =15.519) was also statistically significantly different from the control group (M =32.26, SD =13.088) at $p < .05$.

3.10 Effect Size

To find out the strength of the intervention, the effect size was calculated using Cohen's d for all the possible comparisons of the groups. Effect size is the strength of the difference between groups and indicates the influence of the independent variable (Tabachnick & Fidell, 2013). Cohen (1988) proposed the following guidelines (.2 = small, .5 = medium, .8 = large) and as expanded by Sawilowsky (2009) (1.20 = very large, 2.0 = huge).

$$d = \frac{M_2 - M_1}{SD_{pooled}} \quad \text{SD pooled} = \sqrt{\frac{SD_1^2 + SD_2^2}{2}}$$

Where;

d = Cohen's d

M_1 = mean for one group

M_2 = mean for the other group

SD_1 = standard deviation for one group

SD_2 = standard deviation for the other group

SD_{pooled} = pooled standard deviation

The values obtained for Cohen's dand the effect sizes calculated were .56 (Medium) between experimental group1 and experimental group 2, 1.7 (Very large) between experimental group1and the control group and 2.0 (huge) between experimental group 2 and the control group.

4. Discussion

4.1 Composite Effect of Concept Mapping and ICT on Students' Performance in Organic Chemistry

The study has shown that the composite use of concept mapping and ICT in teaching organic chemistry has a positive effect on senior secondary school students' performance. Particularly, the findings indicate that when concept mapping and ICT are utilised in organic chemistry lessons, secondary school students' comprehension of concepts is improved and in turn, students perform better. The findings are in line with the findings of Lou, Wen, and Tseng (2007) although they had used a different ICT technique.

Additionally, these results indicate that the use of concept mapping and ICT actually do have a huge effect on the performance of students in organic chemistry. Consequently, the study supported the research hypothesis and the researcher concluded that the teaching approach, which involved the composite use of concept mapping and ICT, had a positive effect on students' performance in organic chemistry.

4.2 Effectiveness of Combining Concept Mapping and ICT on Students' Performance

The composite use of concept mapping and ICT was effective in improving students' performance. This is evident from the statistically significant differences in the performance of the students in the experimental group 2 which was taught using a combination of concept mapping and ICT and the experimental group 1 which was taught using concept maps only as well as the control group which was taught using conventional methods. On top of that, effect sizes calculated were large for the experimental group taught using a combination of concept mapping and ICT verifying that the intervention was very effective in improving students' performance.

5. Conclusions

The purpose of this research was to determine the composite effect of concept mapping and ICT on students' performance in organic chemistry. In addition, the study sought to find out if the composite use of concept mapping and ICT was more effective in improving students' performance in organic chemistry as compared to the use of concept mapping and conventional approach. In view of the findings of this study, the conclusion is that, the composite use of concept mapping and ICT approach enhanced students' performance in organic chemistry significantly. Further, the findings reveal that the composite use of concept mapping and ICT is more effective in improving students' performance in organic chemistry as compared to the use of concept mapping and the conventional approach.

Therefore, the study concludes that the composite use of concept mapping and ICT can effectively improve the students' performance in organic chemistry. For that reason, this study concludes that it is relevant to adopt the composite use of concept mapping and ICT in teaching and learning processes.

6. Recommendations

Basing on the findings of this study, it is recommended that efforts should be made to provide an enabling learning environment that encourages and supports the combination of concept mapping and

ICT in the teaching of organic chemistry. The secondary students should have access to cell phones as ICT tools to enable the formation of discussion groups that can help in teaching and learning. Access to the internet will make it easy for students to interact, off course with measures in place to prevent abuse.

6.1 Suggestions for Future Studies

1) Similar studies can be conducted but instead of using manually constructed concept maps, computer generated concept maps can be used with other forms of ICT.

2) This study concentrated on senior secondary school organic chemistry, other studies could also be carried out in other secondary schools and tertiary institutions on different subjects and courses.

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References

American Chemical Society. (2018). Retrieved March 10, 2018, from https://www.acs.org/content/acs/en/careers/college-to-career/areas-of-chemistry/organic-chemistry.html

Ausubel, D. P. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart and Winston.

Ausubel, D. P., Novak, J., & Hanesian, H. (1978). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart and Winston.

Becta. (2003). *What the research says about ICT and whole school improvement Coventry: Becta*. Retrieved from http://becta.org.uk/corporate/publications/documents/personalizedlearning.pdf

Birk, J., & Kurtz, M. (1999). Effect of experience on retention and elimination of misconception about molecular structure. *Journal of Chemical Education*, *76*(1), 124-128. https://doi.org/10.1021/ed076p124

Bruner, J. (1960). *The process of education*. Cambridge, MA: Harvard University Press.

Childs, P. E., & Sheehan, M. (2009). What is Difficulty about Chemistry? An Irish Perspective. *Chemistry Education Research and practice*, *10*, 204-218. https://doi.org/10.1039/b914499b

Cohen, J. W. (1988). *Statistical power analysis for behavioural science* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Examinations Council of Zambia. (2007). *2006 Chief Examiners' Report*. ECZ: Lusaka.

Examinations Council of Zambia. (2008). *2007 Chief Examiners' Report*. ECZ: Lusaka.

Examinations Council of Zambia. (2009). *2008 Chief Examiners' Report*. ECZ: Lusaka.

Examinations Council of Zambia. (2010). *2009 Chief Examiners' Report*. ECZ: Lusaka.

