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Effects of Computer Based Cooperative Mastery Learning (CBCML) on Secondary School Students' Skills Acquisition in Chemistry Practicals

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Abstract: ***Chemistry occupies a central position in the curriculum among the science subjects in the secondary school curriculum. In spite of this importance, the academic performance of Kenya's students in the subject in secondary schools has remained poor over the years. The fundamental challenge facing the teaching and learning of chemistry is how to enhance students' science process skills acquisition. Innovative teaching methods engage the learners in the learning process. Such methods, not only are effective for mastery of concepts but also promote psychomotor characteristics of the learners. Although CBCML may enhance students' Science Process Skills Acquisition in chemistry, its effects have not been determined in Bomet County. This was the focus of the study. Solomon Four Non-equivalent Control Group Design was used. The study sample comprised of 238 form three students from four schools purposively chosen from 21 County Co-educational Secondary Schools in the County. The study involved four groups; two Experimental Groups taught through CBCML and the other two Control Groups taught through the Conventional Teaching Methods (CTM) for six weeks. A Chemistry Practical Skills Acquisition Test (CPSAT) was administered during the Pre-test, reorganised and then administered as a Post-test. The reliability coefficient of the instrument estimated using Kuder-Richardson (K-R21) formula was 0.76. Data analysis was carried out using descriptive as well as inferential statistics. The differences between the group means were checked for statistical significance using t-test and ANCOVA. The findings of the study showed that the students exposed to CBCML had relatively higher scores in CPSAT than those taught through CTM. Gender had no significant effect on students' skills acquisition in Chemistry. Thus, CBCML enhances Students' Skills Acquisition more than CTM. Therefore chemistry teachers should incorporate the use of CBCML in their teaching.***

Keywords: Computer Based Cooperative Mastery Learning, Chemistry, Science Process Skills Acquisition

1. Introduction

Science and Technology have long been recognized as instruments for nation building and every country craves for development (Abbas & Kan, 2007). Science, according to Ogunleye and Babajide (2011), is an instrument for economic, technological and political development. The fourth goal among the Sustainable Development Goals (SDGs) adopted by member states during the year 2015 summit in New York points out that by 2030 all learners should have acquired knowledge and skills needed to promote sustainable development. It also emphasises on gender equality and empowerment of all women and girls. Science subjects including Physics, Biology and Chemistry are an integral component in acquisition of skills for lifelong learning.

Chemistry has contributed tremendously to mankind in a number of ways such as improvement of health, supply of foodstuff, increased comfort, convenience and pleasure, increasing efficiency of industrial processes and reduction of dependence on natural materials (Wachanga, 2005). The general objectives of teaching chemistry in secondary schools in Kenya includes use of the knowledge and skills acquired to solve problems in everyday life as well as applying principles and skills acquired in technological and industrial development. The implication is that the goal of any science teacher should be to foster the development of science process skills. The application of these science process skills allows the students to investigate important issues in the world around them.

Science process skills include skills that every individual could use in each step of his/her daily life by being scientifically literate and increasing the quality and standard of life by comprehending the nature of science. Therefore, these skills affect the personal, social and global life of an individual (Harlen, 1999). Practical examinations in chemistry tests whether candidates have acquired certain skills and competencies which include: manipulative skills such as correct measurement of volume, ability to make accurate observations, ability to record observations, ability to make accurate deductions and the ability to follow a set of instructions and carry out experiments (NRC, 2005). Students may lack these skills, the language involved in using the skills, or the inclination to apply the skills. However, when students work together in cooperative learning groups, they gain competence in manipulation of apparatus to get accurate results.

Chemistry practical skills are science process skills. They are taught as part of the chemistry curriculum. These skills can be acquired and developed through activities involved in the chemistry practical sessions. The assessment of practical work in chemistry and other science subjects in national examinations at the secondary school level in Kenya consists of a practical examination designed to test the candidates' ability to apply knowledge, utilise skills in carrying out experiments and evaluate experimental results and observations. In chemistry, exam questions are set from any section of the syllabus and for a candidate to obtain a credit in chemistry s/he must pass in the practical examination (KNEC, 2005). While this condition by the KNEC shows the importance attached to practical work in

science and chemistry in particular, it could have implications on how practical chemistry is taught and assessed in schools. For example teachers could focus only on certain aspects of practical work as assessed by KNEC. In practical work, an opportunity is provided for testing application of scientific procedures, manipulative abilities as well as scientific skills.

The Kenya National Examinations Council (KNEC) makes use of practical examinations to test students' acquisition of various chemistry practical skills which in essence are science process skills. In these examinations, students are required to carry out chemistry practical activities following some given instructions. The performance of students in the Kenya National Examinations Council in chemistry practical examinations has been below average. For instance in the years 2010, 2011, 2012, 2013 and 2014 the students scored means of 14.87, 11.91, 16.34, 14.67 and 17.57 respectively out of 40 (KNEC, 2015). The scores that students obtain from practical exams are direct reflections of the process skills they could display during the practical examination. At the same time, the final score that a candidate scores in Chemistry is contribution of both the theory examination and the practical examination scores. According to Akinbobola and Afolabi (2010), the practical assessment score of a student is a reflection of the teaching approach that a teacher employed during the learning situation especially the process approach.

In this study, Skills Acquisition refers to the ability of the learner to carry out given tasks in chemistry practical with competence and accuracy. Chemistry Practical Skills Acquisition Test (CPSAT) was used to measure students' skills acquisition in chemistry. CBCML offers many ways of promoting more equal participation among group members. The shared responsibility and interaction are likely to generate better intergroup relations, and result in better self-images for students with histories of poor achievement (Wachanga, 2002).

The items in this instrument included a procedure outlining the steps learners were to follow in carrying out the practical, a blank table for recording the results and questions to be attempted based on the results obtained from the practical. The information sought through these CPSAT items wanted the respondents to demonstrate their level of competence in handling chemistry practical tasks before and after treatment. The skills and competencies assessed in practical examination are in line with some of the general objectives of teaching and learning of chemistry as prescribed in the chemistry syllabus. Examples of such objectives includes to select and handle appropriate apparatus for use in experimental work and to make accurate measurements, observations and draw logical conclusions from experiments (KIE, 2002).

2. Statement of the Problem

The poor performance in chemistry by secondary school students as reflected by the KCSE Examinations results has continued to trigger a lot of concern among educationists and other stakeholders nationally and also in Bomet County over the years. In addition to this, boys have continued to outshine their female counterparts in KCSE Examinations over the years. The poor performance in the subject and gender disparity noted could be as a result of lack of adequate practical work which would otherwise have engaged the learners actively in class hence meaningful learning. Conventional Teaching Methods adopted by most teachers makes the learners to be passive during the teaching/learning process. Chemistry is an experimental science which relies primarily on the harmony between theory and practical. It should therefore be taught as such. It follows therefore that, understanding of concepts in practical chemistry will assist in enhancing student's understanding of chemistry. Although CBCML approach to teaching may enhance students' skills acquisition in chemistry, its effects have not been determined in Bomet County. In view of this gap the study sought to determine the effect of CBCML on secondary school students' skills acquisition in Chemistry practical in Bomet County, Kenya.

Objectives of the Study

The specific objectives of the study were:

a) To compare the level of skills acquisition in Chemistry between students taught through CBCML and those taught through Conventional Teaching Methods (CTM).
b) To investigate whether there gender affects skills acquisition in Chemistry when students are taught through CBCML.

Hypotheses of the Study

The study was guided by the following hypotheses:

$H_0$1 There is no statistically significant difference in students' level of skills acquisition in chemistry between those exposed to CBCML and those taught using CTM.

$H_0$2 There is no statistically significant gender difference in skills acquisition in chemistry between students exposed to CBCML.

3. Conceptual Framework

The conceptual framework used in this study is based on the constructivist theory of learning. In this theory, the teacher serves as a facilitator who attempts to structure an environment in which the learner organises meaning at a personal level (Cooper, Jackson, Nye & Lindsay, 2002). The study was also based on the assumption that the blame for a students' failure rests on the quality of instruction and not lack of student's ability to learn (Bloom, 1981; Levine, 1985). The framework is represented diagrammatically in Figure 1.