Examinations Council of Zambia. (2011). *2010 Chief Examiners' Report*. ECZ: Lusaka.

Examinations Council of Zambia. (2012). *2011 Chief Examiners' Report*. ECZ: Lusaka.

Examinations Council of Zambia. (2013). *2012 Examinations Performance Report: Natural Sciences*. ECZ: Lusaka.

Examinations Council of Zambia. (2014). *2013 Examinations Performance Report: Natural Sciences*. ECZ: Lusaka.

Examinations Council of Zambia. (2015). *2014 Examinations Performance Report: Natural Sciences*. ECZ: Lusaka.

Examinations Council of Zambia. (2016). *2015 Examinations Performance Report: Natural Sciences*. ECZ: Lusaka.

Gabel, D. (1998). The complexity of chemistry and implications for teaching. In B. J. Fraser, & K. G. Tobin (Eds.), *International Handbook of Science Education* (1st ed., pp. 233-248). London: Kluwer Academic Publishers. https://doi.org/10.1007/978-94-011-4940-2_15

Gabel, D. (1999). Improving Teaching and Learning through Chemistry Education Research: A Look to the Future. *Journal of Chemical Education*, *76*(4), 548-553. https://doi.org/10.1021/ed076p548

Gaddis, B. (2001). *Conceptual change in an organic chemistry laboratory: A comparison of computer simulations and traditional laboratory experiments* (Doctoral dissertation). University of Colorado, Denver.

Hayter, A. J. (1986). The Maximum Family wise Error Rate of Fisher's Least Significant Difference test. *Journal of American Statistical Association*, *81*(396), 1000-1004. https://doi.org/10.1080/01621459.1986.10478364

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*, 75-83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Johnstone, A. H. (2006). Chemical education research in Glasgow in perspective. *Chemistry Education Research and Practice*, *7*(2), 49-63. https://doi.org/10.1039/B5RP90021B

Kelly, J. M. (1999). *The Origin and Development of Education in Zambia from Pre-colonial Times to 1996*. Lusaka: Image Publishers Limited.

Leuven, E., Lindahl, M., Oosterbeek, H., & Webink, D. (2004). The Effect of Extra Funding for Disadvantaged Pupils on Achievement. In *IZA Discussion Paper* (No. 1122). Bonn: Institute for the study of Labour.

Lou, S., Wen, H., & Tseng, K. (2007). A study of Integrating Concept Mapping into Computers Assisted Instruction in Chemistry Learning Achievement and learning Attitude at a comprehensive High Schools. *Chinese Journal of Science Education*, *15*(2), 69-194.

Mahajan, D. S., & Singh, G. S. (2005). University Students Performance in Organic Chemistry at Undergraduate Level: Perception of Instructors from Universities in the SADC Region. *Presented at Southern African Association for Research in Mathematics, Science and Technology Education Conference in January 2004 at Cape Town*. South Africa.

Novak, J. (1990). Concept Mapping. A useful tool for science Education. *Journal of Research in* *science teaching*, *58*(7), 45-49. https://doi.org/10.1002/tea.3660271003

Novak, J. D., & Gowin, B. (1984). *Learning how to learn*. New York: Cambridge University Press. https://doi.org/10.1017/CBO9781139173469

Novak, J. D., & Gowin, B. D. (2010). *Learning how to learn* (pp. 15-40). New York: Cambridge University Press.

Novak, J., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Educational Research Journal*, *28*, 117-153. https://doi.org/10.3102/00028312028001117

Nworgu, B. G. (2006). *Educational research: Basic issues and methodologies* (2nd ed.). Nsukka: Wisdom.

O'Dwyer, A., & Childs, P. E. (2011). Second-level Irish pupils and teachers' view of difficulties in organic chemistry. *International Organisation for Science and Technology Education (IOSTE)*—Mini symposium. Reading, UK, 20-21 June.

O'Dwyer, A. (2012). *Identification of the Difficulties in Teaching and learning of Introductory Organic Chemistry in Ireland and the Development of a second-level Intervention Programme to Address These*. Ollscoil Luimnigh: University of Limerick.

Orr, D. W. (2004). *Earth in mind: On education, environment, and human prospect*. Washington DC: Island Press.

Prosser, M. (1987). Is prior knowledge of subject matter important to the development and use of meaningful learning skills. *Programmed Learning and Educational Technology*, *24*, 280-285. https://doi.org/10.1080/0033039870240403

Sawilowsky, S. (2009). New effect size rules of thumb. *Journal of Modern Applied Statistical Methods*, *8*(2), 467-474. https://doi.org/10.22237/jmasm/1257035100

Seaman, M. A., Levin, J. R., & Serlin, R. C. (1991). New developments in pairwise multiple comparisons: Some powerful and practicable procedures. *Psychological Bulletin*, *110*(3), 577-586. https://doi.org/10.1037/0033-2909.110.3.577

Sherri, L. J. (2009). *Research Methods and Statistics: A Critical Thinking Approach* (3rd ed.). Wadsworth: Cengage Learning.

Taagapera, M., & Noori, S. (2000). Mapping students' thinking in learning Organic Chemistry by the use of Knowledge Space Theory. *Journal of Chemical Education*, *77*(9), 1224-1229. https://doi.org/10.1021/ed077p1224

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston: Pearson Education.

Wasacz J. T. (2010). *Organic chemistry preconceptions and their correlation to student success* (Doctoral Dissertation). University of Northern Colorado.