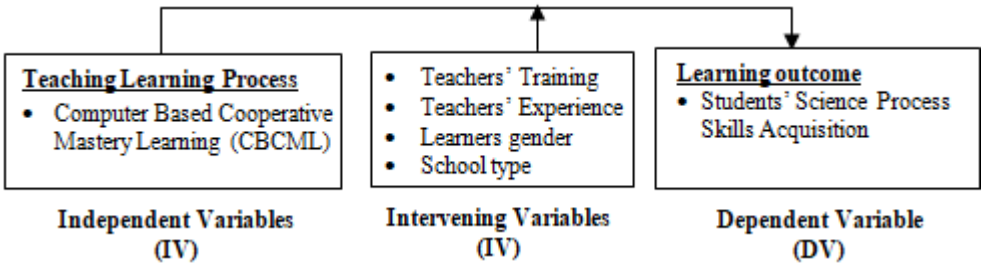

Figure 1: Conceptual Framework for determining the effect of using CBCML on Students' Skills Acquisition in Chemistry

4. Research Methodology

Research Design

The study used Solomon's Four Non-equivalent Control Group Design which is rigorous enough hence appropriate for experimental and quasi-experimental studies (Wachanga & Mwangi, 2004). The design controlled for all major threats to internal validity except those associated with interaction of selection and history, selection and maturation, and selection and instrumentation (Cook & Campell, 1979). This design involved a random assignment of intact classes to four groups. The design is shown in Figure 2.

Group 1	O_1 X O_2	E1
Group 2	O_3 ____ O_4	C1
Group 3	___ X O_5	E2
Group 4	___ ___ O_6	C2

Key: Pre-tests: O_1 and O_3 Treatment: X
Post-tests: O_2, O_4, O_5 and O_6 No pre-test or no-treatment:
Experimental groups: E_1 and E_2 Control groups: C_1 and C_2
Non-equivalent control groups: ----------

Figure 2: Solomon's Four Non-Equivalent Control Group Research Design

Groups 1 and 3 were taught through the CBCML and therefore were the Experimental Groups while Groups 2 and 4 were taught through the CTM and were therefore the Control Groups.

Sampling Procedures and Sample Size

The unit of sampling was secondary schools rather than individual learners because secondary schools operate as intact groups (Borg & Gall, 1996). Purposive sampling was used to select secondary schools that offer computer studies in the County. This ensured that the students have the pre-requisite skills on the use of computers for learning. Form Three classes were purposively selected for the study because the topic to be covered is usually done in Form Three. The Form Three classes in the four Co-educational County secondary schools were randomly assigned to experimental and control groups.

To ensure that the four schools are located far apart from each other and to eliminate diffusion of information regarding treatment from the Experimental Groups to the Control Groups, one school was picked from each of the four sub-counties. The total number of students selected for the study was 238. According to the research design used, the schools selected for use in the study represents the county as a whole.

Instrumentation

Data was collected using a Chemistry Practical Skills Acquisition Test (CPSAT), constructed by the researcher for measurement of the level of skills acquisition before and after treatment. This tool comprised of a practical test on titration with a procedure to be followed involving manipulation of apparatus, measurement of required volumes of solutions, performance of the titration process, making observations and recording the volumes of solutions used to reach the end-point of the neutralization reaction involved. This was then followed by questions requiring students to carry out calculations based on the values obtained during the titration process. The maximum score in this instrument was 10 marks. The CPSAT provided data on the level of skills acquisition before and after treatment among students in chemistry practicals when either CTM or CBCML is used.

Validity and Reliability of Research Instruments

Validity

The CPSAT was validated by the university supervisors and chemistry teachers. It was then moderated by three education specialists from the Department of Curriculum, Instruction and Educational Management of Egerton University and markers of Chemistry registered with Kenya National Examinations Council (KNEC). Comments from these specialists were used to improve the instruments and make them suitable for use in the study. Items which were found inadequate for measuring the variables were either discarded or modified.

Reliability

The instrument was pilot-tested in the neighbouring Narok West Sub-County in selected secondary schools whose subjects were assumed to have similar characteristics with that of the sampled schools. Kuder-Richardson 21 (K-R21) formula was used to calculate the reliability coefficient of the CPSAT. The K-R21 formula was appropriate because the test items were scored dichotomously (Wiersma & Jurs, 2005). This formula gave a reliability coefficient of 0.76. According to Fraenkel and Wallen (2000), an alpha value of 0.7 and above is considered suitable to make possible inferences that are accurate. The items in the instrument were therefore suitable for use in the study.

Data Collection Procedures

The researcher sought a permit to conduct research in the sampled schools in Bomet County from the National

Commission of Science, Technology and Innovation (NACOSTI), through the Board of Postgraduate Studies of Egerton University. Chemistry teachers of the experimental groups were trained on CBCML for two days and then issued with copies of Chemistry Practical Teachers' Manual (CPTM).

Data was collected in two stages during the study. At the beginning, the CPSAT was administered to the Experimental Group 1 (E1) and Control Group 2 (C1) as a pre-test. This was followed by exposure of the Experimental Groups 1 and 3 to treatment which lasted six weeks. Students in the Control Groups were taught through the Conventional Teaching Methods (CTM). At the end of the six-week period, the items in the instruments were re-organised and administered by the researcher as a post-test with the assistance from the chemistry teachers in the respective schools involved in the study. The researcher then scored the tests to get quantitative data to use for data analysis.

Data Analysis

The data obtained from the instrument during the pre-test and post-test assessments were coded and analysed using a t-test and ANOVA. This enabled the researcher to find out whether there was any statistically significant difference between the performance of the two groups, before and after the treatment. This way, it was possible to determine the impact of CBCML on students' Skills acquisition in chemistry.

5. Results and Discussion

Effects of CBCML on Students' Skills Acquisition in Chemistry

The CPSAT pre-test mean scores for Groups 1 and 2 and for male and female students were not significantly different, implying that the groups had comparable characteristics and therefore suitable for use in the study (Table 1).

Table 1: Independent Sample t-test of Pre-test Scores on CPSAT

Scale	Group	N	Mean	SD	Df	t-value	p-value
CPSAT	1	59	1.75	0.94	117	0.349	0.947(ns)
	2	60	1.73	1.07			

ns: non-significant mean differences at $p>0.05$ level; CPSAT Maximum Score = 10

However, the post-test means of the level of competence in chemistry practical skills were 8.17, 5.02, 8.15 and 4.93 for groups 1, 2, 3 and 4 respectively. The findings of this study show that the CPSAT pre-test scores did not interact significantly with the treatment conditions. Thus, the higher scores by the Experimental Groups 1 and 3 are as a result of the CBCML treatment and not the pre-testing effects.

Since the entry behavior of the learners could have an effect performance, it was necessary to use ANCOVA because it has features that takes care of initial differences by making compensating adjustments to the post-test means of the groups involved. The students' KCPE mark was used as covariates.

When the adjusted CPSAT post-test mean scores of the experimental groups were compared to those of the control groups, the results showed that the Experimental groups which received treatment had better mean scores over the control groups despite the fact that the Control Group, C1 received pre-test which would otherwise have influenced the post-test results. Therefore, the pre-test did not influence the skills acquisition of the students who were pre-tested. This implies that the high level of competence in chemistry practical skills was as a result of the treatment and not prior exposure to CPSAT. Table 2 shows ANCOVA results of the post-test CPSAT mean scores with KCPE mark as covariate.

Table 2: Analysis of Covariance (ANCOVA) of the Post-test Scores on CPSAT

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	604.396(b)	4	151.099	48.315	.000
Intercept	83.998	1	83.998	26.859	.000
KCPE	.000	1	.000	.000	.992
GROUP	603.713	3	201.238	64.347	.000(s)
Error	728.684	233	3.127		
Total	11259.000	238			
Corrected Total	1333.080	237			

a. Computed using alpha = .05
b. R Squared = .453 (Adjusted R Squared = .444)

ANCOVA test confirmed that the differences in mean scores of the groups was statistically significant at 0.05 alpha level with regard to the level of skills acquisition among the learners, ($F(3, 233) = 64.347$), $p<0.05$). It can then be concluded that CBCML had a positive effect on students' competence in chemistry practical skills.

After establishing that there was a significant difference in competence to perform chemistry practical by students taught through CBCML and those taught through CTM, it was important to conduct further tests to show where the difference occurred. *Bonferroni post-hoc* analysis was preferred for this study because it controls for the overall error rate hence the observed significance level is adjusted for the fact that multiple comparisons were being made. Whenever there is a difference between the means of different groups, this test in particular shows where the difference occurred.

The results of *Bonferroni post-hoc* pair-wise comparisons of significance for difference between any two means shows that there was a statistically significant difference between the pairs of CPSAT post-test means for groups E1 and C1, groups E1 and C2, groups C1 and E2 and groups E2 and C2 at 0.05 α-level. However, there was no statistically significant difference in the means between Groups E1 and E2 and Groups C1 and C2. It is also evident that CPSAT post-test mean scores of control groups were significantly lower than those of experimental groups. Consequently, $H_0 1$ was rejected.

The students mean gain in skills acquisition was determined for Group 1 and 2 which received both the pre-test and post test. Table 3 shows the mean gain between students' CPSAT pre-test scores and post-test scores.

Table 3: Comparison of Students' Mean Scores with their Mean Gain in CPSAT

	Group 1 (N=59)	*Group 2 (N=60)*	*Overall (N=118)*
Pre-test mean scores	1.75	1.73	1.74
Post-test mean scores	8.17	5.02	6.60
Mean Gain	**6.42**	**3.29**	**4.86**

CPSAT Maximum Score = 10

Results in Table 3 indicate that both Group 1 and 2 acquired skills significantly from the teaching. However, group 1 had a higher mean gain of 6.42 in the level of skills acquisition compared to the control group with a mean gain of 3.29. CBCML improved the skills acquisition among students who were in the experimental groups more than those in control groups. Therefore, CBCML enhances students' skills acquisition in chemistry more than the CTM.

6. Discussion

The t-test results showed significant difference in the mean scores of those exposed to CBCML and those not exposed to it. Further analysis of the post-test data obtained from the CPSAT using the KCPE mark as covariates was done using ANCOVA. Consequently, the results show that the differences in the mean scores of the groups were statistically significant, ($F(3, 233) = 64.347$), $p<0.05$). It can then be concluded that CBCML had a significant positive effect on students' competence in chemistry practical skills.

Bonferroni post-hoc pair-wise comparisons of significance for difference between any two means conducted shows that there was a statistically significant difference between the pairs of CPSAT post-test means for groups E1 and C1, groups E1 and C2, groups C1 and E2 and groups E2 and C2 at 0.05 alpha level. However, there was no statistically significant difference in the means between Groups E1 and E2 and Groups C1 and C2. Consequently $H_0$1 was rejected.

Analysis of the Mean gain between students upon considering the pre-test and post-test scores shows that those in the experimental group outshined their counterparts in the control group. This implies that CBCML improved the skills acquisition of students who were in the experimental groups more than those in control groups.

These results show that the use of CBCML in the teaching and learning of chemistry is beneficial to learners in skills acquisition. The manipulation of apparatus and the computers used in chemistry learning facilitated acquisition of skills among the learners.

Effect of Gender on Students' Skills Acquisition in Chemistry when CBCML is used

An independent t-test results of pre-test scores based on gender in Table 4 shows that CPSAT mean scores of both male and female were not significantly different at 0.05 alpha level ($t(117)=0.895$, $p>0.05$). Thus, there was no gender difference in skills acquisition at the beginning of the treatment and therefore the groups were suitable for use in the study.

Table 4: Independent Sample t-test of Pre-test Scores on CPSAT based on Gender

Scale	Group	N	Mean	SD	Df	t-value	p-value
CPSAT	Male	57	1.61	0.99	117	0.895	0.192(ns)
	Female	62	1.85	1.00			

ns: non-significant mean differences at $p>0.05$ level; CPSAT Maximum Score = 10

Post-test Scores on CPSAT based on Gender

The post-test shows that the CPSAT mean scores for both male and female students is almost equal with that of male student being a mean of 6.53 while that of the female students was 6.39 out of a total mark of 10. This therefore shows CBCML improved the skills acquisition in chemistry practical equally for both boys and girls. Table 5 shows the results of t-test on CPSAT mean scores for both male and female students exposed to CBCML.

Table 5: Independent Sample t-test on Post-test Scores based on Gender on CPSAT

		Levene's Test For Equality of Variances		t-test for Equality of Means		
		F	Sig.	T	df	p-value
CPSAT	Equal variances assumed	1.108	.294	.447	111	.656(ns)
	Equal variances not assumed			.449	235.223	.654

ns: non-significant mean differences at $p > 0.05$ level; CPSAT Maximum Score = 10

The results in Table 5 shows that there was no significant gender difference in skills acquisition in chemistry at the end of CBCML intervention ($t(111)= 0.447$, $p>0.05$). Therefore, $H_0$2 was accepted. Table 6 shows the mean gain for boys and girls on skills acquisition.

Table 6: Students' Mean Gain in CPSAT based on Gender

Gender	N	Pre-test	Post-test	Mean Gain
Male	57	1.61	6.53	4.92
Female	62	1.85	6.39	4.54
Total	**119**	**1.73**	**6.45**	**4.72**

CPSAT Maximum Score = 10

The results in Table 6 show that the mean gains for male and female students were 4.92 and 4.54 respectively. Thus, both boys and girls equally benefited from the CBCML approach in terms of skills acquisition in chemistry.

Discussion

The determination of the effect of gender on students' skills acquisition when CBCML Teaching Strategy is used to teach Volumetric Analysis was guided by hypothesis $H_0$2. The CPSAT mean scores for both male and female students was found to be almost equal with that of male students being 6.53 while that of the female students was 6.39 out of a maximum of 10. A comparison of this CPSAT post-test scores with pre-test scores shows that the mean gain for boys was 4.92 while that of girls was 4.54. This therefore shows that CBCML improved the skills acquisition in chemistry practical equally for boys and girls.

The post-test CPSAT t-test results show that there was no significant gender difference in skills acquisition among

boys and girls exposed to CBCML. This therefore implies that both boys and girls improved in skill competence equally at the end of CBCML intervention. Hypothesis two ($H_0$2) was therefore accepted.

Abanihe (1997) points out that skill acquisition in science is the basis for full promotion and improvement of the status of women for self-reliance. Interactive methods of teaching such as CBCML have been found to rank among the factors that enhance meaningful learning in science classes. No one method of teaching has emerged the best in teaching chemistry content for understanding. However, science teachers who integrate a number of teaching approaches and match the content they are teaching with an appropriate method have succeeded in effective and meaningful learning of science.

Instructional methods employed in teaching should be as participatory in nature as possible and endeavour to teach large classes of learners "how to learn". The use of teaching aids and facilities in order to improve chemistry teaching has greatly increased in recent years (Dyasi, 2005). The reason is that, chemistry materials and apparatus arouse great interest among the learners, encourage cooperation and interaction among learners in group work, enhance stimulus variation and consequently motivate them to learn. CBCML is a good example of such approaches which encourage both boys and girls to effectively acquire skills in chemistry which have direct application in our day to day life. This eventually contributes to meaningful learning of chemistry.

Summary of the Major Findings of the Study

The following are the major findings of the study:

1) The results of the study show that there was a statistically significant difference in skills acquisition in chemistry between students exposed to CBCML and those not exposed to it. CBCML had a positive significant effect on students' skills acquisition in the subject.
2) The results of the study show that gender does not affect skills acquisition when students are taught through CBCML. The use of CBCML enhanced skills acquisition equally for both boys and girls in the Experimental Groups.

7. Conclusions

The CBCML approach enhances students' skills acquisition in chemistry more than the CTM. It was also observed that gender does not affect students' skills acquisition in chemistry when they are taught through CBCML approach.

8. Implications

Students taught through CBCML approach performed better in the CPSAT than those taught through CTM irrespective of gender implying that CBCML would be suitable for teaching both boys and girls. Therefore education authorities in Kenya should encourage chemistry teachers to use this method and teacher education institutions could also make it part of their teacher training curriculum content.

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